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ManuFUTURE vision 2030

Report from ManuFUTURE High-Level Group, December 2018

COMPETITIVE,
SUSTAINABLE AND
RESILIENT EUROPEAN MANUFACTURING

Manu*FUTURE*

—VISION 2030

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SUSTAINABLE AND
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HIGH-LEVEL GROUP, DECEMBER 2018

MANU*FUTURE*-EU

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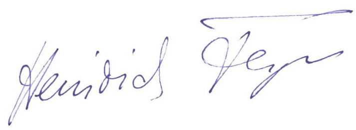
“Sight is seeing
what’s there,
vision is
seeing what’s
possible”

—Retin Obasohan

Manu*FUTURE* Vision 2030 envisions Future Manufacturing as a key driver for growth and sustainability, by exploiting current trends, challenges and opportunities, influencing the development of all manufacturing sectors. This document is a contribution for political, economic, ecological and social orientation from a European perspective.

In recent years, real economy has regained importance as a unique source of value creation, income and prosperity. On almost any product, you can attach a sticker "manufacturing inside". The manufacturing sector is of vital importance for Europe to foster economic growth and job creation and has a pivotal role to play in prompting investment and innovation, in particular as a vehicle for the introduction of radical innovations. The ongoing digitalisation of industry and the integration of new technologies are examples of the manufacturing enabling role and the European leading capabilities.

We are convinced that the base concept of resilient, sustainable and competitive manufacturing is the most suitable and straightforward approach for the foreseeable future and must be the guideline for the development of future products, processes and business models. Europe is an excellent position to lead the next revolutions. It is important to use this momentum to set the right course for a successful future.



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Chairman of the ManuFUTURE High-Level Group
December 2018

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Manu*FUTURE* Sub-Platforms:

AM – Additive Manufacturing European Platform
AET – Agriculture Engineering and Technologies
Joining – Joining Sub-platform
ET – European Tooling Platform
4ZDM – Zero Defect Manufacturing
Manu*FUTURE* National and Regional Technology Platforms Network

Other ETPs and organizations:

ConXEPT – Consumer Goods Cross ETP
ECTP – European Construction, built environment and energy efficient building Technology Platform
EMIRI – Energy Materials Industrial Research Initiative
EuMaT – European Platform for Advanced Engineering Materials and Technologies
EWF – European Welding Federation
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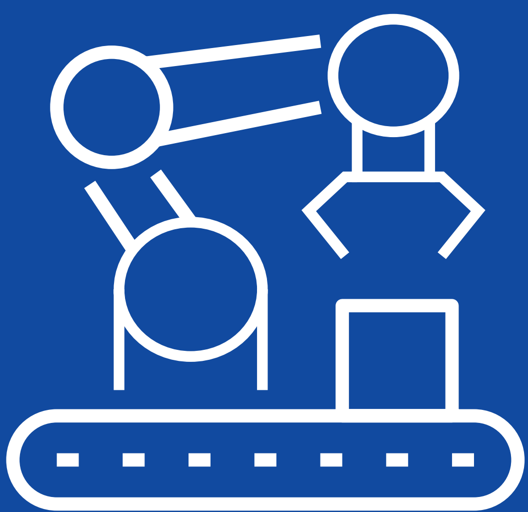
1.

The Manufacturing Industry today



1. The Manufacturing Industry Today

European Manufacturing

Manufacturing is the backbone of the European economy. According to Eurostat [1], 9.0 % of all enterprises in the EU-28's non-financial business economy were considered as manufacturing companies in 2014, a total of 2.1 million enterprises employing nearly 30 million people and generating EUR 1 710 billion of value added. This represents 22.1% of employment (14.2% of the total European workforce) and 26% of the value added of the EU-28's non-financial business economy.

Manufacturing is a complex ecosystem steering many high value-added services, justifying the creation of up to two jobs in other sectors for each direct job in manufacturing [2, 3, 4]. Manufacturing companies, including SMEs, are part of local societies where workers and their families can live because of direct and indirect manufacturing, challenging and well-paid, jobs.

The ongoing 4th Industrial Revolution (Industry 4.0) is impacting manufacturing at global level, starting with developed and progressively spreading to emerging countries. Europe is presently the global leader in the supply of Industry 4.0 technology and it is also a leader in its implementation [5, 6].

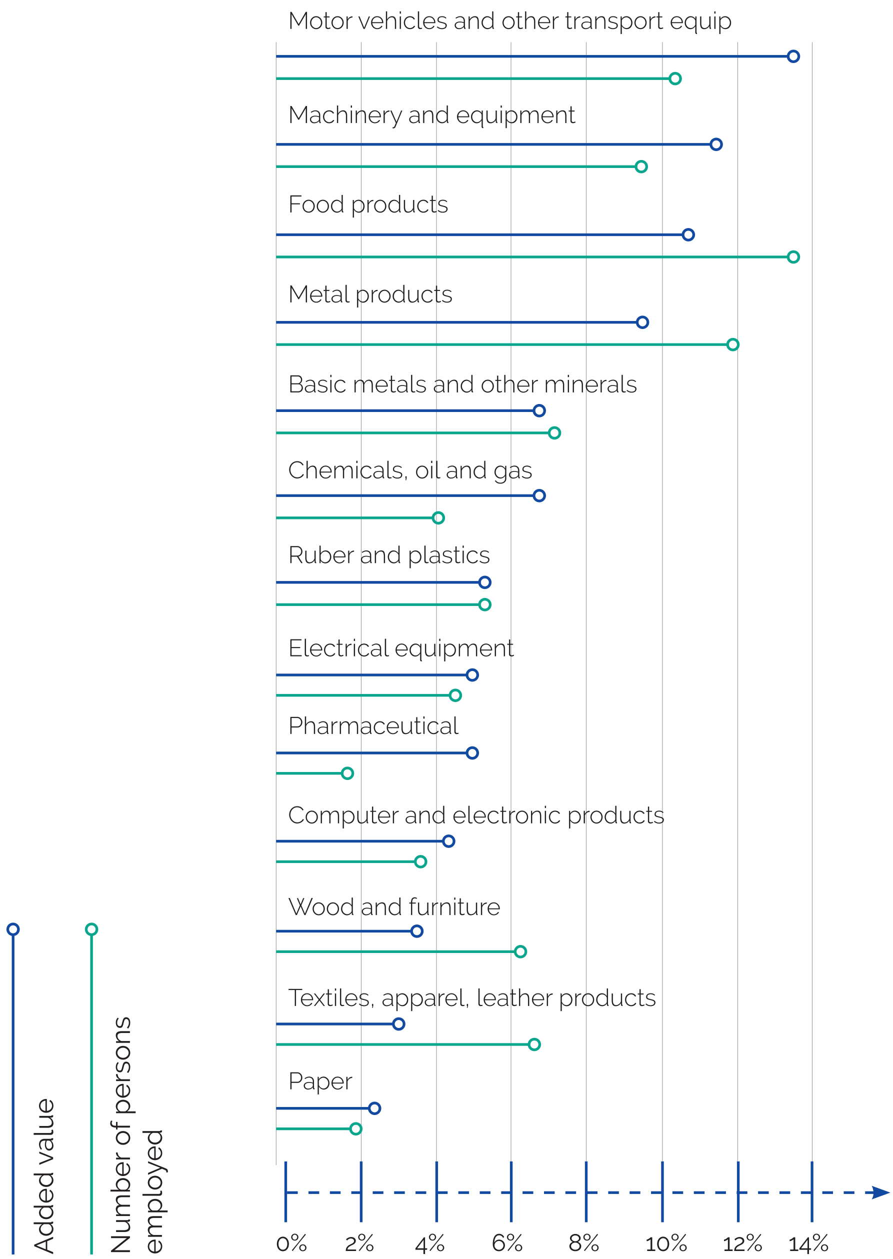


Figure 1 – Manufacturing sectoral analysis, sorted by value added, EU-28 [1]

Global position

Looking at the international dimension, the European Union is the world's biggest exporter of manufactured goods, and is a global market leader for high-quality products. Industrial machinery and transport equipment represented in 2017 42% of total exports, other manufactures products 23.9%, chemicals 17.6% and food, drinks and tobacco 7.5% [8].

Manufactured goods represent 83% of EU exports, present a trade surplus of 233 billion euro in 2017 [8] and contribute greatly to the overall trade balance of the European Union (23 billion euro in the same period), more than compensating the huge imports of needed primary goods such as energy [7]. This trade surplus plays a key role in creating growth and jobs in the European Union and supports the investment in infrastructure and the EU welfare.

However, close attention is needed as European manufacturing has been losing ground compared to other parts of the world [9]. In 1995, European *manufactured products* accounted for 31% of the world total. In 2013, their share fell to 27%. During the same period, the European Union's contribution to *global Value Added* produced by the manufacturing sector fell from 23% to 17%.

This decline is affecting all the main industrialised economies, but European manufacturing is growing less than manufacturing in the United States. Between 2000 and 2014, the value added generated in Europe increased by 20.6%, while the growth in the US was 34%. *Labour productivity* in the European manufacturing sector also grew less than in the United States [9]. Investments have been made, but they are lower than those of the other global players, as illustrated in figure 2.

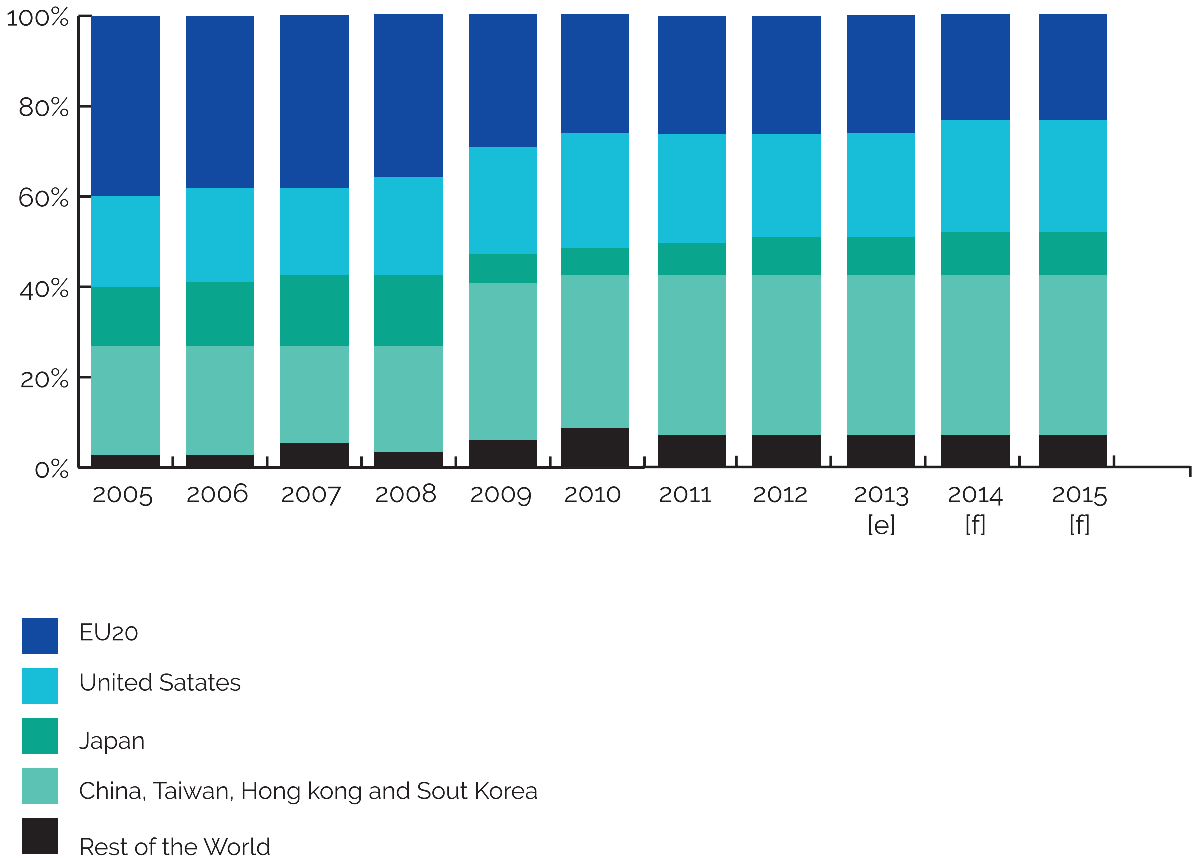


Figure 2 – Share of world's total manufacturing investments by region, Source IHS [6].

In terms of the Manufacturing value added, in 2014, the European Union had already recovered the value before the crisis, but lost first place to China, which was also the fastest growing economy during the 2004-2014 period [11].

