ManuFUTURE Vision 2030

A Competitive, Sustainable and Resilient European Manufacturing

Report of the ManuFUTURE – EU High-Level Group, May 2018

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Preface

"Sight is seeing what's there, vision is seeing what's possible"
— *Retin Obasohan*

The Manu*Future* Vision 2030 continues the visions of Future Manufacturing to fight against de-industrialization for growth and sustainability by taking into account the megatrends and challenges, which influence the development of all manufacturing sectors. This document is a contribution for political, economic, ecologic 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 eventually 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.

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

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1. The Manufacturing Industry Today

European Manufacturing

Manufacturing is the backbone of the European economy. According to Eurostat, around 1 in 11 (9.0 %) of all enterprises in the EU-28's non-financial business economy were considered as manufacturing companies in 2014, that is a total of 2.1 million enterprises employing near 30 millions of people and generating EUR 1 710 billion of value added. This represents within the EU-28's non-financial business economy 22.1 % of employment (14.2% of the total European workforce) and 26 % of the value added.

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

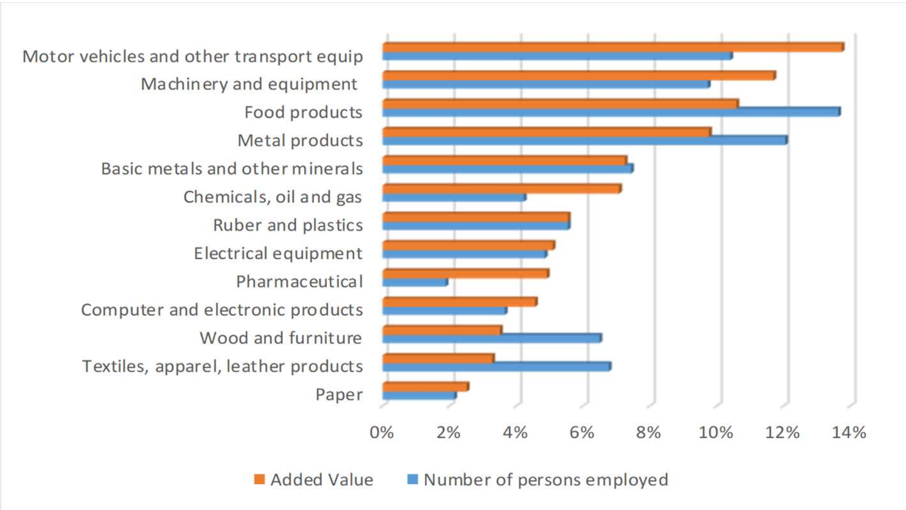

Figure 1 - Manufacturing sectoral analysis, sorted by Added value, EU-28, Eurostat 2014

The ongoing 4th Industrial Revolution (4IR or Industry 4.0) will impact 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 [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 represent 42% of total exports, chemicals 17,6% and food and beverages 6.3%[1].

[1] Main exports and imports EU-28, Source Eurostat 2015

Manufactured goods, with a trade surplus of 153 billion euro in the first semester of 2016, contribute greatly to the overall trade balance of the European Union (21 billion euro in the same period), more than compensating the huge imports of needed primary goods such as energy. This trade surplus plays a key role in creating growth and jobs in the European Union.

However, strong attention is needed as European manufacturing has been losing ground compared to other parts of the world [5]. 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 Added Value* 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 in the United States. Between 2000 and 2014, the added value 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. Investments have been made, but they are lower than those of the other global players, as illustrated in figure 2.

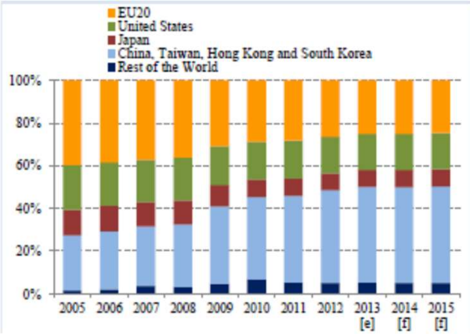

Figure 2 – Share of world's total manufacturing investments by region, Source IHS [6].

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

Despite this reduction, the manufacturing sector remains central to the growth and employment in the European Union, making the **relaunching of the European manufacturing a priority** for the European Union [5].

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, reinforcing progressively Science, Technology and Innovation at the centre of the economic development strategies.

The financial crisis clearly highlighted the importance of manufacturing as fundamental pillar of competitive and wealthy economies, which motivated a strong re-industrialization 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, among others. 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 on R&D, Innovation and Education. Most of them give high priority to digitalisation and Key Enabling Technologies.

The following are some of these relevant programmes:

USA: In the recent past the USA governments and industrial leaders gave high priority and invested heavily in advanced manufacturing. In 2012 the US government recognised the importance of manufacturing as a foundation for economic growth, for the creation of high 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 the US global competitiveness. It includes initiatives such as the coordination of all manufacturing related research programs, the creation of more than a dozen national networks of manufacturing innovations, the provision of incentives for reshoring manufacturing operations back to US and funding to fill the gap between fundamental research and commercialization. Manufacturing USA, a national network 14 institutes for manufacturing innovation, was created. Through Manufacturing USA, industry, academia, and government partners are leveraging existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialization. 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. Inspire in the German programme Industry 4.0, the first stage aims to transform China into a major manufacturing power until 2025, by increasing manufacturing digitalization, mastering core technologies in key areas, improve product quality, energy and material consumption and enhance innovation capacity. By 2035, Chinese manufacturing aim to reach an intermediate level among world manufacturing powers, by greatly improving innovation capability, make breakthroughs in major areas and lead global innovation in industries where China is more competitive. By 2049, a century after the founding of New China, China aims to become the leader among the world's manufacturing powers. 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 government has already invested $3 billion in 300 enterprise experimentation programs. 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) Program focused on Innovative Design/Manufacturing Technologies aim to promote manufacturing digitalization. The Kohsetsushi Centers support SME manufacturers in technology development and innovation activities. In 2014 the Japanese Prime Minister's office promoted an Industrial Revitalization 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 Program ImPACT - Impulsing Paradigm Change through Disruptive Technologies aiming to transform the Japanese industry and society through the promotion of high-risk, high-impact R&D. The ImPACT program has established 16 R&D programs 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 utilization 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 in 2017 the "Connected Industries" vision, a new concept framework in which industries will create new added value and the solutions to various problems in society through connectedness of various facets of modern life, including humans (including the roles as consumers and suppliers), machines, systems, companies. According with 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. 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 RTD 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 on 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 standardize 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 [7]. 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, involving the complete manufacturing innovation ecosystem. EU urgently needs a new impetus in STI, a collaborative and integrated strategy for Manufacturing, including a clear prioritisation of themes and problems to address, as well as a strong focus on companies and innovation.

2. Megatrends and drivers for manufacturing

Today, society and the world economy 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, a fast diffusion of knowledge, the scarcity of resources and new generation of consumers will pose challenges and opportunities for Manufacturing. This will lead to **a new paradigm shift** at a global level.

