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Advanced Manufacturing and Robotics for ICT Manufacturing





This report was prepared by Liliya Pullmann (Fraunhofer ISI).

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European Innovation Council and Small and Medium-sized Enterprises Executive Agency (EISMEA)

Unit I-02.2 — SMP / COSME Pillar

E-mail: EISMEA-SMP-COSME-ENQUIRIES@ec.europa.eu

Directorate General for Internal Market, Industry, Entrepreneurship and SMEs

Unit D.2 — Industrial Forum, Alliances and Clusters

E-mail: GROW-ATI@ec.europa.eu

European Commission

B-1049 Brussels

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Section 1

1. Introduction

Background

The Product Watch Reports have been developed in the framework of the 'Advanced Technologies for Industry' project and serve to identify and analyse 15 promising advanced technology (AT)-based products and their value chains, with an assessment of the strengths and weaknesses of the EU positioning.

Promising AT-based products can be defined as "enabling products for the development of goods and services enhancing their overall commercial and social value; embedded by constituent parts that are based on AR/VR, Big Data & Analytics, Blockchain, Cloud, Artificial Intelligence, the Internet of Things (IoT), Mobility, Robotics, Security & Connectivity, Nanotechnology, Micro-nanoelectronics, Industrial Biotechnology, Advanced Materials and/or Photonics; and, but not limited to, produced by Advanced Manufacturing Technologies".

1.1. Background of this report

The ICT manufacturing sector¹ contributes directly €46.3 bn² to the European (EU-27) economy. The European countries that have benefited most from the ICT production are Germany, contributing 28% to the total European ICT manufacturing sector, France (19%) and Italy (8%). **The EU's ICT manufacturing sector is dominated by the manufacture of electronic components and boards, which provided 55% of the total added value** in 2018 (Figure 1). The next largest ICT manufacturing subsector is **the manufacturing of communication equipment, which accounts for 26% of the EU's value added**, followed by the manufacturing of computers and peripheral equipment (12%) and of consumer electronics (7%). Activities related to the manufacturing of magnetic and optical media account only for 0.1% of the total value added. Despite the disruptions caused by the Covid-19 crisis and the recent US-China trade disputes, **the global market for electronic components is predicted to grow at a compound annual growth rate (CAGR) of about 4.8% from 2020 to 2025.**³ The ICT manufacturing sector benefits from a steady increase in the worldwide demand for electronics - both as final and intermediate products - as a result of rising income and technological advances shifting consumer and producer preferences.⁴ However, **the share of the EU's ICT manufacturing in global ICT manufacturing and electronic industry has steadily declined:** the EU's electronics lost more than 10 percentage points in the worldwide value added since 2000 showing worse performance than the US.⁵

The supply of cutting edge electronic components and systems plays an essential role for the innovativeness and competitiveness of major economic sectors and technologies and is crucial for the economic growth of the EU countries. **Electronics is a key technology, representing a building block of the European digital economy and society.** Therefore, there are growing concerns that the persistent negative trend for electronics manufacturing in the EU and further losses in the global market shares could eventually harm innovation capacities and erode productivity growth in the EU countries.⁶ To maintain the competitive edge and to further develop the ICT manufacturing sector is therefore of high importance for Europe. The potential of **advanced manufacturing technologies can help support localised manufacturing and secure the competitive advantage** in the manufacturing sectors in the EU. The EU has adopted a lot of initiatives in recent years to help speed

¹ According to the OECD official definition (OECD Guide to Measuring the Information Society, 2011) and Eurostat, the ICT manufacturing sector encompasses the following NACE Rev. 2 sectors of economic activity:

26.1 Manufacture of electronic components and boards
26.2 Manufacture of computers and peripheral equipment
26.3 Manufacture of communication equipment
26.4 Manufacture of consumer electronics
26.8 Manufacture of magnetic and optical media.

² Calculation is based on values provided by the Eurostat's Structural Business Statistics for 2018:

<https://ec.europa.eu/eurostat/web/structural-business-statistics/data/database>. As the 2018 values for manufacture of electronic components and boards (261) and manufacture of computers and peripheral equipment (262) are missing at this point of time (March 2021), they were estimated by using the growth rates in the recent periods.