Despite this reduction, the manufacturing sector remains central to growth and employment in the European Union, making the **relaunching of European manufacturing a priority** for the European Union [4, 9].

Manufacturing strategies and programmes at global level

Over the past few decades, the international landscape has changed due to the emergence and growth of economies such as China, Korea, India, Brazil, Israel and South Africa, progressively reinforcing Science, Technology and Innovation at the centre of the economic development strategies.

The financial crisis clearly highlighted the importance of manufacturing as a fundamental pillar of competitive and wealthy economies, which motivated a strong re-industrialisation movement at global level. At European level, besides the launch of the Factories of the Future initiative, most countries defined strategies such as Industry 4.0 in Germany, Industrie du Future in France, Swedish Produktion2030, UK Catapult centres, and more. Several other regions around the world followed Europe's example and launched strategies and programmes to support knowledge-based industrial development, all of them with strong investments in Research and Development (R&D), Innovation and Education. Most of them give high priority to the digital transformation and to the Key Enabling Technologies (KETs).

The following are some of these relevant programmes:

USA:

In the recent past, the US governments and industrial leaders gave high priority and invested heavily in advanced manufacturing [12]. In 2012, the US government recognised the importance of manufacturing as a foundation for economic growth, for the creation of well payed jobs and national security. The Advanced Manufacturing Partnership was launched to secure the US leadership in emerging technologies that will create high-quality manufacturing jobs and enhance US global competitiveness. It includes initiatives such as the coordination of all manufacturing related research programmes, the creation of more than a dozen national manufacturing innovation networks, the provision of incentives for reshoring manufacturing operations back to the US and funding to fill the gap between fundamental research and commercialisation. Manufacturing USA, a national network of 14 manufacturing innovation institutes, was created. Through Manufacturing USA, industry, academia and government partners are leveraging existing resources, working together and co-investing to nurture manufacturing innovation and accelerate commercialisation. These institutes cover areas such as: Photonics, electronics, additive manufacturing, robotics, biotechnology, sensors, digitalisation, composites and energy.

CHINA:

In 2015, the Chinese government unveiled a national strategy with three stages, called Made in China 2025 [13, 14]. Inspired by the German programme, Industry 4.0, the first stage aims to transform China into a major manufacturing power by 2025, by increasing manufacturing digitalisation, mastering core technologies in key areas, improving product quality, energy and material consumption and enhancing innovation capacity. By 2035, Chinese manufacturing aims to reach an intermediate level among world manufacturing powers, by greatly improving innovation capability, making breakthroughs in major areas and leading global innovation in industries where China is more competitive. By 2049, a century after the founding of New China, China aims to become the leading world manufacturing power. It will have the capability to lead innovation and achieve competitive advantages in major manufacturing areas and will develop advanced technology and industrial systems. In the context of Made in China 2025, an Advanced Manufacturing Fund was created with $3 billion and the government has already invested $3 billion in 300 enterprise experimentation programmes. The following are the ten key strategic areas defined by China 2025: next generation IT and communication equipment; high-end CNC machines and robotics; aerospace industry; marine engineering equipment and high-tech ships; rail transportation equipment; energy efficient and new energy vehicles; electric power equipment; agricultural equipment; new materials; biomedicine and high-performance medical equipment.

JAPAN:

The Japanese Industrial Value Chains Initiative (IVI), as well as a Cross-Ministerial Strategic Innovation Promotion (SIP) Programme focused on Innovative Design/Manufacturing Technologies, aim to promote manufacturing digitalisation [15]. The Kohsetsushi Centres support SME manufacturers in technology development and innovation activities. In 2014, the Japanese Prime Minister's office promoted an Industrial Revitalisation Strategy putting the emphasis on the integration of advanced robotics and artificial intelligence in specialised supply chains, setting a goal to lead the world in "robots in the IoT era". The Japanese Science and Technology Agency created the Programme ImPACT - Impulsing Paradigm Change through Disruptive Technologies, aiming to transform Japanese industry and society through the promotion of high-risk, high-impact R&D. The ImPACT programme has established 16 R&D programmes in areas such as ultra-thin and flexible tough polymers; green IT devices with long-life batteries; artificial cell reactor technology; and "Bionic Humanoids Propelling New Industrial Revolution." Japan aims to achieve a "Society 5.0" in the future through the full use of technological innovation including IoT, AI and Big Data, derived from the fourth industrial revolution. To achieve Society 5.0, industries must play a key role and the Japanese government announced the "Connected Industries" vision in 2017, a new concept framework in which industries will create new value added and the solutions to various problems in society through connectedness in various facets of modern life, including humans (in their roles as consumers and suppliers), machines, systems, companies [16]. According to the Japanese Ministry of Economy, Trade and Industry, five main areas are foreseen: Automated driving, energy management and mobility services, smart manufacturing and robotics, biotechnologies and materials, manufacturing plants and infrastructure safety management, using new technologies such as IoT and drones, and smart homes and life.

SOUTH KOREA:

In 2014, the Manufacturing Industry Innovation 3.0 strategy was defined as part of Korea's Creative Economy Initiative [15]. Manufacturing 3.0 focused on the concept of a smart factory embracing automation, data exchange and enhanced manufacturing technologies. The government laid out a roadmap for several R&D areas, including: design technology, technology for quality control, operations software, IIoT (Industry Internet of Things) platforms, smart sensors, data collection, data processing and industrial standards. The government planned to support investment in R&D and facilities in new industries such as: IoT, new energy, smart car, and Bio. In addition, the private sector formed the Smart Factory Standard Research Council to respond effectively to international trends and standardise local regulations.

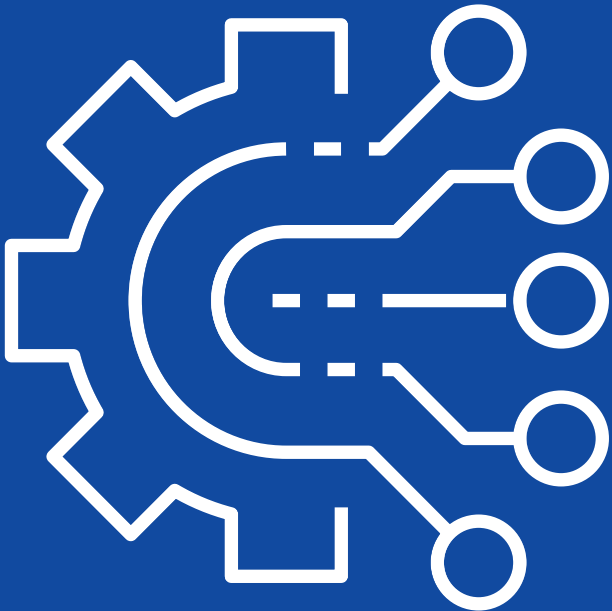
New world scenario – global competition and cooperation and the role of STI

Although Europe, Japan and North America still dominate aggregate STI (Science, Technology and Innovation) and investment globally, their shares are declining and the international landscape is increasingly multipolar [17, 18, 19]. Competition has reached unprecedented levels globally and the industrial structure is changing with important foreign investments, including those of emerging economies in Europe and in the US.

Such changes require investment and policy actions, impacting the complete manufacturing innovation ecosystem. The EU urgently needs a new impetus in STI, a collaborative and integrated strategy for Manufacturing, including clear prioritisation of themes and challenges, definition of collaboration strategies at international level, as well as a strong focus on innovation.

2.

Megatrends and Drivers for Manufacturing



2. Megatrends and drivers for manufacturing

The world economy and the society are undergoing major changes, driving a social transformation as important as the first industrial revolution. These changes are a global phenomenon, affecting the way we live, work and behave. An unprecedented increase in the speed of development in science and technology, fast diffusion of knowledge, the scarcity of resources and a new generation of consumers will drive a **new paradigm shift** at global level and will pose **new challenges and opportunities for European Manufacturing.**

The following are the most relevant trends and drivers for the future of European Manufacturing.

Figure 3 – Megatrends and drivers for future Manufacturing

Changes in demographics: Increase in the middle class, urban and aging population

The world population is expected to grow. According to the United Nations (UN), the world population is expected to grow from 7.6 billion and reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100 [20]. The population growth is mainly concentrated in developing countries, while industrialised areas such as Europe show fertility rates below the level required for the replacement of successive generations. This will lead to an older population – in Europe, 25% of the population is already aged 60 or over and this figure is expected to reach 35% in 2050. An aging population has a profound impact on society, due to the fiscal and political pressures involved. The elderly also have different demands for products, in terms of design and functionality.

The increase in average incomes and the decline in levels of poverty in recent years suggest an increasing middle class at global level. The size of the "global middle class" will increase from 1.8 billion in 2009 to 3.2 billion by 2020 and 4.9 billion by 2030. The majority of this growth will come from Asia and sub-Saharan Africa.

Another pressing trend is the migration of people to urban areas due to the availability of better services, education, mobility, standards of living and professional opportunities [21], which leads to particular consumption patterns and creates the need for infrastructures.

New consumer preferences and environmental awareness

New generation consumers – the Millennials (born post 1980) – are highly demanding regarding products and services. The increasing demand for individual, customised products is introducing major changes into manufacturing. Highly flexible and efficient manufacturing systems, together with demand-oriented production are increasingly enabling the production of individual, customised products at competitive prices.

Environmental awareness is increasing and will remain a strong force for future manufacturing development. An increasing proportion of the highly educated new generation consumers are more environmentally sensitive, shifting their consumption patterns towards the sharing paradigm (e.g. sharing cars instead of owning a car) and "circular" value streams.

Uncertain global political environment

After a period of intensive globalisation efforts, the world is currently experiencing a number of negative effects of (too fast and too unstructured) globalisation, leading to reverse forces like nationalism and protectionism in some countries. How the boundary conditions for industry and their worldwide markets will unfold is an uncertainty, which is increased by emerging markets in developing countries with new and as yet unknown needs.

Climate change and scarcity of natural resources

As the world becomes more populous, urbanised and prosperous, the demand for manufactured products and energy will increase significantly over time. However, the amount of natural resources such as fossil fuels, metals and minerals that can be used to satisfy this demand is finite[22]. The depletion of natural resources manifests itself through environmental pollution, greenhouse gas emissions that contribute to climate change and continued dependence on increasingly scarce natural resources [23].

Wind and solar power have been growing faster than fossil fuels, with major oil companies talking actively about the transition to a low-carbon economy. A recent study [21] shows that the figures in the renewable energy industry are increasing, while fossil fuels sectors are declining sharply.

Resource efficiency is not only a necessity, but also leads to new materials, technologies and business models. The need for reduced transport and logistics costs and impact stimulate a trend towards urban manufacturing. The Circular Economy is slowly being achieved due to political choices, market dynamics and consumer behaviour, with product lifecycles being extended through service, repair, reuse and recycling. This path is needed to reach the targets resulting from the COP21 Paris Agreement [24, 25].

Accelerated technological progress and adoption

The ongoing *4th* Industrial Revolution (Industry 4.0) refers to the development, convergence and application of technologies such as advanced robotics, additive manufacturing, augmented reality, simulation, integration, industrial Internet, cloud computing, cybersecurity, big data and analytics, artificial intelligence, multifunctional and smart materials, enabling the integration of physical and virtual worlds [6]. ICT for cyber-physical manufacturing encompasses the use of sensors to collect data in the real world, together with intelligent control and mechatronics, increased amounts of available data, information and knowledge, enabling detailed digital twins for machines, production lines and complete factories. Flexible automation is increasingly enabling the integration of a multitude of technical processes and self-reconfiguration, self-organisation and self-optimisation of manufacturing systems. Innovation in materials and biotechnology is allowing the development of new materials and more intelligent processes, including recycling, attenuating the impact of natural resources scarcity [15].

These technologies are developing and being adopted at accelerated pace, influencing not only manufacturing processes but also factories and complete value networks.

Global access to knowledge

Fast diffusion and global access to knowledge accelerate global competition. In fact, more and more public and private organisations are making data concerning a wide range of subjects and topics open and accessible, enabling citizens and companies to be aware of and learn about relevant issues, while fostering collective actions.

The scarcity of competent, talented people, the trend towards open data and the increasingly high costs of corporate Research and Innovation will foster new levels of cooperation in Research and Innovation at global level, especially in low Technology Readiness Levels (TRL).

More complex products, processes and value networks

Product complexity is increasing as a result of the adoption of advanced technologies in products and processes and an increased need to address the customer expectations.