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 middle class, urban and aging population

World population is expected to grow. According to the United Nations (UN), the world population is expected to grow from 7.6 billion to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100[2]. The population growth is mainly concentrated on developing countries, with industrialised areas such as Europe showing fertility rates below the level required for the replacement of successive generations. This leads to an older population – in Europe, 25% of the population is already aged 60 years or over and is projected to reach 35% in 2050. Aging population has a profound impact in society, due to fiscal and political pressures involved. The elderlies also have a different demand for products, in terms of design and functionality.

The increase in average incomes and the decline in levels of poverty in the last years suggest an increasing middle class at a global level. The size of the "global middle class"

[2] https://www.un.org/development/desa/en/news/population/world-population prospects-2017.html

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[3].

Another pressing trend is the migration of people to urban areas due to better offer in services, education, mobility and standards of living, which leads to particular consumption patterns and creates the need for infrastructure.

New consumer's preferences and environmental awareness

New generation consumers – the Millennials (born post 1980) – are highly demanding regarding products and services. The increasing demand for individual and customised products is strongly introducing changes in manufacturing. Highly flexible and efficiency manufacturing systems, together with demand oriented production are increasingly enabling the production of individual and 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 environmental sensitive, shifting their consumption patterns towards a more "do-it-yourself" and sharing paradigm (e.g. sharing cars instead of owning a car) and "circular" value streams.

Natural resources scarcity

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 which is finite[4]. Natural resources depletion manifests itself through environmental pollution, emission of greenhouse gases that contribute to climate change and continued dependence on increasingly scarce natural resources[5].

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 PwC study shows that employment numbers in the renewables industry are increasing, while the numbers in the fossil fuels sectors are declining sharply.

Resource efficiency is not only a necessity but also leads to new materials, technologies and business models. Emission reduction and the need for reduced transport and logistics costs and impact stimulate a trend to urban manufacturing.

Circular Economy is slowly being realised due to political choices, market dynamics and consumers' behaviour, with product lifecycles being extended through service, repair, reuse and recycling.

[3] http://oecdobserver.org/news/fullstory.php/aid/3681/An_emerging_middle_class.html
[4] https://www.pwc.co.uk/issues/megatrends/climate-change-and-resource-scarcity.html
[5] http://www.oecd.org/env/indicators-modelling-outlooks/circle.htm

Global political environment is uncertain

After a period of strong globalisation efforts, the world currently experiences a number of negative effects of the (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 yet unknown needs.

Global access to knowledge

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

The scarcity of competent and talented people, the trend for open data and the increasingly high costs of corporate Research and Innovation will foster new levels of cooperation in Research and Innovation at a global level, especially in low TRL levels.

Fierce competition is going up the value chain

Manufacturing is acting on a global scale, with global, complex value networks, global markets, pressuring companies and networks to adopt and change the way they organise the value creation to gain competitive advantage.

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

Accelerated technological progress and adoption

The ongoing 4th Industrial Revolution (Industry 4.0) is characterised by the arrival of new technologies such as digitisation, distributed (artificial and human) intelligence, machine decisions (“autonomous driving of manufacturing”) and multifunctional and smart materials, enabling the integration of physical and virtual worlds. ICT for cyber-physical manufacturing encompasses the use of sensors to collect data in the real world, together with intelligent control and mechatronic actors, increasing the amount of available data, information and knowledge. The high degree of flexible automation is increasingly enabling the integration of different technical processes and self-reconfiguration, self-organisation and self-optimisation of manufacturing systems. Innovation in materials and bio technology is allowing the development of new materials and more intelligent processes, including recycling, that contribute to attenuate the problem of natural resources decrease.

These technologies are influencing not only manufacturing processes but also factories and complete value networks management.

More complex products, processes and value networks

Products complexity is increasing, especially in mechatronic products, requiring also more complex manufacturing processes and a closer interaction with users.

The complexity of value networks of more specialised partners is steadily increasing. The need for precise logistics with minimised storage cost in conjunction with energy and resource efficiency challenges creates trends in two directions: (1) excellent management of the complexity, with the support of digital technologies (Industry 4.0, Smart Manufacturing) and (2) the dramatic reduction of complexity, by providing isolated services and brokerage and management tools to self-responsible users, letting them organise and, eventually, execute the creation of their products ("maker economy").

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 next to 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 high automation degree and exchanging best practices of processes by worldwide information transfer. The equalisation of technical standards allows the production of high quality products everywhere.

Digitalisation and new consumer preferences will enable new business models.

New skills and employment patterns

Advanced manufacturing technologies create a need for skilled workers and engineers. This means a shift in the operator's workplaces, towards less manual work and more highly skilled personnel that requires continue knowledge updates to keep up with technological changes. This can result in less employment of low-skilled workers, larger competence gaps and differences in compensation/salaries between skilled and unskilled workers. At the same time, they generate a demand for educational institutions to create programs that are designed to a non-academic public with limited time to update knowledge. However, while the number of manufacturing shopfloor jobs are stable or decreasing, the productivity and value adding created by these jobs has increased. This means there is a growing demand for indirect jobs creating knowledge and optimisation as well as in service jobs.

There is a dilemma in the fact that, in some parts of Europe, a large number of young people are unemployed and at the same time there is a need for more skilled people in industry. This paradox is more prominent in scenarios where humans will have to work together with intelligent machines that require a more sophisticated set of knowledge 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 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 wellbeing throughout the globe, creating jobs and prosperity in developing countries [2].

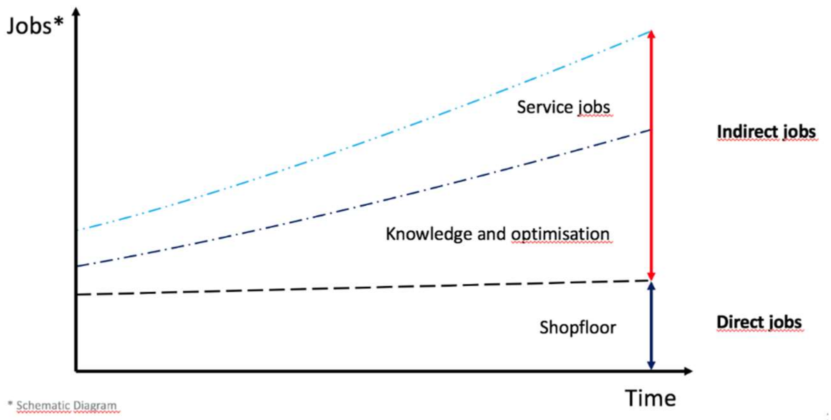

Figure 4 - Indirect jobs increasing in numbers

3. Future Manufacturing Scenarios and Models

3.1 Vision of the manufacturing evolution towards 2030

To respond to the **identified challenges** and to take advantage of the **foreseen opportunities**, European Manufacturing will have to evolve to **exceed the customer's expectations in terms of product design, quality and service and become even more flexible and adaptable**. Significant changes will happen in many areas, including disruptive ones, from technologies to business models, from research to training, from individual customisation to social behaviour.

One of the main changes will probably emerge in value chain's organisation, including the geographical location of manufacturing activities. The combination of trends such as customisation and circular economy, with technologies like 3D Printing, will boost the complete redesign of future manufacturing towards **CONSUMER CENTRIC GRIDs OR WEBs**, aiming at providing the required products and services while optimising the usage of resources, including materials and energy (also in transports), creating balanced and sustainable eco-systems.