³ <https://www.360marketupdates.com/global-electronic-components-market-14830923>

⁴ <https://voxeu.org/article/eu-s-declining-share-global-manufacturing-value-chains>

⁵ <https://voxeu.org/article/eu-s-declining-share-global-manufacturing-value-chains>

⁶ Marschinski et al. (2019). Reassessing the Decline of EU Manufacturing: A Global Value Chain Analysis,

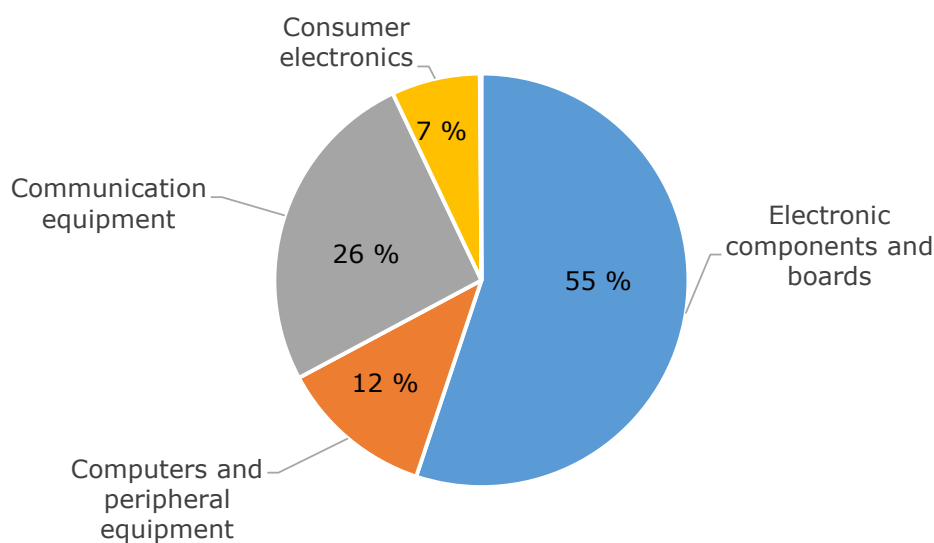


up investments in breakthrough technologies in the strategically important areas to capitalise and exploit their potential in order to reverse the manufacturing decline.⁷

The 2020 New Industrial Strategy of the European Commission⁸ laid the foundation for industrial policy to support the twin transition towards digitalisation and sustainability and to ensure EU's leadership in green and digital technologies. The recent pandemic crisis underlines the importance of a more resilient and competitive European market and the necessity to strengthen the measures on the twin transition.⁹ Based on its economic and technological relevance, but also potential contribution to the decarbonisation, digitalisation and resilience of the EU economy, the electronics industrial ecosystem has been recognised as being of core importance for the EU and one of the main areas for action of European policies.¹⁰ Innovative digital and advanced technologies play a particularly important role in building up the capacity for the transition to sustainability and digitalisation, as well as in increasing EU's competitiveness on global markets.¹¹

Figure 1: EU-27 ICT Manufacturing value added by subsectors

EU-27 ICT Manufacturing Value Added by Subsectors



Source: Fraunhofer ISI, calculations are based on Eurostat Structural Business Statistics

The ICT manufacturing companies are increasingly exposed to the fierce global competition.

To remain competitive, the ICT manufacturing sector needs to be able to combine high standards of quality of products with more efficient processes and improved productivity while lowering operational and production costs. In addition, it has to respond flexibly and dynamically to new market trends and emerging demands, such as rapid new product introduction, increasing personalisation and customisation. As consequence, the **ICT manufacturers have to cope with an ever growing product and process complexity**. Deployment of advanced technologies in the ICT manufacturing sector is a major driving force for improving the productivity and efficiency, quality of products and processes, reducing downtime and providing new opportunities for further developments in the industry. Advanced manufacturing technologies can also help address the need for higher flexibility and responsiveness to the market by making it possible for manufacturers to quickly and easily modify designs and reconfigure production lines according to customer demands. These are the major reasons for a broad application of these technologies by electronics and ICT manufacturing companies. Apart from this, advanced manufacturing and digital technologies can support the green transition by helping

⁷ Dosso (2020). Technological readiness in Europe EU policy perspectives on Industry 4.0.

⁸ European Commission (2020). A New Industrial Strategy for Europe: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0102&from=EN>

⁹ European Commission (2021). Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery.

¹⁰ European Commission (2021). Annual Single Market Report 2021.