The complexity of value networks of specialised industrial companies is steadily increasing. The need for precise logistics with minimised storage costs in conjunction with energy and resource efficiency challenges create trends in two directions: (1) excellent management of the complexity, with the support of digital technologies (Industry 4.0, Smart Manufacturing) and (2) change in business structures and models, by providing isolated services and brokerage and management tools to self-responsible users, letting them organise and, eventually, create their own products (maker economy) [15].

New business models and global value networks

Manufacturing value networks are becoming more and more dynamic. Manufacturers deliver their products to customers through digitalised supply chains, acting in global manufacturing networks, covering both extended or confined geographic regions. Due to the urbanisation trend, production close to the consumer is becoming more common, as well as the creation of products by customers (maker economy).

In this context, global operating companies are adopting similar technologies and systems with a high degree of automation and exchanging best practices in processes by worldwide information transfer. The equalisation of technical standards allows the production of high-quality products everywhere. Global digital ecosystems will emerge.

Digital technologies, new consumer preferences and an increased management sophistication will enable new business models to emerge. Digital technologies and the Internet will support the integration of products and services, increased personalisation and an accelerated globalisation. Data analytics and Artificial Intelligence will enable companies to better understand the market and focus their offerings. Data itself will become a relevant source of revenue.

Fierce competition going up the value chain

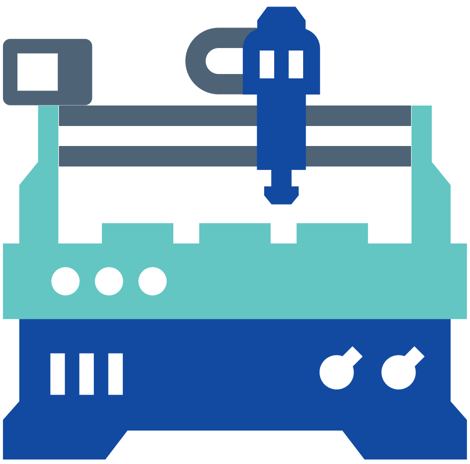
Manufacturing is acting on a global scale, with complex global value networks, global markets, pressuring companies and networks to adopt and change the way they organise value creation to gain a competitive advantage [26]. Concentration trends allowed many markets to be dominated by a small number of multinational companies. Retail and distribution global companies increased their dominance in consumer markets and drive their supply chains to higher levels of efficiency and competition.

The emergence of new players in the technology and industrial markets might disrupt proven company relations and shift the location of value added within supply networks. These new players have high investment capacity, are improving their product development, manufacturing and distribution processes, acquiring established companies and investing more in research and innovation, challenging traditional market leaders.

New skills and employment patterns

Advanced technologies and new management practices create a need for new skills. In manufacturing, this means a shift in operators' workplaces, towards less manual work and more high skilled personnel that require continuous knowledge updates to keep up with technological changes [27, 28]. Support services, management and engineering will also evolve with a more extensive technological support. This will most likely result in less employment of low-skilled workers, larger skills gaps and differences in payment/salaries between skilled and unskilled workers. Educational institutions are challenged to update frequently their programmes and create new offerings to allow employees at all levels to keep up with technological evolution.

In some parts of Europe, a large number of young people are unemployed while, at the same time, there is a need for more skilled people in industry. This paradox is more prominent in scenarios where manufacturing is supported by intelligent machines that require a more sophisticated knowledge set and practical capabilities. Another dilemma is related to global manufacturing. On the one hand, there is a desire to "backsource", reindustrialise Europe and produce locally, resulting in environmentally friendly manufacturing, including less waste and reduced emissions from transport. On the other hand, global manufacturing is important for reaching the UN sustainable development goals such as no poverty, zero hunger, good health and well-being all over the world, creating jobs and prosperity in developing countries [29].



"ADVANCE MANUFACTURING TECHNOLOGIES CREATE A NEED FOR SKILLED WORKERS AND ENGINEERS."

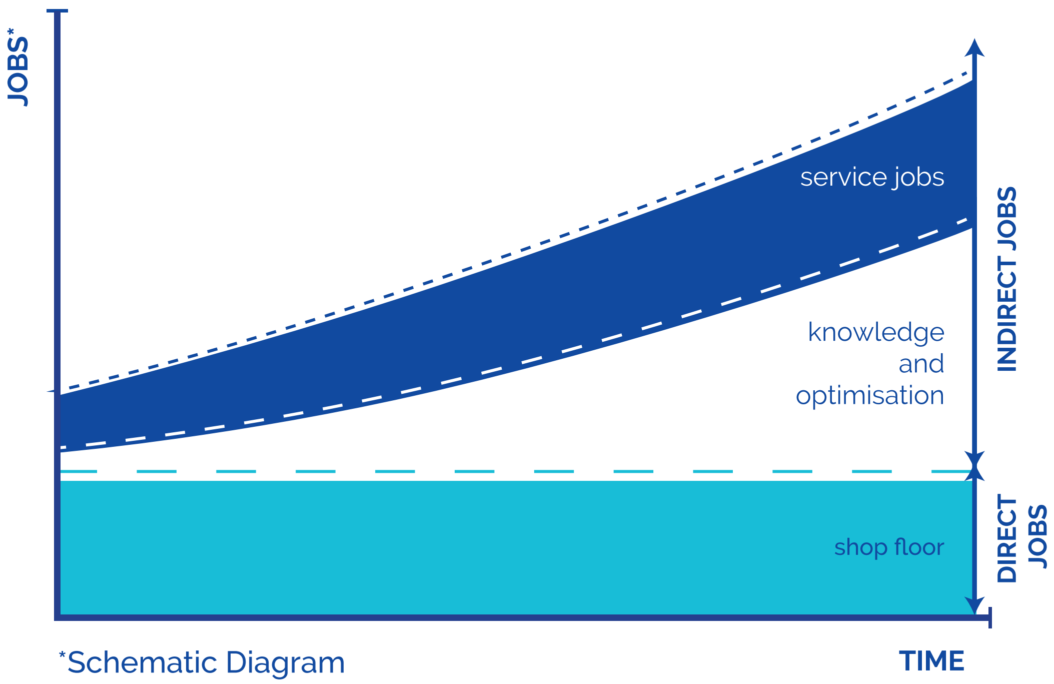
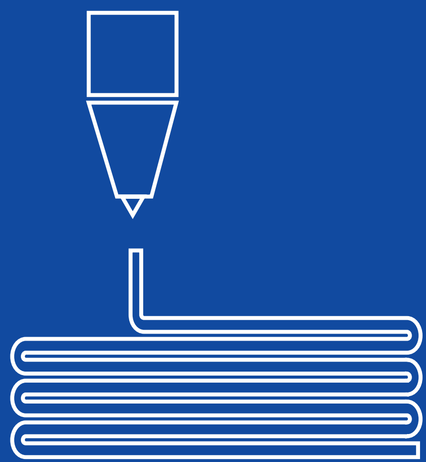


Figure 4 – Indirect jobs increasing in numbers

3.

Challenges and Opportunities for European Manufacturing



3. Challenges and Opportunities for European Manufacturing

To respond to the **megatrends and drivers identified**, European Manufacturing will have to evolve to **become even more flexible and adaptable and reach beyond the customer expectations in terms of product performance, quality and service.** Significant changes will take place in many areas, including disruptive ones, from technologies to business models, from research to training, from individual customisation to social behaviour [30, 31]. The following are the main challenges and opportunities for European Manufacturing.

Customer-centric value creation networks

One of the main changes will probably emerge in value chain organisation, including the geographical location of manufacturing activities. The combination of trends such as customisation and the circular economy, supported by technologies like 3D Printing, will boost the complete redesign of future manufacturing towards **customer-centric grids or webs**, aiming at providing the required products and services while optimising the usage of resources, including materials and energy (also in transport), creating balanced and sustainable ecosystems.

The fast growing development and adoption of AI and Virtual Reality based applications for product and process development, combined with increasingly lower cost of equipment and services for additive manufacturing, empower customers to develop and, eventually, produce conventional and new products. **Customers will have a central role in value creation, with increasingly important participation in design and manufacturing.** Naturally, this poses significant challenges to industry in many domains, such as new business models, co-design, the location of production and service centres, quality and safety.

Leapfrog productivity gains through technology intelligence

Customized products and dynamically changing, customer-centric manufacturing pose substantial challenges for product development, value chain management, sales and support services. Huge amounts of data from multiple sources must be collected, processed and analysed to provide the right products and services at the right time and at the right place. There is a big potential in leapfrogging **productivity gains** in engineering and manufacturing processes by using technology intelligence provided by machine learning, modelling, simulation, among other technologies. New technologies coming e.g. from the computer sciences provide engineers with powerful tools for designing and simulating new manufacturing strategies that have the potential to enhance classic manufacturing technologies and to go beyond the technological limits of today.

HUMANufacturing as a new era of automation

The balance between high value added tasks being carried out mainly by humans and repetitive tasks performed by machines with high speed, precision and security, leads to an increase in the quantity and quality of jobs in manufacturing and related services. **HUMANufacturing** as a new era of automation enhances and augments relevant human capabilities with new technologies. It is the winning combination for highly automated and robotised processes, yet capable of providing flexibility and adaptability to new customer requirements. Industry 4.0 concepts and technologies will be widely adopted. Materials, consumables, intermediate and end products, equipment and processes, quality documentation, etc. will be part of the Internet of Things. Artificial Intelligence will be widely adopted, supporting product design, operations, decision-making and customer interaction. Factories will adapt and become resilient to foreseen and unforeseen changes in the market and in technology.

Simplexity – Making complex manufacturing systems simple

Nature as a complex "manufacturing system" has always been a source of inspiration and knowledge for Industry. In recent decades, these synergies have been intensified, mainly due to relevant developments in the field of Life Sciences and particularly in Biotechnology. Diversified application areas such as sensors and actuators, bio-refineries or energy storage illustrate and fuel continued and stronger cooperation. But **nature inspired manufacturing** can also lead us to design and operate more sustainable ecosystems, from organisational to technology levels, for example, how to combine different "actors and activities" with efficient processes for recycling and reusing materials. Bionic learning and "symplexity" approaches can lead us to design and engineer complex but highly productive and resilient manufacturing systems in a simple and easy to handle manner.

Responsible value creation in a circular economy

Consistent legislative and policy frameworks, the availability of technological solutions and a global shift in consumer preferences, behaviour and environmental awareness will foster wide implementation of the circular economy. European manufacturing companies will contribute to responsible value creation and extend the multiple lifecycles of their products through improved design, manufacturing, use and service, recycling, refurbishment, reuse and remanufacturing. Industrial symbiosis, involving the optimisation of whole manufacturing ecosystem resources, will be achieved to a large extent, leading to minimal consumption of raw materials and energy, supporting global competitiveness and environmental protection. **The circular economy is a large cooperative endeavour and manufacturing is at its core.**

New partnerships for new manufacturing skills

Education and lifelong learning will become critical functions, allowing employees at every level and all functions to adapt to new, fast changing technologies and working methods. Manufacturing will create new careers and job profiles and will be able to attract talented young people. But innovation will be developed at paces never seen before, calling for more intensive collaboration between academia, research organisations and industry, and new and faster methods and channels. Public authorities and organisations play an important role to facilitate new collaborations and reinforcing ecosystems. The still existing segmentation between R&D and Education and Training policies and programmes should be smoothened, aiming at more synergies and joint actions that could align and facilitate the development and validation of advanced technologies with the training of a skilled workforce. Cooperative infrastructures, such as **Learning Factories**, and emerging education and training paradigms, such as the **Teaching Factory**, have the potential to implement this type of cooperation, whether in the manufacturing industry (usually driven by large companies or associations representing SMEs), academia or research and technology organisations.

Manufacturing as networked and dynamic sociotechnical system

Manufacturing in the 21st century will be a complex, multi-facetted, highly networked and dynamic sociotechnical system. The digital revolution dramatically increases the vertical and horizontal integration, considering the whole lifecycle of manufactured products. Physical products and service components are fully integrated into the lifecycle, including design and engineering, embedded systems, process support systems, production technology and support services. Thus, manufacturing goes far beyond factories and refers to networked and dynamic value creation systems, which can be organised in multifaceted ways. The coincidence of various value creation systems, which are adapted to specific needs and framework conditions, contribute to a resilient European manufacturing system in a dynamically changing and uncertain world.