The fast growing development and adoption of AI and Virtual Reality based applications for product and process development, combined with increasingly lower cost equipment and services for additive manufacturing, empower costumers 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 places a significant challenge to the industry in many domains, like new business models, the location of production and service centres, quality and safety.

The balance between high value added tasks being mainly executed by humans and repetitive tasks executed by machines with high speed, precision and security, leads to an increase in quantity and quality of jobs in manufacturing and related services. **BIONIC MANUFACTURING**, where technology enhances and augments relevant human capabilities, 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 documentations, 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.

Nature, as a “manufacturing system” has always been a source of inspiration and knowledge for Industry. However, in the last decades, those synergies were intensified, mainly due to relevant developments in the field of Life Sciences and particularly in Biotechnology. Diversified application areas such sensors and actuators, bio-refineries or energy storage illustrate and fuel a continued and stronger collaboration. But a **NATURE INSPIRED MANUFACTURING** can also lead us to design and operate more sustainable eco-systems, from the organisational to the technology levels, for example, how to combine different “actors and activities” with efficient processes to recycle and reuse materials.

Consistent legislative and policy frameworks, the availability of technological solutions and a global shift in consumer preferences, behaviour and environmental awareness will foster the circular economy wide implementation. European manufacturing companies will 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 ecosystems resources, will be realised to a large extent, leading to a minimal consumption of raw materials and energy, supporting global competitiveness. **CIRCULAR ECONOMY IS A LARGE COLLABORATIVE ENDEAVOUR AND MANUFACTURING IS AT ITS CORE.**

Education and lifelong learning will become critical functions, allowing workers to adapt to new and fast changing technologies and working methods. Manufacturing will create new careers and job profiles and will be able to attract young and talented people. But innovation will be developed at paces never seen before, calling for a more intense collaboration between academia, research organisations and industry, and new and faster methods and channels. 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. Collaborative infrastructures, such as **LEARNING FACTORIES**, have the potential to implement this type of collaboration, either in manufacturing industry (usually driven by large companies or associations representing SME's), academia or research and technology organisations.

3.2 Value Networks Future Models and Challenges

Aligned with the foreseen evolution of manufacturing towards 2030, MANU*FUTURE* ETP developed four models for the development of value networks and manufacturing systems: Globally Integrated Value Networks (Model 1); Regional Value Creation for Global Markets (Model 2); Regional Value Creation for Regional Markets (Model 3); Regionally Regulated Virtual Value Networks (Model 4). Companies will adapt and combine these generic models to optimally address specific market requirements, product characteristics and manufacturing resources availability.

Model 2: Regional Value Creation for Global Markets	Model 1: Globally Integrated Value Networks
Model 3: Regional Value Creation for Regional Markets	Model 4: Dynamic Virtual Value Networks

Figure 5 - Value Networks Future Models

Model 1: Globally Integrated Value Networks

This Model encompasses a further development from today's global supply networks. It will comprise a **globally harmonised regulation** and governance and will exploit the use of technologies. This is supported by systems predominantly based in **artificial intelligence (AI)**, within or external to the value network, which monitor the potential customers, identify needs and wishes and interact with product design and a **high and real-time integration of physical and virtual worlds**.

In this context, globally acting companies such as vehicle OEMs **operate and** orchestrate a **global supplier network, including highly automated assembly factories** in the most relevant markets, with high cost, speed and flexibility pressures. Companies have full control of market access of their products.

Challenges for the development of Model 1 are:

- Complex management – governance, coordination, collaboration – possibly supported by **AI-based systems**;
- Development of **novel digital/physical architectures** from the factory to the networks (**digital twin**, **factory as a product**, etc.) to allow for vertical and horizontal integration and more flexibility and responsivity;
- Optimisation of cost and quality: **standardisation** at the highest technological level, **zero failure**, minimisation of the use of resources.

Model 2: Regional Value Creation for Global Markets

As Model 1, this Model targets **global markets**. Dominating the production side are **regional networks of design and manufacturing companies**, including SMEs. Manufacturing systems are built according to frugal principles, **cost and effort optimised** and conformant to all relevant regulations. Digital platforms support product design and development, possibly including the end consumer, and operations management. These networks are unique and world leading and are based on the appropriate norms and standards, taking into account the regionally available manufacturing capabilities and services. According to the principle of the Regional Smart Specialisation, the regions specialised on specific successful products, deliver them to the global world. These **regional networks** are highly **flexible** and **dynamic**.

In the described context, highly specialised companies such as factory equipment and automation suppliers have a high ratio of in-house production while controlling complete customer-specific value chains.

Challenges for the development of Model 2 are:

- Regional intelligent specialisation
  - Regions with many leading protagonists, in relevant technology fields;
  - Flexible structure of medium-sized enterprises with high specialisation (hidden champions);
  - Focus of efficiency and intelligence;
  - Capabilities for **customer-specific system integration.**
- Regional technological centres, including digital service centres (cooperative society models)
  - Safety and security mechanisms supported by mutual trust in the region;
  - **Regional innovation hubs.**
- Policy tasks: to create supportive conditions, infrastructure and a **regulation framework**
- Focus on highly specialised and complex products

Model 3: Regional Value Creation for Regional Markets

This prototypic Model has an even stronger regional focus than Model 2, by encompassing **regional manufacturing for local customers**. Due to the **Urbanisation** Megatrend, manufacturing will be increasingly realised in urban areas, as cities have strong economic and social assets. An example of this paradigm is **Urban Manufacturing**, but manufacturing in more rural areas is alike. Sourcing of elements and components is done at a global level, while the final assembly or personalisation is mainly performed near or even by the consumer.

In a context of urban manufacturing, the complete production, the final assembly or personalisation takes place on demand for products such as shoes, clothes and food, as well as furniture or household equipment. Urban manufacturing is also applied to craftsmanship oriented small industries that produce specialised products for niche markets, including maintenance, personalisation and product lifecycle services industries. The **close-to-service manufacturing model** is also managed under these circumstances.

Challenges for the development of Model 3 are:

- **Emission-free factories** (zero emission, zero waste);
- Flexible work organisation and flexible automation;
- Local service centres;
- Compact design of factories and availability of affordable estate in urban areas;
- Customer driven and individual personalisation
- Responsive environment and cost effective goods **transportation** in urban areas.

Model 4: Dynamic Virtual Value Networks

Complementing the centrally controlled value networks of Model 1, Model 4 is completely decentralised. **Platform-based ad-hoc value networks** emerge spontaneously for the production of specific lots of specific products. Manufacturing companies of different sizes and service providers offer their competences and capacities on the platform. Each person with a business idea can set up a **manufacturing network** to produce and sell a defined lot of a specific product. Professional platforms support the management of the ad-hoc manufacturing value network of regional manufacturing service providers, including the legal and financial transaction. The network maybe global.

An example of an application within this context are **temporal companies**, which operate in a **platform economy model**. Platform providers assemble temporal limited process chains, while each authorised user can have access to the platform.