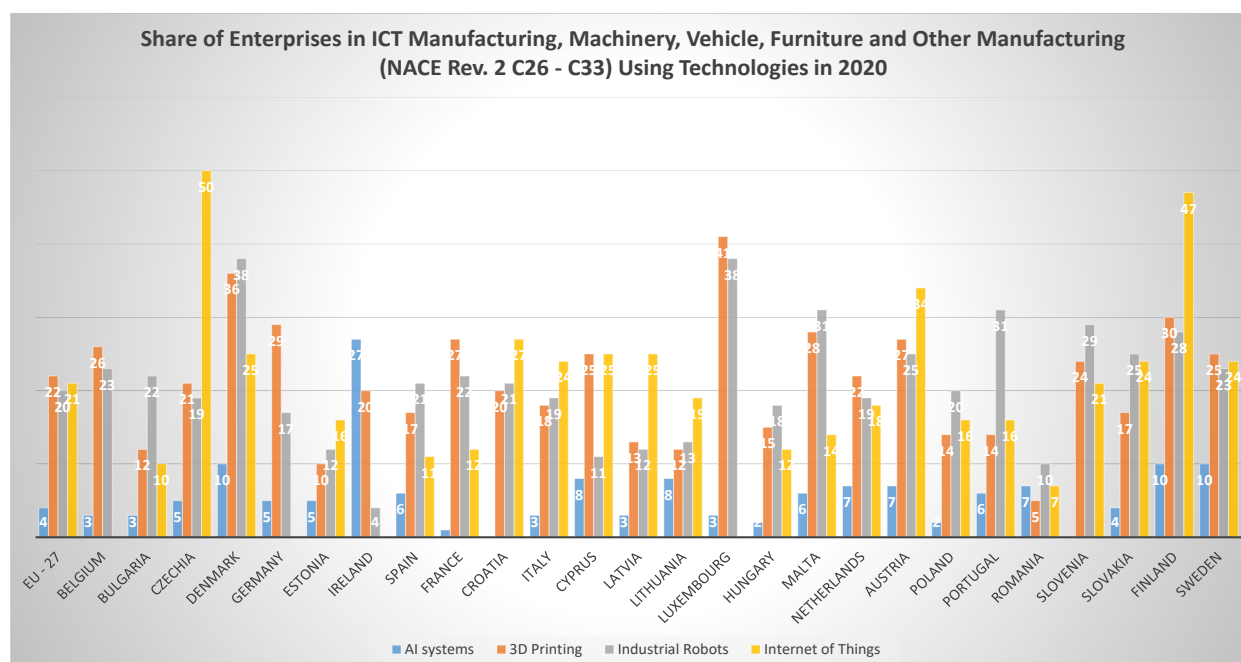
¹¹ European Commission (2021). Annual Single Market Report 2021.



industries - including electronics¹² - optimise their use of resources¹³, increase energy efficiency, reduce waste and speed up the circular economy¹⁴.

There is a broad range of advanced manufacturing technologies that might deliver significant advantages in terms of productivity, efficiency gains and quality improvements to companies across the ICT manufacturing sector. Most of the **advanced manufacturing technologies have been enabled by the increasing digitisation of the industry, connectivity and the rising performance of enabling hardware and software**. Continuous technological progress, efficiency race and development of advanced technological infrastructure is going to accelerate the adoption of the next generation of advanced manufacturing technologies. These are primarily technologies that are referred to as **Industry 4.0 or smart manufacturing** and are **characterised by cyber-physical systems and smart machines that are interconnected and use data to communicate**. In this Product Watch, we focus on the most commonly cited understanding of the Industry 4.0 concept involving technologies, such as industrial Internet of Things, Cloud Computing, (Advanced) Robotics, Digital Design, Simulation and Integration, Big Data Analytics, Artificial Intelligence, Cybersecurity and Additive Manufacturing.¹⁵ These technologies have general purpose characteristics and can be applied to a vast range of branches and products. The ICT manufacturing companies in the European countries along with companies from other manufacturing sectors - especially vehicle manufacturing - have been increasingly taking advantage of these technologies (Figure 2). **Industry 4.0 technologies promise substantial productivity and growth effects¹⁶ and are expected to make radical efficiency improvements to the electronics manufacturing industry.¹⁷** Due to the growing adoption rate in near future, advanced manufacturing technologies' markets are expected to undergo a considerable growth (Table 1).

Figure 2: Percentage of enterprises in EU-27 countries¹⁸ using selected Advanced Manufacturing Technologies in manufacturing sectors C26-C33 (NACE Rev. 2).



Source: Eurostat, Digital Economy and Society Database (Note: For Belgium, Germany, Luxembourg, the official data on the application of Industry of Things technologies and for Slovenia and Croatia, data on AI systems are missing).

¹² Bai et al. (2020). Industry 4.0 technologies assessment: A sustainability perspective.

¹³ https://ec.europa.eu/environment/ecoap/about-eco-innovation/good-practices/can-new-tech-ai-save-resources-and-environment_en

¹⁴ https://ec.europa.eu/environment/ecoap/about-eco-innovation/policies-matters/green-and-digital-twin-transition-also-spurs-inclusive-eco_en

¹⁵ See, for example: Fassio and Nathan (2020); Boston Consulting Group (2016).

¹⁶ Fassio and Nathan (2020). Exploring Industry 4.0 production in Sweden.