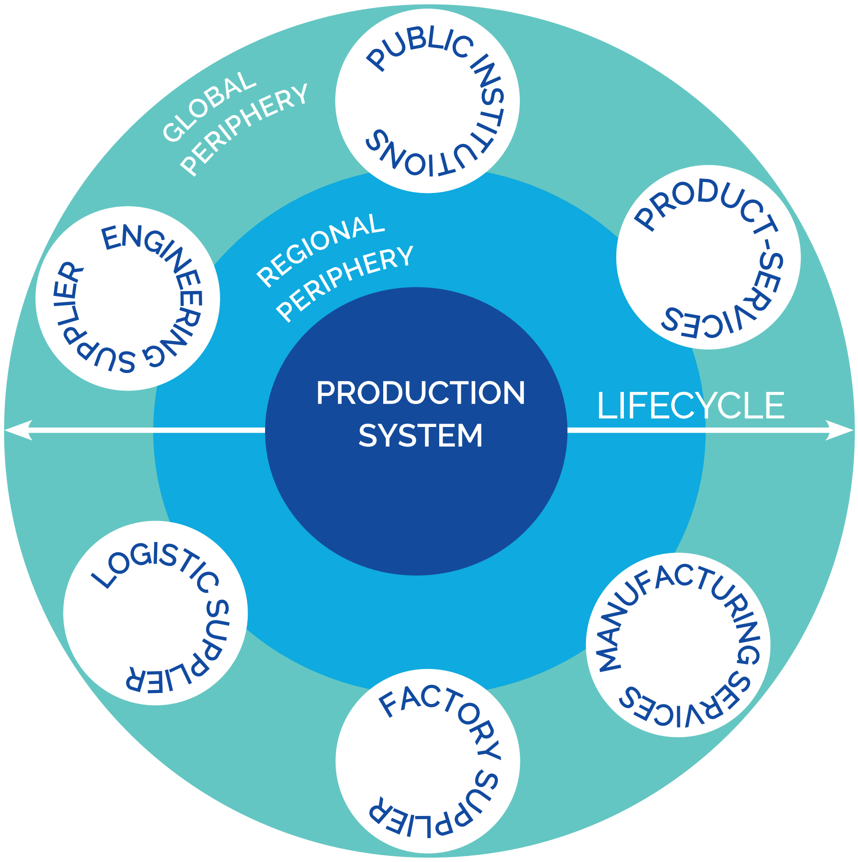


Figure 5 – Manufacturing innovation system, a complex and highly dynamic sociotechnical system.

Value creation networks

Manu*FUTURE* envisions four relevant archetypal types of value creation networks that companies may configure or even combine to target different markets or product lines:

1. Highly Integrated Global Supply Networks
2. Regional Value Creation for Global Markets
3. Local Value Creation for Local Markets
4. Dynamic Virtual Value Networks

1. Highly Integrated Global Supply Networks

Globally acting companies, such as already today vehicle OEMs, will operate and orchestrate **global supplier networks, including highly automated assembly factories** in the most relevant markets with cost, speed and flexibility pressures. **Globally harmonised regulation** and governance and extensive digitalisation will enable highly integrated global value creation networks. There will be a tremendous **need for managing the complexity** of the supply chain. Value creation intelligence based on **artificial intelligence (AI)** technologies and on **real-time integration of physical and virtual worlds** will be realised to monitor the potential customers, to identify needs and wishes and to interact with the product design. **Novel digital/physical architectures will emerge** (digital twin, factory as a product, etc.) from the factory to the network level to allow extreme levels of vertical and horizontal integration and more flexibility and responsiveness. The productivity and performance of the highly integrated value creation network rely on **standardisation at the highest technological level, zero failure and resource efficiency approaches.**

2. Regional Value Creation for Global Markets

Highly specialised companies, including SMEs, will drive regional **value creation networks** to target **global markets.** Companies within these networks have a high ratio of in-house production while controlling complete customer-specific value chains. In this context, the manufacturing systems are built according to frugal principles, optimised for cost and performance and compliance with all relevant regulations. Digital platforms support product design and development, possibly including the end consumer, and operations management. Regions with many leading protagonists (hidden champions) in relevant technology fields develop flexible structures of medium-sized enterprises focused on efficiency and intelligence. According to the principle of Regional Smart Specialisation, regions specialise in specific product lines and deliver them to the global market. These **regional networks** are highly **specialized, flexible** and **dynamic** and will frequently focus in highly specific and/or complex products. Regions shall create supportive conditions, infrastructures and a regulatory framework and support the development of technological centres and Regional innovation hubs.

3. Local Value Creation for Local Markets

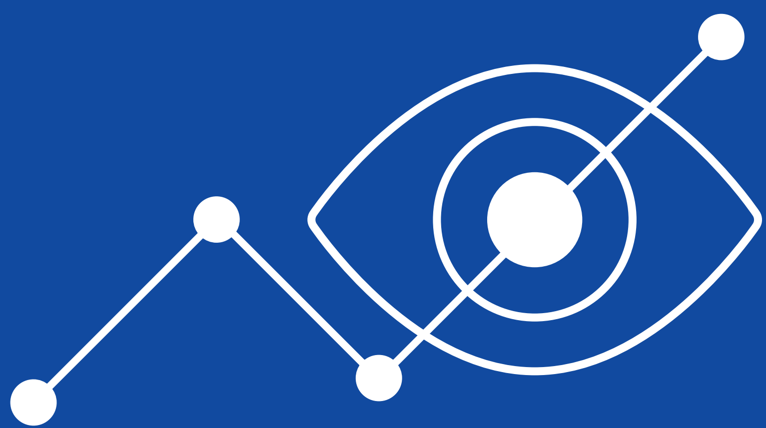
Due to the **Urbanisation** megatrend and the need to target specific consumer preferences, manufacturing will be increasingly carried out near the consumer in urban areas, as cities have strong economic and social assets. **Urban Manufacturing** is one form of value creation where materials and components are sourced globally, while the final assembly or personalisation is mainly performed locally near or even by the customer. In this context, the complete production, the final assembly or personalisation takes place on demand for products such as apparel, food, household equipment or furniture. Urban Manufacturing is also applied to craftsmanship-oriented small industries that produce specialised products for niche markets, including maintenance, personalisation and product lifecycle service industries. Manufacturing in these conditions should have zero-emissions, zero waste, be highly flexible and adopt compact designs to be affordable in urban areas.

4. Dynamic Virtual Value Networks

Compared to the highly integrated and centrally controlled global value creation networks, **platform-based ad-hoc value networks** emerge spontaneously to match specific business opportunities at global level. Manufacturing companies of different sizes and service providers offer their skills and capacities on the platform. Each agent can set up a **manufacturing network** to produce and sell a defined batch of a specific product. Advanced IT platforms will provide business intelligence and advanced decision-making. Platform providers assemble temporal limited process chains and allow traditional companies to better orchestrate their business, grab new business opportunities and implement new business models. Manufacturing, engineering, logistic and service companies will interact supported by interoperable systems and open standards. Complex products are manufactured in highly automated and flexible plants with total quality and safety assurance.

4.

Manu*FUTURE* high level vision and strategy for 2030

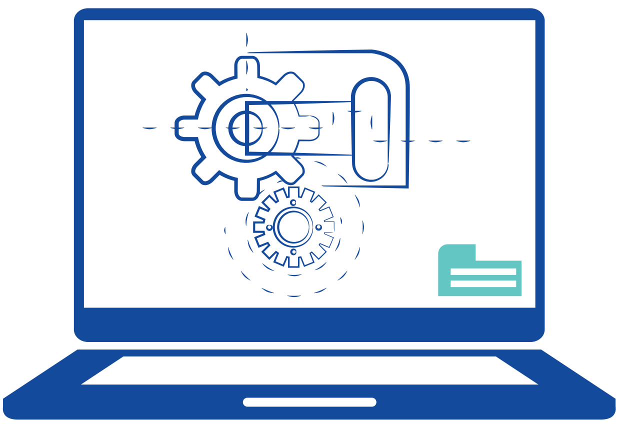


4. Manu*FUTURE* VISION AND STRATEGY FOR 2030

4.1 Manu*FUTURE* Vision

In a context where competition is becoming much stronger and is going up the value chain and consumers are becoming more demanding, **Europe will have to address new challenges and opportunities and to increase its investment in manufacturing to reinforce its future position.**

The goal is to increment the number and attractiveness of jobs, while at the same time securing the environmental, economic and social sustainability for future generations in Europe. In the global competition, these goals have to be achieved while continuously improving the productivity of the factories, which in return provide the floor for increasing services around manufacturing and along the product lifecycle.



"EUROPEAN MANUFACTURING IN 2030 WILL BE A GLOBALLY COMPETITIVE, INTERCONNECTED AND ADAPTIVE SOCIOTECHNICAL VALUE CREATION SYSTEM THAT ENSURES SUSTAINABLE GROWTH AND SOCIAL WELFARE, IN A RESOURCE-CONSTRAINED WORLD."

In 2030 the European manufacturing industry will be delivering **solutions of excellence,** ensuring individual user-satisfaction (including customised products and services), high quality and environmental and social sustainability.

While global competition is increasingly challenging, Europe will reinforce its position because of its **technical and technological leadership and capacity to handle complexity.** 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.

Europe will be the **leader in manufacturing 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.

Europe will be at the forefront **in resource efficiency and circular economy implementation,** which will contribute to its competitiveness at 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, productions systems and services.

Starting from a strong **scientific and technical leadership**, the Manu*FUTURE* Vision evolved over time. Moving from a pure focus on ensuring **competitiveness** in its early days, to the inclusion of **sustainability requirements**, the 2030 Vision addresses now also the need for a **resilient and adaptive manufacturing ecosystem** able to cope with increasing levels and environmental and social requirements.

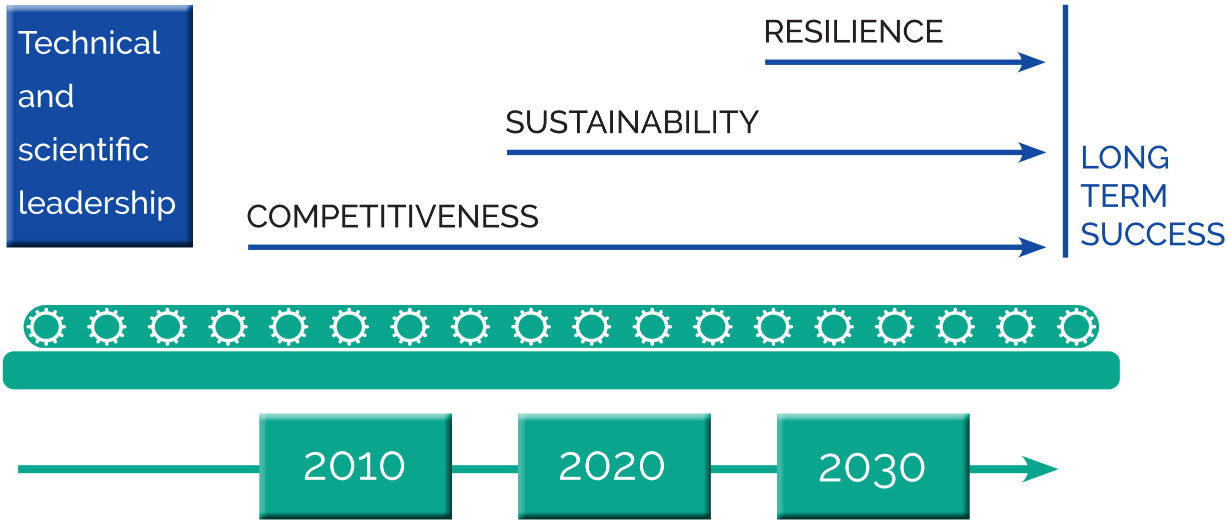


Figure 6 – High-level vision for European Manufacturing 2030

4.2 MANU*FUTURE* Strategy

Aiming at long-term competitiveness and success, the Manu*FUTURE* Vision for 2030 proposes that Europe needs to build on its proven capabilities and **invest more to ensure its leadership in:**

- **Key Enabling Technologies**
- **Digital transformation and new business models**
- **Mastering complexity of products, processes and systems**
- **Resource efficiency and sustainable development**
- **Resilient and adaptive manufacturing**
- **Innovation ecosystem**