Challenges for the development of Model 4 are:

- Logistics and sales platforms for supply, manufacturing services and end market products, supporting interoperability and open standards;
- Highly flexible, adaptive automation throughout highly networked value network partners, including legal contracting and money transfer;
- Demanding, complex and unique products;
- New business logics, business intelligence and advanced decision-making;
- Total quality and safety assurance.

4. MANU*FUTURE* High Level Vision and Strategy for 2030

4.1 High Level Vision

In a context where competition is going up the value chain and is becoming much stronger 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 position**.

The goal is to maintain or even expand the number of jobs, increase the wealth generated, improve the wellbeing and social sustainability for new generations in Europe.

European manufacturing in 2030 will be a **globally leading, interconnected and adaptive socio-technical value creation system that ensures sustainable economic growth and social welfare, well balanced in a resource-constrained world.**

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

While global competition is increasingly challenging, Europe will keep its leading position because of its **technical leadership and capacity to handle complexity**. Europe will **lead 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 **leader in manufacturing engineering for highly personalised and complex products** and related services in a broad range of sectors, including aeronautics, automotive, production equipment, renewable energies, space and defence.

Europe will be **leader in resource efficiency and circular economy implementation**, which will contribute for its competitiveness at global level and support its environmental sustainability.

Europe will also be a leading “solution provider” in production technology, digitalisation, resource efficiency and circular economy implementation.

Manufacturing systems in Europe will be flexible and resilient, with an optimal balance and integration between humans and machines.

Starting from a strong **scientific and technical and leadership,** the MANU*FUTURE* vision evolved over time. Moving from a pure focus on ensuring **competitiveness** in its early days, it has evolved to include **sustainability requirements**, addressing now also the need for a **resilient and adaptive manufacturing ecosystem** able to attain increasing levels of global competition and social requirements.

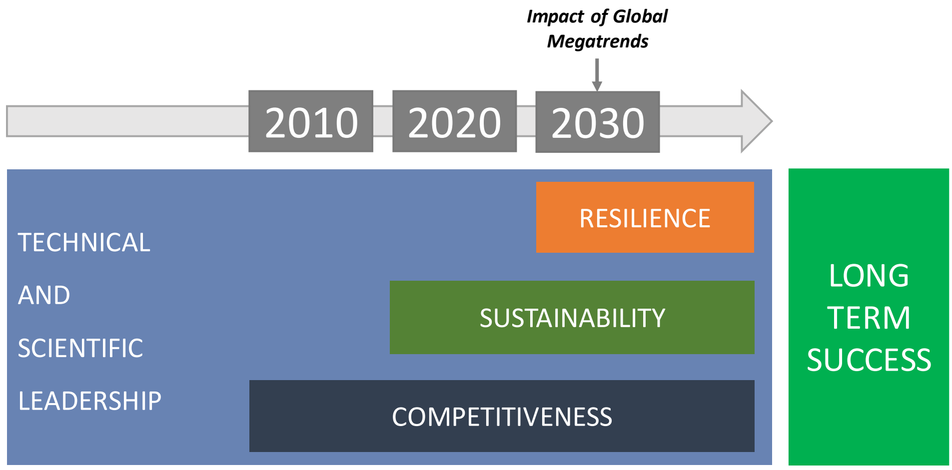

Figure 6 - High-level vision for European Manufacturing 2030

4.2 MANUFUTURE Strategy for 2030

As a summary, the MANU*FUTURE* Vision for 2030 proposes that to **ensure its competitiveness and long-term success** Europe will have to build on its proven capabilities and **invest more to ensure its leadership in**:

- **Digitalisation, manufacturing technology and new business models**
- **Mastering complexity of products, processes and systems**
- **Resource efficiency and sustainable development**
- **Resilient manufacturing**, adaptive to rapidly changing environments
- **Innovation ecosystem**: highly networked and life cycle oriented socio-technical system, addressing also education and training needs and challenges.

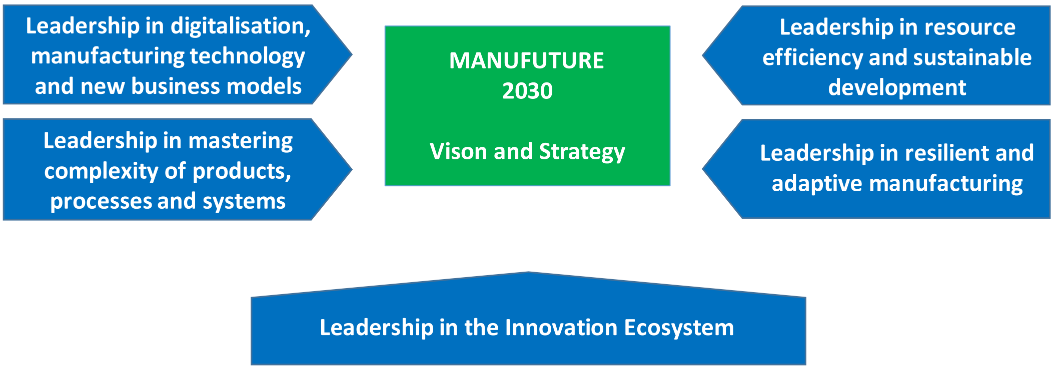

Figure 7 - MANUFUTURE Vison and Strategy for 2030

Leadership in digitalisation, manufacturing technology and new business models

In 2030, customer-driven value creation is prevalent. Manufacturing is highly automated in high-performance and zero-defect production processes. Flexibility and short delivery time outbalance production costs as main criteria for competitive advantage. Europe is the leading market for personalised products due to its well-functioning single market with highly demanding customers that drive innovation. Thanks to high investments in advanced manufacturing technologies and unique skills, production will be relocated in Europe. High-quality products are manufactured closer to the customers e.g. in urban manufacturing facilities.

In the verge of the 4th industrial revolution, it is important to continue the investments in the development and implementation of digital technologies, but, at the same time, it is mandatory to reinforce the European strong position in manufacturing processes and related industrial machinery. **Promoting the integration of digitalisation and manufacturing technologies** will valorise a great European heritage and will reinforce the European leadership in both domains.

The **diffusion and wide implementation** of these innovative technologies in Europe should support manufacturing sustainability, flexibility and resilience. The 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: on the medium term, Europe cannot be globally competitive on one without the other.

New paradigms are emerging, such as the circular economy, addressed later in this section, and the sharing and outcome economies. In this environment, manufactures will have to devise **new business models and logics**, both in Business to Consumer and Business to Business.

Sharing economy is a concept with few realized models (particularly in manufacturing), in which individuals or companies are able to borrow or rent assets owned by someone else. These models are most likely to be used when the price of a particular asset is high and its utilization rate is low. The main purpose of the **Outcome economy** is to ensure the production of measurable results for the clients or customers, using their success parameters as their own. This implies a shift from competing through selling products and services, to competing on delivering measurable outcomes important to the customer.

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

Europe is the leader in engineering highly effective and complex life cycle oriented products, processes and value creation (eco)systems, thanks to its excellent manufacturing and engineering know-how. Linear production processes are intelligently re-organised towards more circular 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 a fundamentally increased productivity and value added in the European economy.