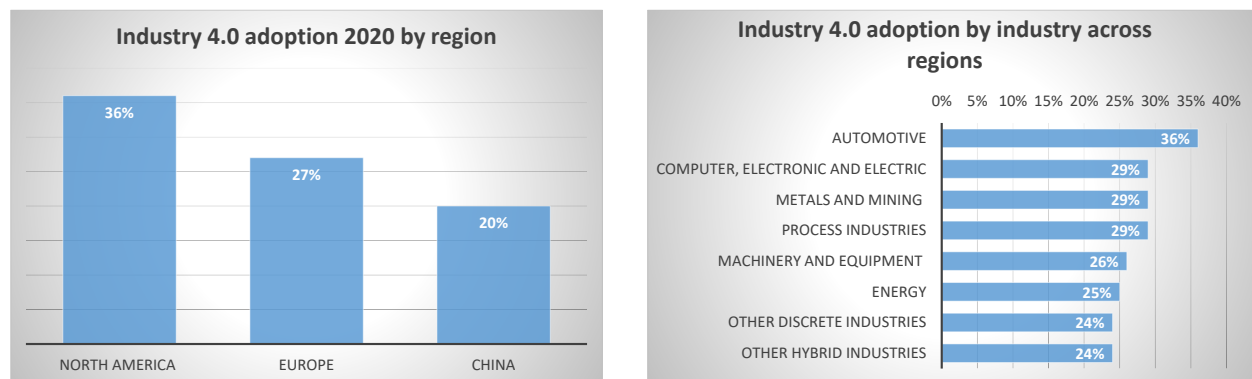
¹⁷ Roland Berger Focus (2018). The Race for Efficiency. Industry 4.0 and its impact on electronics assembly..

¹⁸



The ICT manufacturing industry is among the early and large adopters of Industry 4.0 technologies (Figure 3) applying them to various stages of production processes. As a whole, Europe¹⁹ is after North America the second largest region in terms of the overall Industry 4.0 adoption followed by China (Figure 3). **At the EU level, advanced and digital technologies, including Industry 4.0,²⁰ are considered a central component of the industrial policy to increase the competitiveness of the European economy and to support the transition towards a digital and green economy²¹,** however the main responsibilities lie with the Member States, their governments and administrative bodies, institutions and agencies.²²

Figure 3: Adoption of Industry 4.0 by regions and industries in 2020



Source: based on data provided by IoT Analytics Research 2020²³ (Note: data is based on the survey of 150 leading manufacturers from North America, Europe and China).

Within the Industry 4.0 technologies, **Advanced Robotics and Artificial Intelligence (AI)** are becoming particularly important for the ICT manufacturing sector²⁴ and expected to have an even greater impact in the future. When combined with Artificial Intelligence, manufacturing processes can reach further efficiency and effectiveness improvements. The benefits of AI for the manufacturing systems emanate from the capabilities enabled by the AI, such as cognition, including computer vision, natural language processing, speech recognition, planning and scheduling and the ability of machines to improve their performance by analysing data. By means of the embedded AI, production processes can reach a certain degree of autonomy being able to solve problems, optimise processes and make decisions autonomously, continuously learning from data. Despite its high potential, the actual degree of AI applications in production processes is relatively low yet (Figure 2) due to high costs and the considerable efforts needed for their integration in the workflow. At present, the ICT manufacturing companies are increasingly integrating Machine Learning (ML) techniques, such as regression and supervised ML, to analyse production process data for different purposes, like maintenance support, production planning, control and quality related decisions. However, the current AI enabled production control applications are still not so advanced.²⁵ AI applications are more likely to be found in large companies used in robotics and resource management, while SMEs use AI applications predominantly for production management, quality control and supply chain optimisation. The real value of AI applications in different sectors, including ICT manufacturing, lies, however, in the achievement of a higher degree of production systems' autonomy and the associated value creation.²⁶ Although it is not a standard technology in most of the ICT manufacturing companies yet, it might be spread more broadly in the near future due to the rapid advancements of related technologies along with more powerful computing and analytical capabilities.

Automation technologies represent a further important field of technologies that have high relevance for the ICT manufacturing sector. Automation is not new to electronics and ICT manufacturing. During the last decades, there has been a steady automation of processes in the electronics manufacturing

¹⁹ In the relevant studies and reports, Europe is referred to as a geographical entity, not a political and economic one, as in case with the European Union.

²⁰ See Europe 2020 Strategy for smart, sustainable and inclusive growth.

²¹ European Commission (2021). Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery.

²² Dosso (2020). Technological readiness in Europe EU policy perspectives on Industry 4.0.

²³ <https://iot-analytics.com/industry-4-0-adoption-2020-who-is-ahead/>

²⁴ Siemens PLM Software (2018). Smart Manufacturing for Electronics. White Paper.