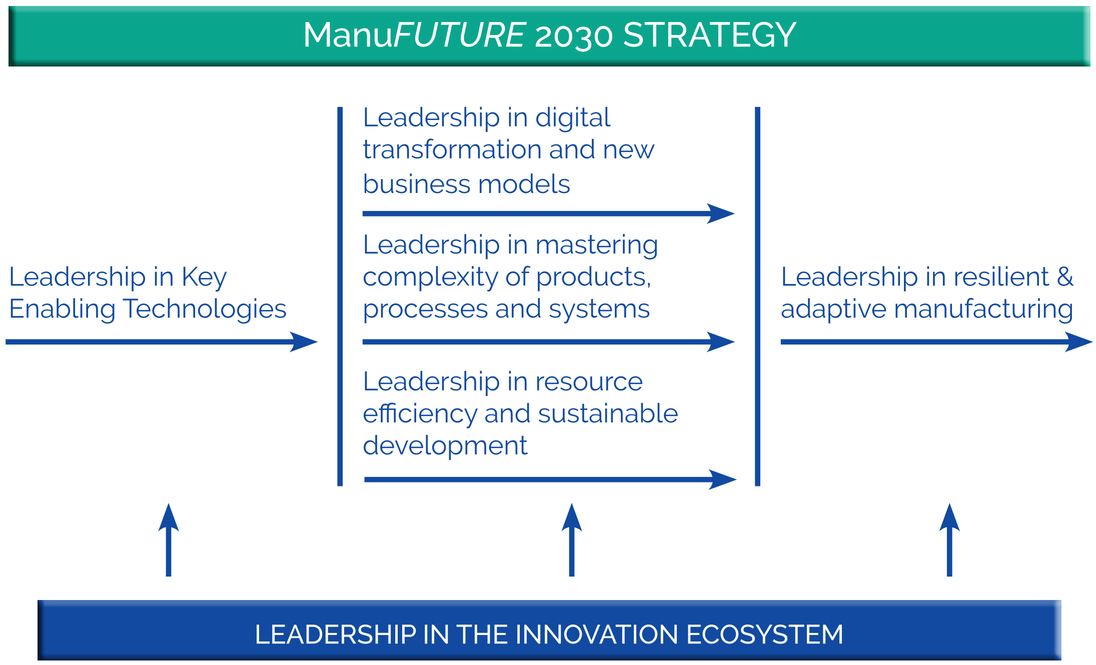


Figure 7 – ManuFUTURE Vision and Strategy for 2030

Leadership in Key Enabling Technologies

In 2030, European manufacturing will be competitive at global level due to its high-performance and technological level, targeting zero-defect, zero-delay, zero-surprise and zero-waste production processes.

Technology leadership will ensure long-term differentiation and market success. The horizontal nature of **Key Enabling Technologies (KETs)** makes them **especially critical because of their potential impact on a vast number of sectors and value chains.** KETs will enable the development of new high value added businesses (e.g.: manufacturing technology, nano or biotechnology) and will reinforce the competitiveness of all industrial sectors (including more mature ones).

Europe needs to reinforce its investment in KETs, including new technology domains such as Artificial Intelligence and Digital Security and Connectivity [33], also to outbalance the investments of its main competitors in these areas. Knowledge transfer and cross-fertilisation will create synergies and amplify the returns across different industrial sectors.

Advanced manufacturing technologies have a special role in the (current) KET universe, as they are necessary to produce and/or enable the use the other KETs (nanotechnologies, advanced materials, biotechnology, etc.). They justify the title of "Enabling Technology" of the current KETs. They are also an integration platform for all the other KETs, including potential new ones. Europe will reinforce its position as a leading supplier of advanced manufacturing technologies and will increase the respective value added.

Advanced materials and nanotechnology in turn have a potential impact on several domains, including the circular economy, and can be an important source of differentiation and competitiveness.

Particular relevance is attributed to those emerging from the digital revolution, namely **Artificial Intelligence (AI) and Digital Security and Connectivity.** AI will enable increased levels of automation and human interaction, while Cyber Security will be a prerequisite for global collaboration and interaction.

Micro-Nanoelectronics and Photonics enable advanced products and manufacturing processes, particularly in areas such as functionalisation and miniaturisation.

Life Science Technologies will become increasingly important, with relevant contributions in areas such as energy harvesting and consumption, environmental impact, new materials and process efficiency.

Leadership in digital transformation and new business models

In 2030, customer-driven value creation will be prevalent. Flexibility and short delivery time will outbalance production costs as the main criteria for competitive advantage. Europe will be the leading market for personalised products due to its single market with highly demanding customers that drive innovation.

Thanks to its unique skills and the investment and maturity in digital transformation, design and high-value production activities will be located in Europe. On the verge of the 4th industrial revolution, Europe will deepen its **digital transformation and the integration of advanced manufacturing technologies** and will reinforce its position as the leading technology provider for these areas. Europe will valorise its unique heritage and will ensure the world best position in both domains.

The diffusion and wide implementation of these innovative technologies in Europe should **support manufacturing sustainability, flexibility and resilience.** Access to these technologies by European manufacturing earlier than the other competitors will be a key and sustainable competitive advantage. Digitalisation and manufacturing are interdependent: in the medium term, Europe cannot be globally competitive in one without the other.

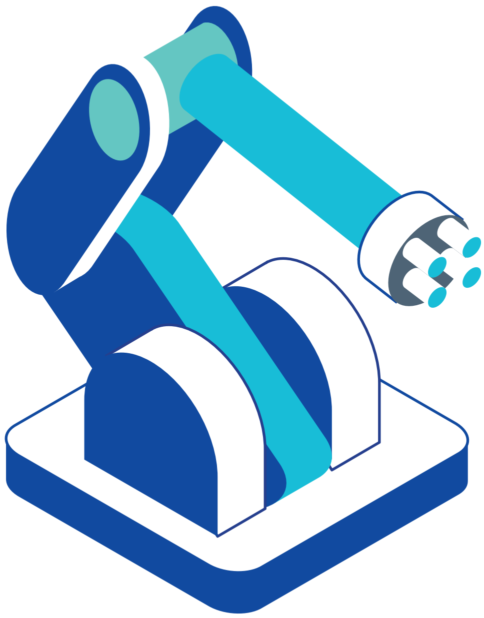
New paradigms have emerged, such as the sharing and the outcome economies. In this environment, manufacturers will have to devise **new business models and logics,** both in Business to Consumer and Business to Business.

The concept of the **sharing economy** is evolving (particularly in manufacturing), allowing individuals or companies to have access to products that would be otherwise out of reach, particularly relevant when the price of a specific asset is high and its utilisation rate is low. The **outcome economy** ensures the production of measurable results for the clients or customers, using their success parameters as trade reference. This implies a shift from competing through selling products and services, to competing on delivering measurable outcomes that are important to the customer.

Leadership in mastering complexity of materials, products, processes and systems

Europe is the leader in engineering highly effective and complex lifecycle-oriented products, processes and value creation (eco)systems, thanks to its excellent manufacturing and engineering know-how. Linear production processes are intelligently reorganised towards circular and networked production-consumption-recycling systems, e.g. in the field of e-vehicle manufacturing with refurbishing and recycling facilities. The engineering know-how is broadly shared e.g. in specific knowledge and innovation hubs and used in other sectors (e.g. for intelligent buildings, home care, agriculture etc.), thus contributing to fundamentally increased productivity and value added in the European economy.

Thanks to its infrastructure, innovation ecosystem and European-wide standardised education system, Europe is the leading global provider of engineering know-how, utilising the whole technology spectrum from fundamental science up to ground-breaking and system technologies. Social sciences, business and entrepreneurship are integrated parts of this system.



Leadership in resource efficiency and sustainable development

In 2030, European manufacturing stakeholders will be balancing longer-term entrepreneurial profit with responsible and sustainable business impact. Sustainable entrepreneurial profit-making – as compensation for risk-taking endeavours – serves as a driving force for innovative and highly competitive value creation. With its financially strong and economically vital manufacturing sector, Europe will be the best place for future-oriented public and private investments. In their decision-making, European manufacturing stakeholders respect longer-term impacts on all economic, societal and ecological aspects. In line with comprehensive policy goals such as the UN Sustainable Development Goals, investment decisions in the European Manufacturing System serve all triple helix aspects of "People-Planet-Profit". European companies will focus on operational efficiency and effectiveness of manufacturing in terms of resource utilisation and waste minimisation, to protect and nurture the natural environment. Europe will be leading in recycling and circular economy processes and technologies, a clear future market opportunity.

The shift towards a circular economy starts with rethinking the initial design and manufacturing of the product, considering its second life reutilisation or material recyclability. De-manufacturing facilities will handle a high variety of products in different lifecycle stages. Remanufacturing plants will be the main driver towards the increase in reuse, repair and remanufacturing of products, providing equipment, technologies and know-how to manage these phases. For high-value and highly complex products (e.g. in the automotive, instrumental goods or energy sector), remanufacturing and de-manufacturing activities will rather be integrated with manufacturing plants, sharing the same equipment and technologies.

Working and living conditions will be improved, as well as the political and social cohesion, stability and welfare (more rewarding jobs, fewer people suffering from or at risk of poverty and social exclusion). Humans will surely play a key role in European manufacturing in 2030. European citizens, well-prepared for continuously changing job requirements and lifelong learning, will make the difference at a global scale. Thus, European manufacturing in 2030 will provide a robust foundation for economically, socially and ecologically sustainable development of the European Union and contribute to increase sustainability in a global context.

Leadership in resilient manufacturing systems, adaptive to rapidly changing environments

The 21st century will be characterised by a high degree of uncertainty. Increased interconnection and integration within global systems also means increased dependencies, and thus vulnerability, as seen in financial and economic crises. Continued climate change, deteriorating environmental conditions, urbanisation, geopolitical volatility, the increase in automation, emerging markets and changes in society are challenging the European manufacturing industry with a more competitive and volatile environment.

Understanding these challenges and transforming them into opportunities is a major priority for European manufacturing. Thus, the European **manufacturing system in 2030 must be resilient and adaptive** to cope with a rapidly changing and unpredictable environment, overcome disruptions and adapt to meet the changing market needs.

Resilience in this context also means continuous monitoring of the environmental change, the gathering of strategic intelligence along the whole policy cycle and the evaluation of the potential impact on manufacturing. Thus, joint efforts by multiple actors (science, industry, public authorities, civil society) across multiple governance levels (regional, national, EU) are needed to achieve the vision of a globally leading and resilient manufacturing system able to adapt to rapidly changing environments.

The four models described in chapter 3 address resilience in different ways. The highly integrated and highly complex global supply networks of Model 1 are resilient due to their sheer size. But they have to develop more agility in the exchange of companies in the value network and within the companies to be able to quickly respond to external drivers. Model 2 and even more Model 3 are especially valid when protectionism of nations increases. The dynamic virtual value networks of Model 4 tackle resilience by their limited lifetime.

Leadership in the manufacturing innovation system

The highly competitive and resilient European manufacturing system will be based on a comprehensive Manufacturing Research and Innovation Ecosystem which overcame the fragmentation of the past. In 2030, joint efforts and strategically aligned investment decisions of multiple innovation actors from multiple sectors across multiple governance levels will be achieved:

- multi-actor: stakeholders from public authorities, civil society and financial institutions, to industry, universities and research organizations

- multi-sector: various industry sectors and political "sectors" along the knowledge triangle "education – research – innovation" (e.g. synchronising education, research, industry and regional policy), with a strong interaction beteween sectors providing and using, advanced manufacturing technology.

- multi-level: interlinked European, national and regional programs and initiatives

As a result, in 2030 Europe will have a worldwide leading innovation ecosystem which acknowledges the broader socio-ecological environment as an important driver for manufacturing innovation and where the impact and strategic importance of manufacturing is measured in terms of value added and direct and indirect jobs. Europe will introduce on the market new products and technology faster than any other region at global level, reinforcing its value added and market share.

Europe will have a highly qualified workforce in Manufacturing. The permanent adaptation of education and training programmes and the development of European Qualification Systems for Manufacturing will ensure that all EU countries have the necessary workforce required for the European Manufacturing System in 2030.

4.3 Implementation Roadmap

The European industry will experience several "transformational" waves in the next years and decades, as a result of technological development, competition and societal changes.

An Implementation Roadmap (IR) is designed to anticipate the impact of these transformational waves and prepare industry to take advantage of related opportunities. Complementary to a technological roadmap, the IR addresses the conditions for mass adoption of innovative technologies, processes, services and business models, including training and education, adequate public and private funding and financing, regulation and customer and societal awareness.