European manufacturing benefits from an excellent business and innovation ecosystem which includes e.g. a European-wide standardised education system and European-wide joint efforts in infrastructure, key technologies, etc. Thanks to this innovation ecosystem, Europe is the globally leading provider of engineering know-how, utilising the whole technology spectrum from basic technologies up to ground-breaking and system technologies.

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 is the best place for future-oriented public and private investments. European manufacturing stakeholders respect in their decision making longer-term impacts on all economic, societal and ecological aspects. In line with comprehensive policy goals such as e.g. 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[6]. Europe will become also a leader in recycling and circular economy processes and technologies, which will become competitive and a significant market opportunity.

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

They also focus on decent working and living conditions as well as on political and social cohesion, stability and welfare (more rewarding jobs, fewer people in or at risk of poverty and social exclusion)[7]. Humans still play a key role in European manufacturing of 2030. The people, which are well-prepared for changing job requirements and life-long learning, make the difference at global scale. Thus, European manufacturing in 2030 provides the robust foundation for economically, socially and ecologically sustainable development of the European Union and contributing to increasing sustainability also in a global context.

Leadership in Resilient manufacturing systems, adaptive to rapidly changing environments

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

[6] UN Development Goal "Responsible Consumption and Production", http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-12-responsible-consumption-and-production.html
[7] e.g. UN Development Goal "Decent work and economic growth" http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-8-decent-work-and-economic-growth.html

Understanding these challenges and how to transform them in opportunities is a major priority for European manufacturing. Thus, the European **manufacturing system in 2030 is resilient and adaptive** to rapidly changing and unpredictable environments and has the capacity to overcome disruptions and adapt to meet the changing market needs.

Resilience in this context also means continuous debates of changing environments and their potential impact on manufacturing and gather strategic intelligence along the whole policy cycle (from analysis to scenario- and vision-building, and from agenda-setting to action-planning and -taking). Thus, joint efforts of multiple actors (science, industry, public authorities, civil society) from multiple sectors (various industry as well as policy sectors) across multiple governance levels (regional, national, EU) are needed to realise the vision of a globally leading and resilient manufacturing system that is adaptive to rapidly changing environments.

Leadership in the Manufacturing Innovation System: highly networked and life cycle oriented socio-technical system

Manufacturing in the 21st century is a complex, multi-facetted, highly networked and, dynamic socio-technical system. The digital revolution dramatically increases the vertical and horizontal integration, considering the whole life cycle of manufactured products. Physical products and service offerings are fully integrated into the lifecycle, including design and engineering, embedded systems, process support systems, production technology and support services. In this broad ecosystem, the manufacturing impact and strategic importance can be measured in terms of value added and created direct and indirect jobs.

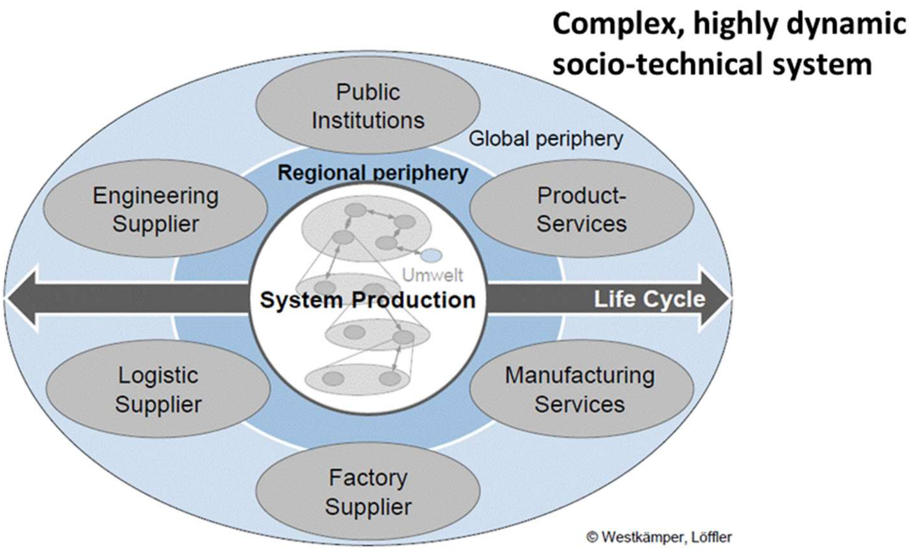

Figure 8 - Manufacturing innovation system, a complex and highly dynamic socio-technical system.

National and regional manufacturing systems are embedded in global value creation processes and are strongly interwoven with the broader (economic, societal and ecological) environment. In 2030, European Manufacturing has developed towards the globally leading life cycle oriented and sustainable manufacturing (eco)system.

Europe will have a highly qualified workforce in Manufacturing. The creation of an European Harmonised Qualification System in Manufacturing will ensure that training and qualification of personnel in manufacturing becomes an European activity, instead of mainly a national or regional activity. Such a System, where the educational programmes are mapped and harmonised at the European level and then deployed through a network of universities and training centres will ensure that all EU countries have the necessary workforce required for the European Manufacturing System in 2030.

4.3 Reinforce investment in Key Enabling Technologies

Key enabling technologies (KETs) have been a priority for EU industrial policy since 2009. They were defined as 'knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and high-skilled employment'. They enable innovation in process, goods and service throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalise on their research effort'. The six KETs identified in 2009 were: advanced manufacturing technologies, advanced materials, nanotechnology, micro-/nano-electronics, industrial biotechnology, and photonics.

Technology is critical for long-term market leadership. The horizontal nature of **KETs** makes them **especially relevant due to the potential impact they can have in a vast number of sectors and value chains**. The investment in KETs has a double positive effect: 1) It develops new high added value industries (e.g.: manufacturing technology, digitalization, nano or bio-technology) and 2) it supports the development and reinforces competitiveness of other industrial sectors (including more mature ones).

In the future, Europe needs to: (1) Take full advantage and impact of those previous investments in KETs, by promoting knowledge transfer and valorisation, and also cross fertilization; (2) Continue to invest in the previous KETs, to maintain and reinforce scientific and technological leadership and (3) Identify new KETs and start investing in R&D.

Given the importance of KETs for competitiveness and employment and since Europe's main competitors (USA, China, Japan, Korea and many others) are presently investing heavily in KETs, it is essential that Europe will reinforce its investment in these domains to maintain its present position.

MANUFUTURE welcomes and supports the report of the Independent High Level Group on Industrial Technologies and its recommendations for maintaining the previous KETs and the inclusion of Artificial Intelligence and Digital Security and Connectivity, as new KETs[8].

In particular, **advanced manufacturing technologies** have a special role in the (current) KETs universe, since they are necessary to produce and/or enable the use the other KET's (nanotechnologies, advanced materials, biotechnology, etc.). They justify the title of "Enabling Technology" of current KET's. They are also an integration platform for all the other KETs, including the new ones.

Advanced materials and nanotechnology, on its turn, has a potential impact in several domains, including 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 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, namely in areas such as functionalization and miniaturization.

Life Science Technologies will become increasingly important with a critical role in the longer term.