²⁵ Lingitz et al. (2019). Cycle time prediction with machine learning in the wafer production. In: A SemI40 Project Prospective. Industry4.0 from Evolution to Revolution. SemI40 Consortium. [HTTP://WWW.SEMI40.EU](http://www.semi40.eu)

²⁶ https://www.plattform-i40.de/PI40/Redaktion/DE/Downloads/Publikation/KI-industrie-40.pdf?__blob=publicationFile&v=10



industry. **The major driving force behind the present wave of automation within the ICT manufacturing is the need to increase productivity and flexibility of production processes, improve product quality and reduce the operational and production costs.** An important goal of automation in the ICT manufacturing is to automate repetitive tasks. Among the major areas that are currently increasingly automated in the ICT manufacturing are the material and component handling, assembly lines, etching, inspections, testing and packaging.²⁷ At the same time, the automation of mundane and repetitive tasks unleashes new opportunities for moving human dexterity, creativity and adaptive skills to be used in more critical and high value added processes.

Due to automation demands of the sector, **the electrical/electronics (E&E) industry is along with automotive manufactures one of the dominant sectors for robot sales.** The automation wave led to the rapid increase of robot installation by the electronic industry, which rose by 15% on average per year between 2013 and 2018. However, it declined during the two subsequent years due to the recent economic downturn in the electrical/electronics industry. 79% of the total robot installations in the electrical/electronics industry are attributable to three countries with major ICT production sites: China (43%), Republic of Korea (19%) and Japan (17%).²⁸

Electronics manufacturing is increasingly becoming complex as the size of components and circuits continues to shrink. Issues, like high component density, small pitches, multiple layers, and small and delicate parts that require precise placement are likely to introduce challenges that can slow down the assembly and testing of products. Also, the delicate nature of electronics requires a very delicate handling and there is a significant likelihood of errors, wastage and inefficiencies related to it.²⁹ **Many of these challenges in the ICT manufacturing can be addressed thanks to the recent technological progress that enabled a new generation of Advanced Robots.** These robots are equipped with advanced functionalities (due to advances in sensor and actuator technologies, dynamic programming, computer vision technologies and application of AI techniques) and can deal with less structured applications performing tasks that require more flexibility and accuracy than traditional robots.³⁰ By means of AI and being interconnected with other systems they are increasingly capable of interacting and responding to their environment as well as adapting to new situations and conditions. The rapid technological progress has also led to improved automated robots that support the miniaturisation trend in the electronics as they can handle very small parts at high speed, with very high degrees of precision, enabling electronics manufacturers to ensure quality whilst optimising production costs.³¹ As the new generation of robots is able to communicate with one another and other production systems, the entire production systems and supply chains can also become more efficient and adaptive contributing considerably to the flexibilisation of the ICT manufacturing. These and the increasing economic viability of the automated robots are the main reasons for the rapid growth of Advanced Robotics in the E&E industry.³²

The EU is one of the global leaders in terms of deployment of industrial robots. However, its share has been continuously shrinking since 2010 due to the intensive automation and robotisation of industries in the Asian countries, particularly China. By contrast, the US together with NAFTA regions have managed to keep their positions.³³ In the EU-27, countries with the highest share of companies using industrial robots are Denmark, Malta, Portugal, Slovenia, Finland, Sweden and Austria (Figure 2). Within the Visegrád countries, the growth in terms of deployment of industrial robots was particularly driven by Czechia, followed by Poland, Hungary and Slovakia. However, more than half of all industrial robots installed are used in the car manufacturing. A much smaller share has been so far deployed in the electrical and electronics companies.³⁴

Developments in sensors and power-force limiting technologies led also to the **emergence of new robot types** that are compact and can share workspaces with employees referred to as **Collaborative Robots (Cobots)**. They are becoming easier to program, enabling faster re-tasking that can be done by workers themselves. Further, integration of AI techniques and data fusion make real time decisions possible and help robots better adapt to their working environment. These and further advantages, such as mobility, lightweight and power efficiency are driving the adoption of the technology.³⁵ **Cobots offer more flexibility and are particularly attractive for the SMEs.** Accordingly, the collaborative robot

²⁷ <https://www.automationmag.com/3935-automation-integration-opportunities-in-electronics-manufacturing/>

²⁸ <https://ifr.org/case-studies/service-robots/the-autonomous-way-to-industry-4.0>

²⁹ <https://medium.com/supplyframe-hardware/robots-and-automation-in-electronics-manufacturing-a77f177585eb>

³⁰ Eurofound (2019). The future of manufacturing in Europe.

³¹ <https://medium.com/supplyframe-hardware/robots-and-automation-in-electronics-manufacturing-a77f177585eb>

³² <https://ifr.org/post/automation-boom-in-electrical-electronics-industry-drives-30-increase-in-sa>

³³ Septimiu (2020). Transition to Industry 4.0 in the Visegrád Countries.

³⁴ Septimiu (2020). Transition to Industry 4.0 in the Visegrád Countries.