The following paragraphs present a vision of the implementation timeline for mass adoption of the foreseen three transformational waves:

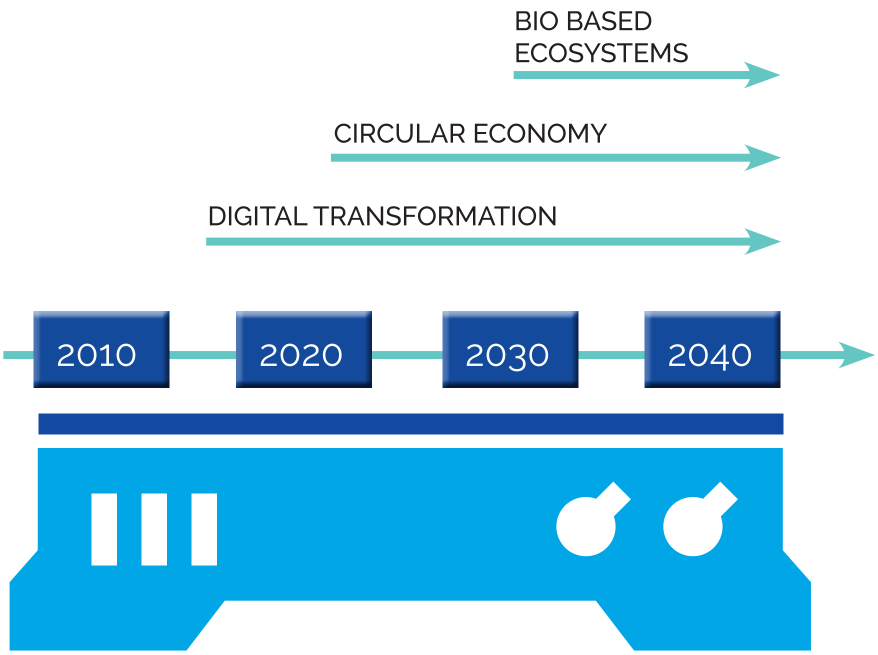


Figure 8 – Three transformational waves

DIGITAL TRANSFORMATION

Is part of our society, with already a strong impact. There are many technologies, products and services available and a significant dissemination and promotion effort is being made, both by public and private organisations, namely under the umbrella of several "Industry 4.0" initiatives and programmes. The main challenge now is the absorption capacity of the industry, considering the related requirements, especially in terms of investment, organisation and human resources. Complementarily, many SMEs find existing solutions still too complex and call for further developments towards simplification, modularity and implementation support tools. Naturally, new research is needed, particularly in areas such as Artificial Intelligence and Cybersecurity.

CIRCULAR ECONOMY

Mass implementation of significant Circular Economy concepts still needs a considerable R&D effort, namely in new materials and processes. But it also calls for significant changes in the mindset and practices of both consumers and industry, which should be boosted via new and consistent regulations and incentives. Due to its relevant contribution to the implementation of the Circular Economy, the **Sharing Economy** will follow a similar implementation path, although it is important to highlight that, in this case, there are significant sector specificities. The Circular Economy and the Sharing Economy demand similar steps: further R&D is needed and also new regulations (public side) and new consumer behaviours.

BIO-BASED ECOSYSTEMS:

Although biotechnology has already led to significant developments and applications in some sectors (chemical, food or energy), a much larger relevance and impact for manufacturing is foreseen for the broader area of Life Sciences, towards nature inspired, bio-integrated and finally bio-intelligent ecosystems with tight interaction between technical, informational and biological systems. The development of these concepts calls for a significant R&D effort and close cooperation between the related scientific and technological areas and teams. The mass implementation of these results will be in the mid- to the long-term.

5.

The ManuFUTURE vision building blocks

5. The ManuFUTURE VISION BUILDING BLOCKS

To achieve the Vision and Strategy defined above, the Manu*FUTURE* 2030 Vision defines three building blocks: science and technology, innovation and entrepreneurship and education and training.

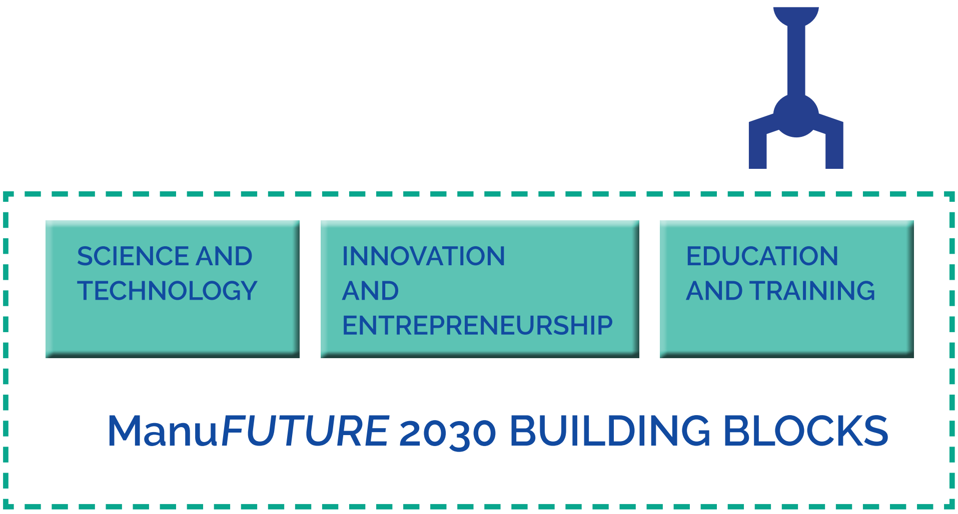


Figure 9 – ManuFUTURE 2030 Building Blocks

5.1 Science and Technology

The first building block for successful manufacturing in Europe by 2030 is Science and Technology.

The competitiveness of companies and the sustainability of societies are strongly related to the continuous success in research, development and innovation (R&D&I) investments. As detailed above, in the current competitive environment, Europe will only be able to keep and further improve its position in manufacturing and to secure the current level of employment if it is able to ensure a technological leadership at global level. To this end, Europe will have to invest more in:

- Applied Research;
- Fundamental Research;
- Social Sciences and Humanities.

Contribution from Applied Research

The main contribution from applied research and technological development to manufacturing competitiveness and innovativeness stems from the following:

- **New business logics and models:** Mastering product complexity with ondemand, personalised products will require new collaboration structures and networks. In a circular economy, customer services will play a more important role and new business models and logics will emerge beyond paradigms such as the sharing economy and the outcome economy. These will become game changers and will be enabled by disruptive technologies such as high-performance clouds, artificial intelligence & machine learning, data analytics, swarm intelligence, bioprocessing, functional additive manufacturing, autonomous systems and many more.

- **Design and management of agile manufacturing systems:** New strategies, methodologies and tools to design and manage the manufacturing systems of the future will enable unprecedented levels of agility, modularity, flexibility and resilience. These will have to consider the capabilities of new digital and process technologies and enable the implementation of new business models and manufacturing strategies.
  Agility in its extreme is the intrinsic concept in the 4th type of value creation networks in chapter 3. A successful implementation of type 1 will, in contrast, depend largely on highly organised agility, as presented in section 4.2. The agility of Types 2 and 3 have a foundation in the close proximity of the value network partners but especially Type 2 has to assure a high responsivity to changing global needs.

- **Digital transformation and smart products:** Digital transition affects manufacturing industry at all levels from customer interaction, to supply networks, to machines and workers at shop floor. Digitalisation provides the means to address challenges such as mass customisation, lot-size-one production, re- and de-manufacturing and zero-defect manufacturing and enables continuous improvement in flexibility, productivity, accuracy, security and sustainability. Smart products integrate smart sensors, artificial intelligence, robotics, and extensive connectivity. New generations of products and new manufacturing paradigms will emerge like cloud- and edge-based manufacturing. AI will enable the extraction of knowledge from the huge amounts of data generated and captured at all levels from consumer behaviour, product utilisation, manufacturing and global supply networks. AI will support all human activity in manufacturing with a special emphasis on analysis and decision-making considering uncertainty factors. Next to Big Data and Artificial Intelligence, also platforms for storage of sensor data and traceability of transactions in blockchains as well as the cyber security, including privacy protection will gain significant importance in manufacturing. And finally international standardisation on all levels from physical till data semantics of machine to machine and factory to factory communication will be needed to avoid costly and innovation limiting vendor lock-ins need to maintain the knowledge of multi systems, in particular for the small and medium sized companies.

- **Biological transformation of products, processes and value creation:** New biological processes, technologies and value chains will allow the recovery of agricultural, forest and urban waste, enable the development of new materials, new sensors and actuators and inspire new value-added systems. Bio-manufacturing will open up new opportunities for using biomass from different sources to produce chemical, pharmaceutical and food products with reduced energy requirements and environmental impact.

Biotechnology will reduce Europe's raw material and energy requirements and boost the development of new energy harvesting and storage technologies.

- **Robotics and flexible automation:** Developments in robotics and automation will enable the simultaneous improvement of efficiency and flexibility. Collaboration and integration between humans and machines will augment human capabilities rather than replace them, allowing humans to focus on more value added, creative and socially relevant activities.

- **Manufacturing processes and technologies:** New manufacturing technologies, production processes and manufacturing systems engineering will reinforce the European capability to design, manufacture and **provide the best production equipment and systems globally.** More specific fields of engineering such as product design engineering, mechanical engineering, mechatronics and electrical and electronic engineering will also contribute to better European products and factories, as well as to better services provided by European manufacturing industries.

- **Nanotechnology and new materials:** Materials engineering and nanotechnology will play a key role in relation to the physical properties of the European products and components, as well as the processes needed to manufacture, re-manufacture and recycle them. Utilisation of diverse advanced materials and their combination in manufacturing value chains will be enabled by material encoded data, contributing to the circular economy challenges. In addition, the full lifecycle of products and processes must be considered and therefore, technologies related to engineering, joining, disassembling and recycling will strongly contribute to the environmental sustainability and competitiveness of European industry.

- **Customer Driven manufacturing:** Future manufacturing will address the needs of each individual customer, through highly flexible and integrated manufacturing systems. Customers will be able to configure, personalise or customise the products they need, with an increasingly more important role in product conception and design. Advanced technology will enable manufacturing to better capture and integrate customer preferences and requirements and to design better products.

- **Human centred manufacturing:** New technology will not replace humans in creativity and decision power in key areas. Technology will support human activity and augment their capabilities to higher levels of effectiveness and value added. New interfaces between humans and machines and also between machines will enable new levels of cooperation. Factories will be designed to provide an appealing and challenging environment for humans, attracting the best professionals and talents for European manufacturing.

- **Circular economy, resource and energy efficiency:** Solutions to minimise the costs and environmental impact of manufacturing, particularly by reducing the consumption of resources like materials, water and energy. The shift towards a circular economy requires designing products that are easier to repair and maintain, upgrade and recycle, with an enlarged customer service. Processes, technologies, skills and facilities devoted to maintaining, repairing, upgrading, remanufacturing and/or recycling products and their components is another major challenge for future European manufacturing. Remanufacturing facilities will operate together with or be embedded in manufacturing plants to manage the whole lifecycle of products. New solutions for optimal energy efficiency, recovery, harvesting and storage are needed to enable Europe leadership in resource efficiency and sustainability.

Contribution from Fundamental Research

Science and technology have been the engine and the foundation for innovation for decades and, in manufacturing, it is expected to be even more so in the years to come. Europe is a strong global player in fundamental research, but its connection with more applied research and technology development needs to be reinforced in the field of manufacturing.

The future of manufacturing will rely on interdisciplinary scientific discoveries. To stay at the forefront, scientific disciplines need to interconnect to a much higher degree: applied mathematics and computer sciences will impact manufacturing networks, industrial cybersecurity, complex manufacturing processes and systems modelling, a renewed era of artificial intelligence and learning systems, novel human-technology interaction. Physical sciences (e.g. materials, nano/micromaterials, functional materials, magnetics, superconductivity, fluids, plasma, quantum science) as well as chemical sciences (e.g. new polymers, batteries) and biotechnology and life sciences (e.g. new synthetic biological processes, biopharmaceuticals, new sensors and actuators) will impact on many fields, related to the properties of materials, the way they are processed and integrated into new products and devices.

A key element for the successful uptake of scientific results will be the establishment of communities or ecosystems, of networks of diverse types of scientists and technologists, where both the needs and challenges from the technology market side as well as the promising technological and non-technological outcomes of relevant scientific fields can be shared and discussed, aiming at using them to the benefit of European industry.

Contribution from Social Sciences and Humanities

In a highly interlinked society, also reflected through complex manufacturing value networks, relevant challenges cannot be addressed on a single-discipline or single-technology basis. Human behaviour, perceptions, emotions, consumer preferences and design, as well as social aspects related to the desirable society structure for Europe and globally, the relationships between stakeholders, etc., require approaches that will combine technical aspects as well as humanities and social sciences.

Relevant challenges include making European products more attractive and offering better places to work or, in other words, being able to generate positive emotions in the people involved in manufacturing. Besides marketing and communication initiatives, this has to include aspects such as product design but also the architecture of plants and design of work spaces. Also, the role of the manufacturing worker has to move from traditional repetitive tasks towards new and more sophisticated activities (e.g. product conception, user support services, monitoring, process design, teaching robots, developing, configuring and supporting IT solutions), promoting cooperation with advanced support systems, such as cooperative robots or AI enabled technologies.