4.4 Implementation Roadmap

European citizens, economy and industry will face several "transformational" waves in the next years and decades, resulting mainly from technological development and societal changes. It is very important to foresee an Implementation Roadmap (IR) capable of anticipating the period when those waves will hit the market and (in particular) industry, preparing them both for the respective opportunities and impact. Complementary to a technological roadmap, an IR will address the conditions for mass adoption of innovative products, services, processes and business models, including skilled human resources, adequate public and private funding and financing, regulation, customer awareness and acceptance, etc.

The following paragraphs (and picture) present a vision of the implementation timeline for mass adoption of these three transformational waves.

8 Re-finding Industry – Defining Innovation. EC, DG for Research and Innovation. ISBN 978-92-79-85271-8. https://publications.europa.eu/en/publication-detail/-/publication/28e1c485-476a-11e8-be1d-01aa75ed71a1/language-en

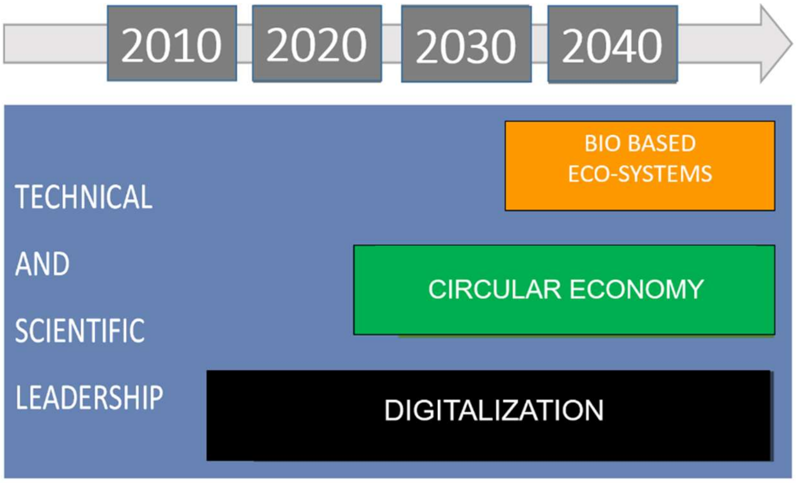

Figure 9 - Implementation timeline

- **Digitalization**: already hit the market with 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 organizations, namely under the umbrella of several "Industry 4.0" initiatives and programmes. The main challenge is now the absorption capacity from the industry, considering the related requirements, namely in terms of investment and human resources. Complementary, many SMEs find existing solutions still two 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 need 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, that should be boosted via new and consistent regulations and incentives. Due to its relevant contribution to the implementation of Circular Economy, **Sharing Economy** will follow a similar implementation path, although it is important to highlight that, in this case, there are significant sector specificities. Another reason for this time alignment is the fact that Sharing Economy demands similar steps: further R&D needed (namely cybersecurity, blockchain, etc.) and also new regulations (public side) and behaviour (consumers).
- **Bio based eco-systems**: although biotechnology has already significant developments and applications in some sectors (namely chemical, food or energy), a much larger relevance and impact for manufacturing is foreseen from the broader area of Life Sciences, towards Nature inspired (bio-based) eco-systems. The development of these concepts call for a significant R&D effort, a strong collaboration between the related scientific and technological areas and teams and the mass implementation of the results will be a mid to long term target

5. The MANUFUTURE Vision Building Blocks

To reach the above defined Vision and Strategy, the MANU*FUTURE* 2030 Vision defines three building blocks, presented in the next sections.

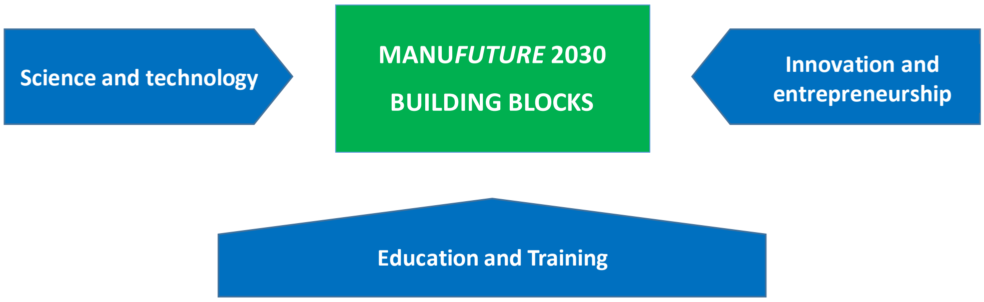

Figure 10 - MANUFuture 2030 Building Blocks

5.1 Science and Technology

The first building block for a 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 R&D&I investments. As detailed before, in the current competitive environment Europe will only be able to keep or improve its position in manufacturing and to secure the current level of employment if it will be able to ensure the global technological leadership. To this end, Europe will have to invest more in scientific research and technological development in key areas in:

- Applied Research and Manufacturing Technology, where Key Enabling Technologies (KETs) play a relevant role
- Basic Science
- Social Sciences and Humanities

Contribution from Applied Research and Manufacturing Technology

The main contribution from applied research and technological development to manufacturing competitiveness and innovativeness come from the fields of:

- **New business logics and models:** Mastering product complexity with on demand, personalised products will require new collaboration structures and networks. In a circular economy, customer service will reach a new level 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, bio-processing, 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.

- **Digitalisation, Artificial Intelligence and Cybersecurity**: The digitalisation of industry, by means of cyber-physical production systems, modelling and simulation, cloud and edge based manufacturing, manufacturing as a service and smart manufacturing will change manufacturing paradigms and provide the means to address challenges such as mass customisation and the need for continuous improvements in flexibility, productivity, accuracy, security and sustainability, in cybersecure environments. It is crucial for the manufacturing community to develop or exploit the associated technologies (e.g. artificial intelligence, robotics, 3D printing, wireless connectivity, big data, digital platforms & standards, digital value chains, as well as next generation connectivity, MEMS, smart sensors and actuators) to the best benefit of European production sector. 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's activity in manufacturing with a special emphasis in analysis and decision making. Big data analytics, learning systems, analysis and decision-making support considering uncertainty factors.
- **Biotech transformation of products and processes:** New biological processes, technologies and value chains will allow the recovery of agricultural, forest and urban waste. Bio-manufacturing will open new opportunities for using biomass from different sources to produce chemical, pharmaceutical and food products with lower energy requirements and environment impact. Biotechnology will reduce Europe´s raw materials 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 technology will augment human capabilities, instead of replacing them, allowing humans to concentrate on more added value, 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 globally the best production equipment and systems**. 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.
- **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 customize 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 the customer preferences and requirements and to design better products.

- **Human centred manufacturing**: New technology will not replace humans in the creativity and decision power in key areas. Technology will support human activity and augment its capabilities to higher levels of effectiveness and added value. New interfaces between humans and machines and 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, namely 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 and 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 life cycle of products. New solutions for optimal energy efficiency, recovery, harvesting and storage are needed to enable Europe leadership in resource efficiency and sustainability.
- **Nano-technology and new materials:** Materials engineering and nano-technology 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. Besides, the full life-cycle 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.