³⁵ <https://www.fortunebusinessinsights.com/industry-reports/collaborative-robots-market-101692>



market has exhibited high growth rates recently reaching more than 30% in revenue terms with automotive and electronics representing its largest end-user industries. The European market for collaborative robots accounted for approx. €292 million in 2019, which makes almost 50% of the entire global market. Europe is going to remain the largest and fastest growing region in near future, followed by China, North America and the rest of APAC countries.³⁶ The assembling application and material handling are going to be the key application domains for Cobots in the electrical, electronics and semiconductor industries.³⁷ Moreover, the deployment of Cobots helps combine the leveraging of human work and automation processes, enabling new efficiency gains in the ICT manufacturing.

At present, investments in automation are somewhat restrained by uncertainties of the global economy linked to the Covid-19 crises and increasing protectionist measures in the US, China and other Asian countries. However, the **incentives to invest in automation and other advanced manufacturing technologies remain strong** and the electrical and electronics industry is anticipated to show considerable growth in the integration of robotics³⁸ and other advanced technologies in the near future. Table 1 presents an overview of the global market size, leading markets and growth prediction for selected advanced manufacturing technologies over the next few years.

Table 1: Overview of the market development for selected advanced manufacturing technologies

Advanced Manufacturing Technology	Market Volume	Expected Growth Rates (CAGR)	Largest Markets (in descending order)
Manufacturing Execution System (MES)	€9.8 bn in 2020	4.5% (2020-2025)	Asia Pacific (particularly China), North America, Europe
Industrial Internet of Things	€27.4 bn in 2019	10% (2020-2025)	North America, Asia Pacific
Artificial Intelligence in Manufacturing	€0.9 bn in 2020	57% (2020-2026)	APAC countries (China, Japan), North America
Industrial Robots	€18 bn in 2019	15% (2020-2027)	Asia Pacific (China, Japan, South Korea, India), North America, Europe
Collaborative Robots	€599.9 m in 2019	42% (2020-2037)	Europe, China, North America, rest of APAC countries, Eastern Europe

Source: Based on data provided by Fortune Business Insight and Markets and Markets.

1.2. Objectives of this report

The ICT manufacturing sector and electronics in general play a strategically important role for the EU's economy and society. The adoption of advanced manufacturing technologies is key to help the European companies maintain and improve their competitive edge and to better address the need for higher flexibility responding to the growing trends, such as personalisation and customisation of products and technologies.

This report therefore aims to provide an overview of the positioning of the EU's ICT manufacturing companies in terms of the adoption of advanced manufacturing technologies broadly referred to as Industry 4.0 technologies. Key insights are gained by assessing specific characteristics of strengths and opportunities, but also challenges and risks that the European stakeholders are likely to be confronted with when operating in their environment. The further objective is to map the advanced manufacturing value chain and the interactions along the value chain. Due to the broad range of advanced manufacturing technologies and the scope of this report, we focus rather on general characteristics and functions of advanced manufacturing/Industry 4.0 technologies than on specifics that individual technologies might display. Analyses provided in this report are based on desk-research, the internal expertise of Fraunhofer ISI and on expert interviews.

³⁶ <https://www.interactanalysis.com/the-collaborative-robot-market-2019-infographic/>

³⁷ <https://www.fortunebusinessinsights.com/industry-reports/collaborative-robots-market-101692>

³⁸ <https://www.fortunebusinessinsights.com/industry-reports/industrial-robots-market-100360>