The fields of economics and management provide insights about the future business environment, logics behind and related models. Other crucial topics for a competitive future industry are entrepreneurship, industrial relations, management and production management and networked enterprises. In addition, there is a need to address the framework conditions of our economy and industry, to set European (and global) standards, to address working conditions, ergonomics, labour relations, etc. Law and political sciences, as well as Ethics will play a role in these subjects.

Finally, relevant key aspects for European manufacturing are its perception in the society, the role of women and men in the factories, how to make factories more attractive to young talents, lifelong training of industrial workers and fostering entrepreneurship. Education, psychology and sociology will have a key role.

Global Cooperation in Science and Technology

Science and technology strategies and tools at European level cannot be designed without considering its position and potential cooperation at global level. New **levels of cooperation** in Research and Innovation **will emerge at global level** in response to common global needs and to the increasing complexity of converging technological fields, with large investment requirements.

To maintain European leadership in manufacturing and to deal with the soaring costs of Research and Innovation and the scarcity of skilled and talented people, fruitful international cooperation is needed. The following aspects should be considered:

- Identifying the emerging technologies that are "critical" for the medium/long-term future of Manufacturing;
- Assessing the position of the EU Science, Technology and Innovation (STI) system regarding the critical technologies, in terms of scientific and industrial capabilities and resources devoted to their development;
- Identifying the countries outside the EU that either hold a strong competitive position regarding the critical technologies for Manufacturing or are investing heavily in their development, and assessing their strengths and evaluating the feasibility of cooperation with the EU, based on complementarities, synergies and economies of scale;
- Identifying the critical technologies that are determinant for market success. These should be developed internally and should require the highest investments. For more horizontal and enabling technologies, the potential for international collaboration should be evaluated and its implementation promoted;
- Generating a set of recommendations to establish international STI agreements in the field of manufacturing (at institutional, scientific and industrial levels).

5.2 Innovation and Entrepreneurship

The second building block for successful manufacturing in Europe by 2030 is innovation and entrepreneurship.

As mentioned before, Europe is a strong global player in science and technology, but its capability to translate its excellent performance in knowledge generation into successful new products and new business needs to be significantly improved [34].

The **development and mastering of new and unique technologies and skills** are effective and durable sources of differentiation. In the manufacturing domain, a single new technology might take decades to mature to an industrially relevant level, and years to complement and finally replace old methods and technologies in the industry. Innovation, the process of translating an idea, an invention or a technology into a new product or service that creates value for which customers will pay can be measured by the "time-to-profit". To be a real and solid source of competitive advantage, Innovation must be both disruptive and replicable at an economical cost and must satisfy a specific need.

Manufacturing is a **complex and heterogeneous ecosystem** with a wide range of actors, including companies of different sizes and sectors, technology and material suppliers, universities, training centres, research and technology organisations (RTOs), customers, consumers and society at large. The ecosystem grows and prospers thanks to a dynamic equilibrium where different and often conflicting interests are harmonised and cooperation ensures sustainability at environmental, economic and social levels.

The manufacturing industry acts as an "innovation enabler" and offers opportunities for technology push and market pull. A new manufacturing process or technology can enable the production of products that used to be totally impossible or extremely expensive to manufacture. Therefore, innovation in manufacturing is an important enabler for innovation in final products and solutions, creating real sources of competitive advantage.

Although the innovation process is nonlinear, in the manufacturing domain two main gaps can be identified at European level (and in many national or regional subsystems). The first between fundamental research and applied research and the second between applied research and market uptake. In the manufacturing domain, these gaps pose specific challenges and should be addressed with specific instruments and funding mechanisms.

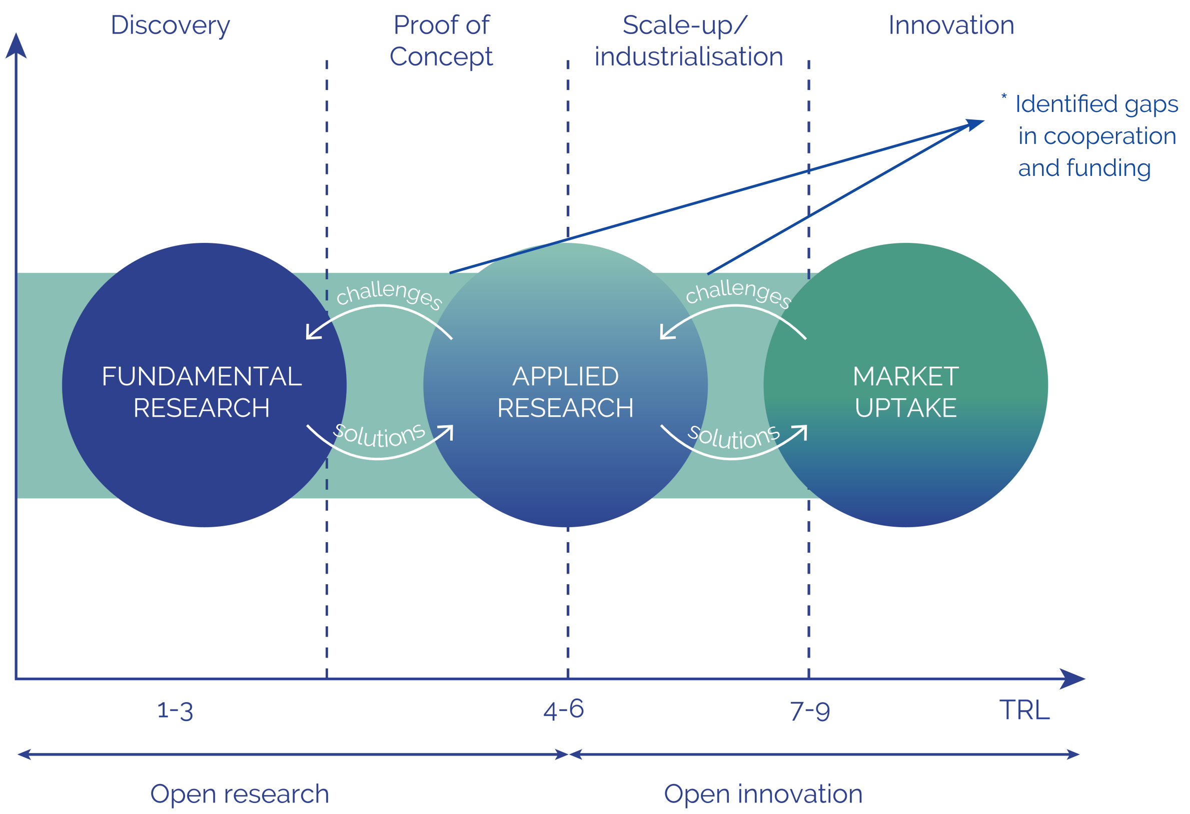


Figure 10 – The innovation process

Several measures are proposed for a more effective and efficient innovation process in manufacturing ecosystems:

- **Promoting a long-term, integrated strategy** aiming at research and innovation leadership by the European Manufacturing Ecosystem. Promote the necessary **fundamental and applied research** and its diffusion to the relevant stakeholders, in the domains identified above. For effective diffusion proof of concept, experiments, demonstrators and pilot lines should be promoted and the necessary skills developed accordingly. Education and standardisation have to be aligned and synchronised with innovation, to avoid delayed acceptance and implementation by industry.

- Public support should be foreseen for **the complete innovation cycle,** including support for start-ups, risk capital, loans and grants:

a) **Promoting fundamental research,** as its results (breakthrough knowledge and technologies) are often the foundation for manufacturing innovations. Traditionally, fundamental and applied research are still seen as separate activities, but the existence of links and synergies between them is extremely important, since fundamental research fuels applications much more profoundly. To have a higher probability of success in the applied arena, it is extremely important to be well-grounded in the fundamentals of the targets aimed at. The value of fundamental research is often the discovery of something that was not expected — that, in fact, nobody expected. In other words, it enables the emergence of radical innovation, that we were just unable to imagine it at the time.

b) **Promoting collaborative RTD projects** as an excellent instrument for bringing specialised organisations together in the development of unique and outperforming technologies and solutions. **Collaborative RTD platforms,** such as clusters, innovation hubs and other industrially oriented infrastructures, should bring together a set of organisations with relevant technical skills but also with the necessary skills and marketing structures to support the introduction of the expected results into the market. This is extremely important, as **research and innovation costs** will represent an increasing share of manufacturing investments. A **dynamic and globally competitive research and innovation ecosystem** will be key for the future competitiveness of European Manufacturing.

In the future, **complementary partnerships** and business arrangements should be developed to enable the maximisation of market impact, including the capability to address other geographical areas, other application domains and exploit cross-fertilisation. **New partnerships** and technological transfers should be implemented to bring unexpected RTD results to the market.

c) **Promoting experiments and proofs of concept with research results with low TRL levels** (up to 4). This is extremely important to reduce the abovementioned gaps between research and its application.

d) **Promoting industrially oriented infrastructures** (including demonstrators and pilot lines) as good instruments to facilitate knowledge diffusion and quicker prototyping, which will shorten the time to industrial scale-up. When companies can better evaluate the return on the investments (ROI) and mitigate the financial risks associated with new products, technologies and processes, it will be easier for them to decide when and how to invest.

- The funds available at European, national and regional level need to be **aligned and made compatible for a quick and flexible set-up to fund research and innovation projects,** promoting synergies and making the right funding available at each level.

- **Restructuring and reinforcing support to entrepreneurship and new business creation.** More and easier access to risk capital and loans should be made available, especially for science-based entrepreneurship. Innovation Hubs, technological centre science parks and incubators should be promoted and supported.

- **Promoting an environment and culture open to innovation and entrepreneurship.** Creativity and entrepreneurial attitudes and best practices should be encouraged and disseminated in European society. An overly risk averse attitude needs to be overcome by disseminating new business achievements and learnings.

5.3 Education and Training

The third building block for a successful manufacturing in Europe by 2030 is education and training.

Education and the development of human capital will play an important role in the reindustrialisation of Europe. Industrial companies worldwide already rank the quality and availability of highly skilled people, which facilitates a shift towards innovation and advanced manufacturing strategies, as one of the most critical drivers of global manufacturing competitiveness.

The introduction of new technologies and the growing digitalisation and automation of design and manufacturing processes will require employees at all levels to have increased technical skills. In particular, it is expected that employees will need skills in digital techniques, computing, analytical thinking, machine ergonomics and manufacturing methodologies. "Education and Training" was also identified as being of high importance for the transition to the Circular Economy. Relevant knowledge needs to be conveyed, beginning with students at secondary school and university, up to workers/engineers/managers at enterprise level, throughout their professional lives. Education and training institutions need to ensure that the initial training they provide is constantly updated to cover the technological evolutions and need to make available training that allows all citizens to acquire the new competences and skills they need during their professional life.

Goals and priorities

Some key goals and priorities for future manufacturing education arise within this context:

- Creating European Manufacturing Qualification and Training programmes that answer the evolving Manufacturing requirements and that can be easily adapted and transferred at national and regional level;

- Delivering manufacturing specific knowledge, skills and competences in full accordance with the real business world and working environment, their constraints and future needs. Facilitating closer cooperation between need (industry) and seed (academia), the coordination of efforts at national and regional levels and supporting cross-border partnerships European level.

- Improving and mobilising all the skills, talents, competences and abilities needed throughout the product lifecycle. Bring a breakthrough in manufacturing performance in Europe by improving the role of humans in manufacturing and re-valuing people and their capacity to run the enterprise.

- Addressing recent trends, such as the digital transformation, innovative manufacturing processes and technologies, integrated value-added systems (goods-service integration), multidisciplinary approaches.

- Creating lifelong learning to address the increased rate of change. Enable all employees to keep their digital skill up to date and prepared for the digital transformation industry is facing as well as the many new digital tools they will be using in due time. This is of particular importance for employees with only vocational qualifications as well as for all employees who never got a proper training on digital aspects. With the baby-boom generation leaving the workforce during the next two decades, we face a shortage of skilled technical training 35-55 year old employees in manufacturing and we can't afford them to drop out due to lack of technical/digital skills.

- Also addressing non-technological skills, perception and behaviour abilities, such as the capacity for understanding complex situations, awareness, proactivity, problem solving, decision making, leadership, team spirit, entrepreneurship and communication in multiple languages. Knowledge sharing and social learning will play a key role in this.