Contribution from Basic Science

Basic Science has been the engine and the foundation for innovative solutions through decades and, in manufacturing, it is expected to be even more in the years to come. Europe is a strong global player in basic science but the connection between basic science and 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 keep the forefront, scientific disciplines need to interconnect in 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 in 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 an increasingly sophisticated society, also reflected through more complex manufacturing value networks, most of the challenges cannot be faced by stand-alone scientific disciplines nor solely by technologies. Human behaviour, perceptions, emotions, consumer preferences and design, as well as social aspects related to the type of society we want for Europe and globally, the relationships between stakeholders, etc., require approaches that will combine technical aspects, as described in most of the previous paragraphs, as well as knowledge related to 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 to the people involved in one way or another with manufacturing. This leads to considering aspects not only of marketing or communication, but also arts for product design or architecture for plants and working space design. Also, the role of the manufacturing worker will be changed from typical operations towards new and more sophisticated activities (e.g. product conception, user support services, monitoring, process design, teaching robots, developing, configuring and supporting IT solutions), increasingly in 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, networked enterprises. In addition, there is a need to address the framework conditions of our economy and industry, to set European (and worldwide) standards, to address working conditions, etc. Law and Political sciences, as well as Ethics will play a role in these subjects.

Finally, an aspect of relevance to European manufacturing relates to the perception of manufacturing, the role of women and men in the factories, how to make these factories more attractive to young talents, life-long training of industrial workers, 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, leading to demanding investment requirements.

To keep up European leadership in manufacturing and to deal with the soaring costs of Research and Innovation and scarcity of competent and talented people, a fruitful international collaboration is needed and 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 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 EU that either hold a strong competitive position regarding the critical technologies for Manufacturing or are investing heavily for their development, and assessing their strengths and evaluating the feasibility of cooperation with EU, based on complementarities, synergies and economies of scale;
- Identify 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 a 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 in successful new products and new business needs to be significantly improved.

The **development and mastering of new and unique technologies and competencies** are effective and durable sources of differentiation. In the manufacturing domain, one simple-appearing technology might take decades to mature into 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 competitiveness, 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 centers, research and technology organisations (RTOs), customers, consumers and the society at large. The ecosystem grows and prospers thanks to a dynamic equilibrium where different and often conflicting interests are harmonised and collaboration 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. By this, innovation in manufacturing is an important enabler for innovation in final products, creating real sources of competitive advantage.

Two main gaps can be found in the current innovation process 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 demand for specific instruments and funding mechanisms.

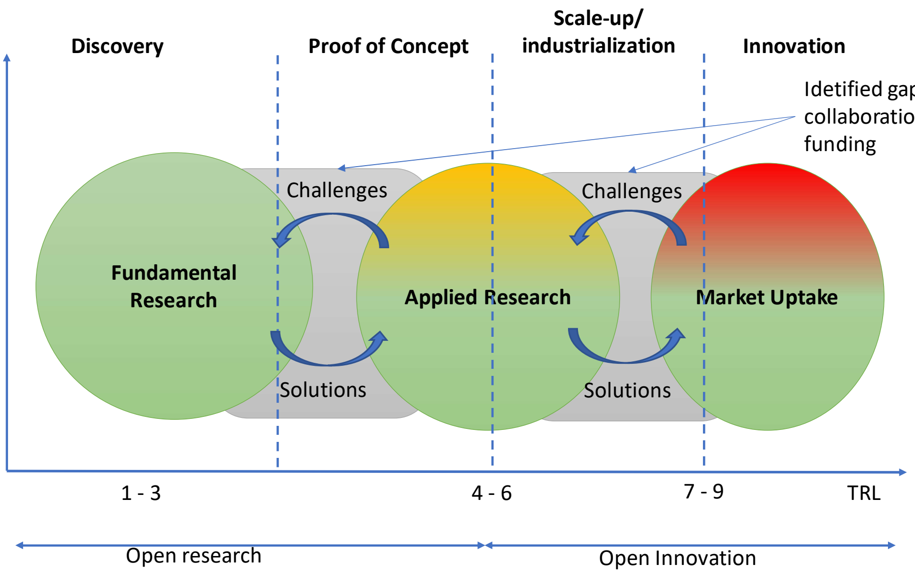

Figure 11 - The innovation process

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

- **Promote a long term and integrated strategy** aiming at the research and innovation leadership of the European Manufacturing Ecosystem. Promote the necessary **basic and applied research** and its diffusion among the relevant stakeholders. For its effective diffusion Proof of Concept, Experiments, Demonstrators and Pilot Lines should be promoted and the necessary skills developed accordingly. Education and standardisation has 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 the support to start-ups, risk capital, loans and grants:
    a) **Promote fundamental research**, as its results (breakthrough knowledge and technologies) are often the foundation for manufacturing innovations. In general, some think of basic and applied research as separate, but it's an

extremely important and quite often coupled mix. Often [9]basic science fuels applications in a much more profound way. To have a higher probability of success in the applied arena, it is extremely important to be well-grounded in the basic mechanism of the targets we're after. The value of fundamental research is often to discover something that was not expected — that, in fact, nobody expected. And it is where almost everything we now expect came from. In other words, it enables the emergence of radical innovation, we just couldn't imagine at the time.

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

   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 transfer should be implemented to bring unexpected RTD results to the market.

c) **Promote experiments and proofs of concept with research results with low TRL levels** (up to 4). This is extremely important to reduce the above-mentioned gap between more fundamental research and its application.

d) **Promote demonstrators and pilot lines** as good instruments to facilitate the knowledge diffusion and a quicker prototyping that will shorten the time to industrial scale-up. When companies can better evaluate the 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 the quick and flexible set up and funding of innovation projects**, promoting synergy and making available the right funding at each respective level.
- **Restructure and reinforce the 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 centres science parks and incubators should be promoted and supported.
- **Promote an environment and culture prone to innovation and entrepreneurship.** Creativity and entrepreneurial attitudes and best practices should be encouraged

[9] According to MIT.

and disseminated among European society. An over risk adverse 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 workers, which facilitate a shift towards innovation and advanced manufacturing strategies, as one of the most critical driver of global manufacturing competitiveness.

The introduction of new technologies and the growing digitalisation and automation of manufacturing processes will require industry workers to have increased technical skills. In particular, it is expected that workers will require skills in digital techniques, computing, analytical thinking, machine ergonomics and manufacturing methodologies. “Education and Training” was also identified with high importance for the transition to the Circular Economy. Relevant knowledge needs to be conveyed, starting from students at high school and university level up to workers/engineers/managers at enterprise level, along their professional life.

Objectives and priorities

Some key objectives and priorities for future manufacturing education rise within this context:

- Create an Harmonised European Manufacturing Qualification System, that can be deployed and used across Europe;
- Deliver manufacturing knowledge, skills and competencies in full accordance with the real business world and working environment, their constraints and future needs. Facilitate closer co-operation between need (industry) and seed (academia) and a co-ordination of efforts at national and regional levels, and support cross-border partnerships from across Europe.
- Act as a lever for improving and mobilising all skills, talents, competencies and abilities needed all along 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.
- Address recent trends, such as the digital transformation, the innovative manufacturing processes and technologies, servitisation, multidisciplinary approaches.
- Address also non-technological skills, perception and behaviour abilities, such as 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.
- Implement the Teaching / Learning Factory as a framework for education / training paradigm focused on practical learning and based on a dual approach.