Section 2

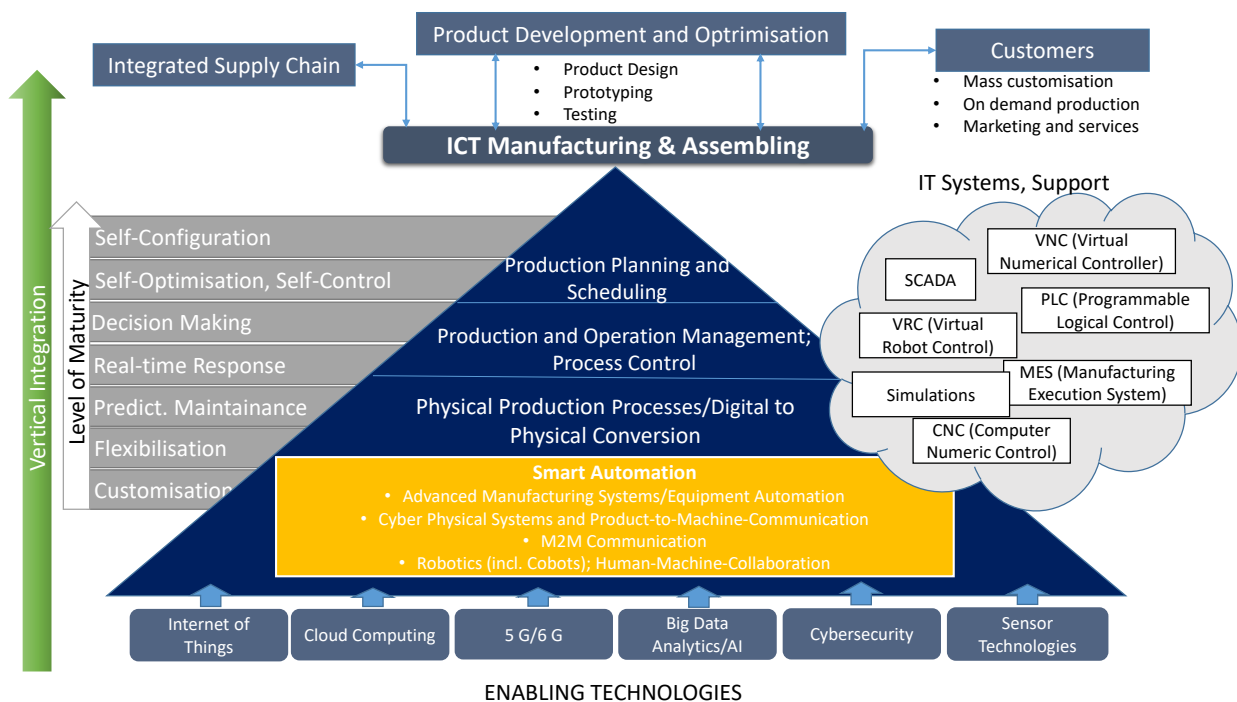
2. Value chain analysis

The following chapter explores the value chain of Industry 4.0 in the context of ICT manufacturing and assembling including the key actors and the current state of play of cross-chain linkages.

2.1 Value chain structure

The ICT manufacturing in the context of Industry 4.0 consists of different continuously interconnected dimensions, the flows and the conversion of the digital and physical world. The interconnectivity can be established between every component, process, actor and technology in real time. Consequently, the entire manufacturing system can interact and is interconnected with Industry 4.0 enabling technologies (Figure 4). The analytics is one key integral part of Industry 4.0 to generate insights and suggest actions based on data analysis.

Figure 4: Value chain of Industry 4.0 in ICT Manufacturing



Source: Faunhofer ISI

At the operational level, the first hierarchy block of an Industry 4.0 manufacturing system within a company is the production planning and scheduling optimisation processes (Figure 4). They help achieve an optimum balance between the workloads of each production line and ensure the shortest possible changeover and reconfiguration times. The system helps handle the increased complexity of production, improve workers' utilisation and ensure that the new, more complex production schedules are met.³⁹ The next hierarchy level represents the production and operation management process control that allows real-time management, control and maintenance operations. The hierarchy levels rely on the IT systems and software tools representing a critical foundation around which Industry 4.0 application systems in a company can be built. Key systems at the operative levels are Manufacturing Execution System (MES) that support main production operations, Supervisory Control and Data Acquisition (SCADA) and controllers on machine/device level, such as Programmable Logic Controllers (PLCs), robot and other controllers that control and guide the automation processes.⁴⁰ At present, the integration of

³⁹ Roland Berger Focus (2018). The Race for Efficiency. Industry 4.0 and its impact on electronics assembly.

⁴⁰ Rojko (2017). Industry 4.0 Concept: Background and Overview. Special Focus Paper.



advance data analytics and Artificial Intelligence techniques make the manufacturing systems more adaptable and responsive allowing a higher level of flexibilisation and customisation, better planning, predictive maintenance and decision making. In Industry 4.0, the physical production elements have their virtual identity in form of data including a variety of information characterising them stored in the cloud.

The core system block of the Industry 4.0 is the digital to physical conversion to reconfigurable manufacturing system and the hardware-centric blocs represented by the smart automation technologies. Digital-physical conversion and a continuous flow of information allow a high level of flexibility and adaptability of the production processes. Smart manufacturing and automation incorporate a variety of advanced technologies, such as automated equipment and machinery, robotics including new technology, such as cobots, and new manufacturing techniques, like additive manufacturing. Flexible and smart (equipped with AI) robots are an essential manufacturing technology that contributes further to the flexibilisation and reconfiguration of the ICT manufacturing and helps decrease production costs. Cyber-Physical Systems and advanced automation technologies can to a certain degree operate autonomously and make decisions based on AI algorithms and real data analytics, as machines and devices can communicate and cooperate with each other (Machine-to-Machine Communication).