- Implementing the Teaching / Learning Factory as a framework for the education / training paradigm, focused on practical learning and based on a dual approach.

- Developing digital skills and embedding e-learning in manufacturing. Key points for a digital skills development strategy include [35]: (i) Developing / strengthening links between the world of learning and the world of work; (ii) Providing relevant training for workers; (iii) Convincing adults of the benefits coming from better skills; (iv) Providing easy-to-find information about adult education activities; (v) making manufacturing more attractive to young people; (vi) Recognising and certifying skills proficiency.

Creating European Manufacturing Qualification and Training programmes

The introduction of new technologies into Manufacturing requires always new qualifications and skills. To leverage new solutions and drive the industry forward, reskilling, retraining and developing new qualifications that can be broadly used and recognised are all of paramount importance. The workforce profile is changing fast and companies, universities, training institutions and governments must work together, at European level and not just at a national level. It is necessary to align formal and informal qualifications, adding flexibility to the curriculums, allowing lifelong learning in all its dimensions, and, more importantly, implementing all of this at European level.

European Qualification and Training programmes for Manufacturing should be developed at the European level and introduced and adapted to national and regional needs/requirements, ensuring that the future manufacturing workforce is prepared for the challenges ahead. To achieve this, there is the need to:

- Identify necessary skills at the European, national and regional levels;

- Develop, in collaboration with Industry, European Qualifications in Manufacturing, that can be easily adapted and transferred to the national and regional level;

- Align industry qualifications and needs with the European Qualifications Framework, hence ensuring a more qualified and mobile workforce within the EU;

- Integrate modularity into the Qualifications systems;
- Facilitate retraining, reskilling;
- Ensure that new skills are addressed more quickly;
- Ensure transferability between traditional education systems and technical education;
- Governments and industrial organisations should proactively find ways to coordinate initiatives that can foster the qualification, transition and transfer of professionals, as well as fostering the creation of new jobs.

Enabling technologies for reshaping manufacturing education and training in Europe

Innovative digital tools and technologies, including Virtual and Augmented Reality (VR, AR), Cyber-Physical Systems (CPS), the Internet of Things, Serious Games, as well as web-based cooperation environments will play an important role in manufacturing education and training. Such technologies can also be considered as knowledge delivery mechanisms for future manufacturing education and training. These delivery mechanisms should facilitate the communication of knowledge and interaction between the knowledge "producers" (e.g. academia, RTOs, technology developers) and the knowledge "receivers" (e.g. students and workers at all levels).

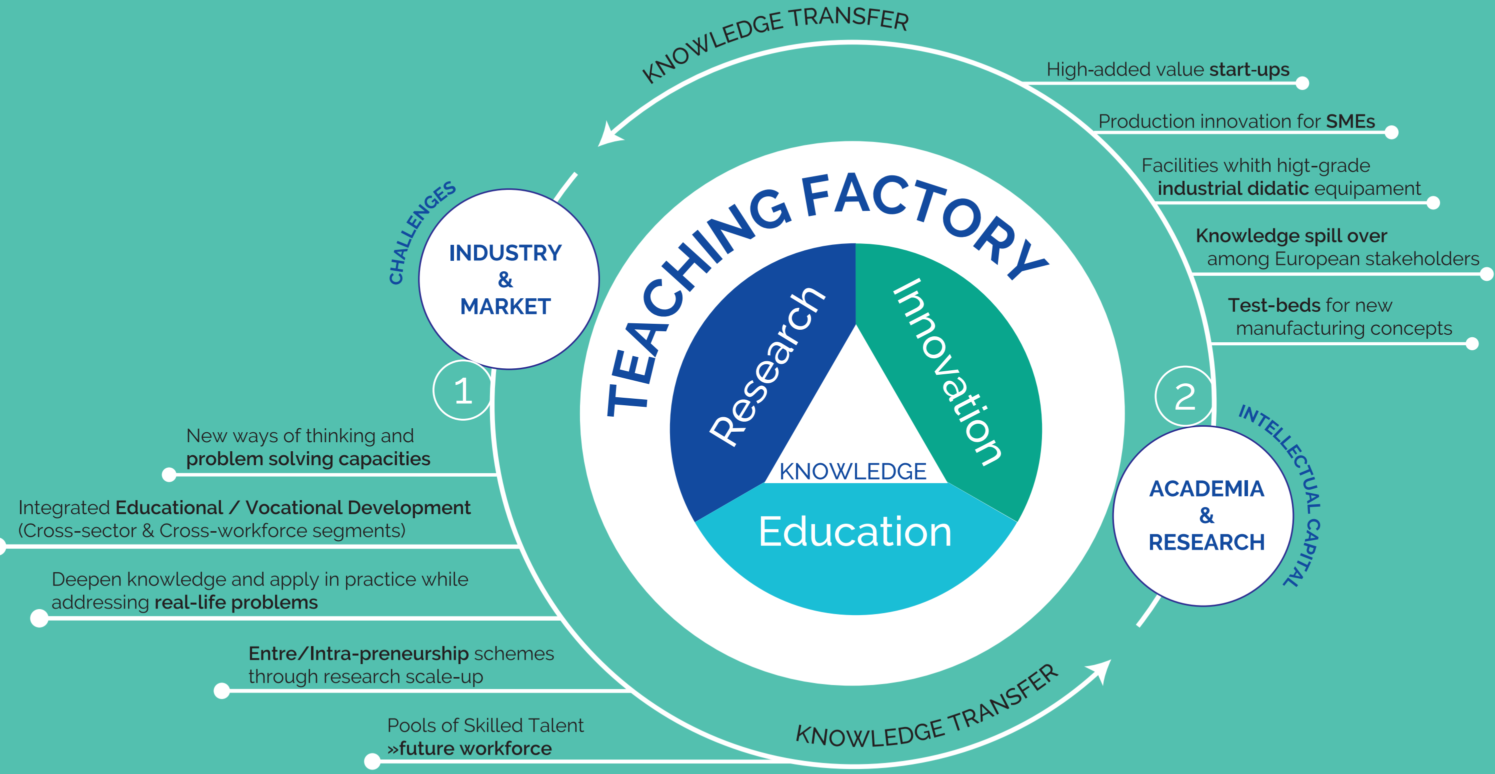
Emerging manufacturing education paradigms – The Teaching / Learning Factory

The "Teaching and Learning Factory" paradigms have received major interest in various educational and business pilot activities. Among their main objectives are the modernisation of teaching processes and bringing them closer to industry, providing young engineers with "hands-on-experience". These learning environments are also excellent opportunities for testing and evaluating the potential of new technologies, promoting entrepreneurship and the adoption of new technology.

Novel lifelong learning schemes are needed to keep the human capital up-to-date with rapid advances in production-related technologies, tools and techniques. Leveraging manufacturing teaching and training up to the standards of future challenges is a critical requirement. The future challenges of manufacturing are multidimensional and the people that will address these challenges need to be educated under a new paradigm that brings academic/research practices and industrial/market practices together.

Complementary, the acceleration of the technological development process calls for new approaches regarding its relation with education and training. Already today, manufacturing companies need not only new technologies but even more the skilled people necessary to deploy them. A reinforced articulation between science and technology development and education and training needs to be implemented.

The Teaching / Learning Factory approach will help fill in the skills gap and address the increasing demand for highly skilled employees by serving as a novel paradigm for cooperation and knowledge transfer between both sides of the innovation cycle. This paradigm has at its core the development of problem-solving competences based on real industrial cases. It can also be an ideal ground for the needed synergies between technological development and education and training.



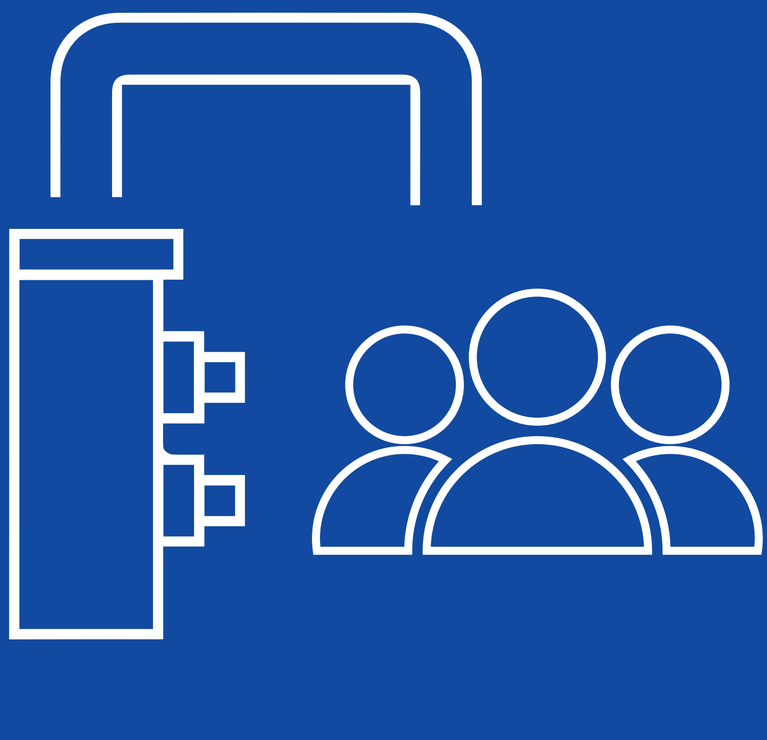
① Industry & Market

② Academia & Research

Figure 11 – Teaching Factory: An educational paradigm for future manufacturing in Europe

6.

Manufacturing and society



6. Manufacturing and Society

Europe has the potential to become the most attractive and competitive innovation ecosystem, at global level, for the development and production of advanced products and services, capable of meeting the increasingly sophisticated needs and expectations of current and future generations. Europe has:

- A demanding market, with a relatively strong purchasing power per capita;
- High standards of design, quality and environmental protection and unique culture and tradition;
- A strong scientific and technological landscape and high levels of education;
- A leadership in complex systems, with a strong engineering and industrial background.

On the other hand, Europe is also facing some challenges, resulting from the fact that:

- The Single Market is still not fully implemented (having multiple languages, regulations, standards, etc.);
- Although a very high level of scientific results compared to many other parts of the world, Europe is less performant regarding knowledge transfer and valorisation;
- A majority of EU Member States do not reach the 3 % target of GDP investments into research and innovation, as well the financial situation of several counties and of Europe globally limits its investment capabilities, particularly in areas of higher risk, such as high-tech entrepreneurship;
- There is a global competition for qualified people, particularly young people, and Europe needs to ensure a competitive position in this crucial area.

To fully realise this potential, a collaborative effort is needed from all stakeholders. Citizens (as consumers and tax payers), Member States together with the European Institutions, namely in their legislative and support (funding and financing) roles, in collaboration with industry, need to take mutual responsibility to invest and implement a comprehensive industrial strategy to support Europe's reindustrialisation.

European citizens need to:

- Be coherent with European values by demanding high standards of quality, environmental protection and human rights, regardless of the place of origin of the products and services;
- Be open minded towards the development and adoption of new technologies, products and services, particularly those using emerging technologies;
- Understand the crucial role of manufacturing for jobs and growth and the importance of investing in R&D, innovation and education and training for sustainable competitiveness, thus accepting that a growing percentage of their taxes is invested in those areas.

Complementarily, public stakeholders need to:

- Invest in R&D, Innovation, education and training, and create an attractive framework to induce private investment, ensuring that Europe produces enough knowledge and people to feed its innovation ecosystem;
- Take a leading active role in the creation of an Innovation friendly environment, particularly by using public procurement and large public investments to induce innovation and also by reducing the barriers still hampering further exploitation and value generation, for example via the simplification and harmonisation of regulations and standards towards broader implementation of the European single market for products and services;
- Ensure a level playing field regarding competing nations. European Manufacturing industry embraces the challenges and opportunities of growing levels of globalisation, but also calls for fair and balanced rules for all the players.

The European society and its citizens will have great benefits from a modern, sustainable and competitive manufacturing industry. European Manufacturing industry will be able to **"pay back" European Society and its citizens** by:

- Delivering high value added products and services capable of meeting the customer expectations;
- Responding adequately to citizens' concerns related with sustainability, environment and climate change;
- Generating high quality jobs (salary, working conditions) across Europe;
- Generating wealth capable of supporting European investments and standards of living;
- Providing more balanced and sustainable development in Europe, reducing inequalities between regions;
- Ensuring technological and economic independence regarding other nations, providing Europe with a strong position in the context of globalisation.

Naturally, innovative and high value added solutions developed and produced in Europe will target the global market. This in turn will generate fruitful collaborations globally and will help to promote a sustainable development in manufacturing worldwide.

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