- Promote the use of enhanced ICT-based technologies and training methodologies to make manufacturing more attractive to the young people.
- Develop digital skills and embed e-learning in manufacturing. Key points for a digital skills development strategy include[10]: (i) Develop / strengthen links between the world of learning and the world of work; (ii) Provide relevant training for workers; (iii) Convince adults of benefits from better skills; (iv) Provide easy-to-find information about adult education activities; (v) Recognise and certify skills proficiency.

Creating an European Manufacturing Qualification System

The introduction of new technologies in Manufacturing poses an urgent need for new qualifications. 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. A fast-changing workforce profile is underway 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, at more important, implement all of this at European level.

An European Qualification System in Manufacturing should be introduced, ensuring that the future manufacturing workforce is prepared for the challenges ahead. To achieve this, there is the need to:

- Facilitate retraining, reskilling
- Ensure that new skills are addressed in a faster way
- Ensure transferability between traditional education systems and technical education
- Integrate modularity on the Qualifications systems
- Align industry’s qualifications and needs with the European Qualifications Framework, hence ensuring a more qualified and mobile workforce within EU
- Governments and industrial organisations should proactively find ways to coordinate initiatives that can foster qualification, transition and transfer of professionals, as well as nurturing the creation of new jobs.

Enabling technologies for re-shaping manufacturing education and training in Europe

Innovative digital tools and technologies, including Virtual and Augmented Reality (VR, AR), Cyber-Physical Systems (CPS), Internet of Things, Serious Games, as well as web-based collaboration environments will play an important role in manufacturing education. 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 the interaction between the knowledge “producers” (e.g. academia, RTO’s, technology developers) and the knowledge “receivers” (e.g. students and workers at all levels).

[10] As identified by OECD.

Emerging manufacturing education paradigms – The Teaching / Learning Factory

The "Teaching and Learning Factory" paradigms have gained major interest in various educational and business pilot activities. Among their main objectives are to modernise the teaching processes and bring them close to the industry, providing young engineers with "hands-on-experience". These learning environments are also excellent to test and evaluate the potential of new technologies, promoting entrepreneurship and adoption of new technology.

Novel life-long 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 multi-dimensional and the people that will address these challenges need to be educated under a new paradigm that brings together the academic/research practice and the industrial/market practice.

The Teaching / Learning Factory approach will help filling-in the skills gap and addressing 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.

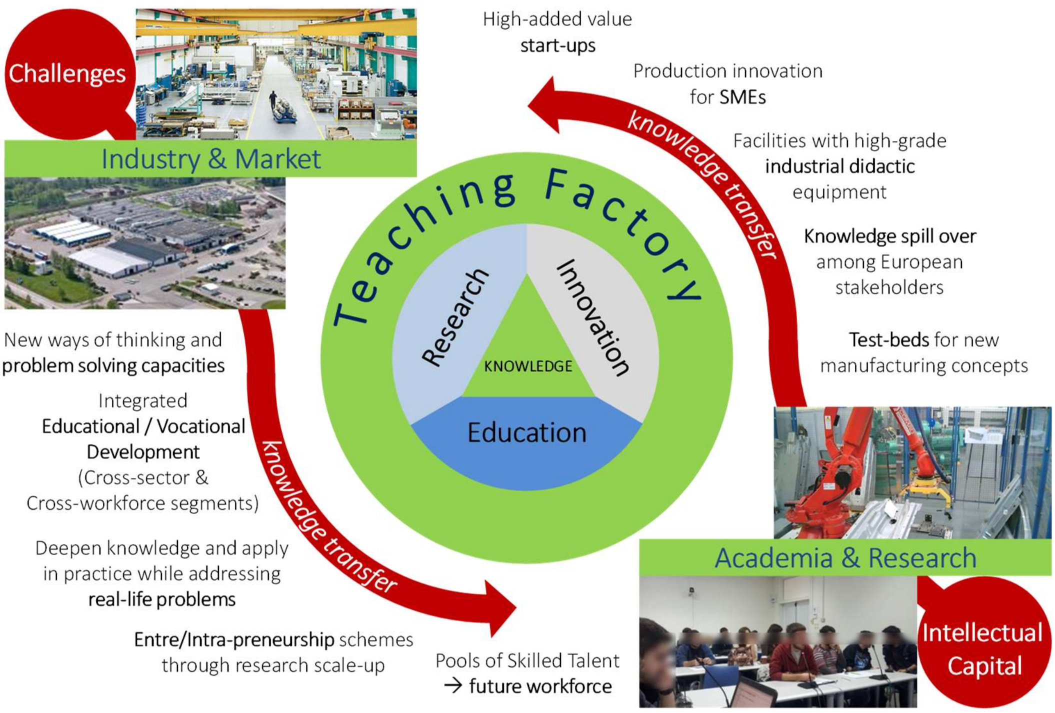

Figure 12 - Teaching Factory: An educational paradigm for future manufacturing in Europe

6. Manufacturing and Society

Europe has the potential to become the most attractive and competitive innovation hub (or a set of innovation hubs), 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:

- It's a demanding market, with a strong purchasing power per capita;
- With high standards of design, quality and environmental protection and a unique culture and tradition;
- It has a strong scientific and technological landscape and high levels of education;
- And is leader in complex (ciber-physical) systems, with a strong engineering and industrial background.

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

- It's not a single market (having multiple languages, regulations, standards, etc.);
- Compared with some other regions of the world, it seems to be less performant regarding knowledge transfer and valorisation;
- 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 ones, and Europe needs to ensure a competitive position in this crucial area.

To fully realize this potential, a collaborative effort is needed from all relevant stakeholders, including the European citizens, as consumers but also as tax payers, and the Governments and public organizations, namely in their legislative and supporting (funding and financing) roles, and also as customers of innovation (public procurement).

European citizens need to:

- Be coherent with the European values and demand 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, namely 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 a sustainable competitiveness, thus accepting that a growing percentage of their taxes is invested in those areas.

Complementary, public stakeholders need to:

- Invest in R&D, Innovation, education and training, and create an attractive framework to induce private investments, ensuring that Europe produces enough knowledge and people to feed its innovation eco-system;
- Have a more active role in the creation of an Innovation boosting framework, namely 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 harmonization of regulations and standards towards a deeper 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 globalization but also calls for fair and balanced rules for all the players.

Under these conditions, **manufacturing industry will be able to "pay back" European Society and its citizens** for their investment and commitment by:

- Delivering products and services capable of meeting their expectations;
- Generating well paid jobs, in manufacturing and related services;
- Generating wealth capable of supporting European investments and standards of living;
- Providing a more balanced and sustainable development in Europe, reducing the inequalities between regions;
- Ensuring technological and economic independence regarding other nations, providing Europe a strong position in the context of globalization.

Naturally, these innovative products and services will be targeting the global markets and this will call also for collaboration and exchange with stakeholders from other nations (including academia, RTOs, companies and governments), thus promoting the development of those societies as well.

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