Within a company the whole manufacturing ecosystem is networked by vertical integration, which provides the foundation for exchanging information and collaboration among different levels of the hierarchy.⁴¹

Reconfigurable manufacturing technologies and systems support the shifting of ICT manufacturing from mass towards customised production and helps manufacturing companies adapt their manufacturing capacities for a wider product variation and make the entire production processes more flexible. With increased capacities of computing and combining microprocessors and advanced AI with products and machines, the manufacturing system can in the future reach a higher level of autonomy and ability of self-optimisation, self-adaptation, self-control and autonomous decision making.⁴²

The implemented Industry 4.0 concept is not limited to the production system only, but includes the complete value chain through the horizontal integration from suppliers to customers and assumes a broad support of an entire life cycle of systems and products. The data that such smart products might provide outside the production facility gives the manufacturer valuable information about their state, reliability during their lifetime and can be used for preventive maintenance.⁴³ The networking with customers and data flows allows to focus on specific customer needs associated with the customisation of products while maintaining production efficiency and quality. Moreover, the Industry 4.0 opens new capabilities to product development, design, rapid product optimisation and prototyping.

2.2 Key actors in the value chain

As Figure 4 shows the value chain is complex and large, as different technologies and related actors are of relevance. In the following, we focus on four key groups of technology players providing key technologies to the ICT manufacturing across the Industry 4.0 value chain: software and system solutions providers, industrial Internet of Things players, robotics for ICT manufacturing and finally AI and data analytics for manufacturing processes.

Software and system solutions providers

Software and system solutions providers are offering solutions for the Industry 4.0 technology blocks including process master control systems, production scheduling optimisation systems, predictive maintenance, machine and line performance optimisation systems with a high level of customisation.

Most ICT manufacturers source software systems from external partners. However, given the complexity of finding the right partner and the significant integration effort in terms of customisation with existing systems needed and costs, some players have built up their own software development know-how and do not have to rely on external suppliers.⁴⁴ Table 2 provides a non-exhaustive list of software and system solution players offering software-centric technologies for the ICT and other manufacturing companies.

⁴¹ Alcácer and Cruz-Machadoa (2019). Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. *Engineering Science and Technology*. Issue 22, pp. 899-919.

⁴² Alcácer and Cruz-Machadoa (2019). Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. *Engineering Science and Technology*. Issue 22, pp. 899-919.

⁴³ Rojko (2017). Industry 4.0 Concept: Background and Overview. Special Focus Paper.

⁴⁴ Roland Berger Focus (2018). The Race for Efficiency. Industry 4.0 and its impact on electronics assembly.



Table 2: Software and system solutions providers

Company	Headquarters	Link to Advanced Manufacturing Technologies	Website
B&R Industrial Automation GmbH	Austria	Process control software solutions	https://www.br-automation.com/en/
Confirm Smart Manufacturing Research Centre	Ireland	Data analytics, artificial intelligence, robotics and control (research institute)	https://confirm.ie/
EuroCPS	France	European Cyber-Physical Systems platform	https://www.eurocps.org/
Fraunhofer Institute for Manufacturing Engineering and Automation IPA	Germany	Robot and assistive systems, DigiTools for manufacturing	https://www.ipa.fraunhofer.de/en.html
Fraunhofer Institute for Reliability and Microintegration IZM	Germany	Wireless sensors for cyber-physical systems	https://www.izm.fraunhofer.de/
GE Digital	United States of America	MES software	https://www.ge.com/digital/
INTEMAC	Czechia	Industry 4.0 and production technology (research institute)	https://www.intemac.cz/en/
Irish Manufacturing Research	Ireland	Automation and control, digitisation (research institute)	https://imr.ie/
MaPS (Manufacturing Processes and Systems) – KU Leuven	Belgium	Advanced manufacturing (research institute)	https://www.mech.kuleuven.be/en/research/manufacturing
SAP SE	Germany	MES software	https://www.sap.com
Schiller Automatisierungstechnik GmbH	Austria	Automation solutions	https://www.schiller.de/de/produkte#automation
Siemens	Germany	Process control software solutions, data management, IoT and lifecycle analysis solutions	https://www.plm.automation.siemens.com/
TUP	Germany	Data management, intralogistics software solutions	https://www.tup.com/en/

Source: Fraunhofer ISI

Industrial Internet of Things

Industrial Internet of Things technologies are a backbone for the Industry 4.0 implementation. They represent networking and especially wireless technology. Numerous machines and sensor nodes are connected to the Internet using these technologies to facilitate Machine-to-Machine communication⁴⁵ and a general exchange of information between different machines and devices. Table 3 lists key market players in the field of Industrial Internet of Things.

⁴⁵ <https://www.marketsandmarkets.com/Market-Reports/industrial-internet-of-things-market-129733727.html>



Table 3: Industrial Internet of Things players

Company	Headquarters	Link to Advanced Manufacturing Technologies	Website
Atos	France	Industrial IoT for manufacturing	https://atos.net/en/
Bosch.IO	Germany	Industrial IoT; product: Bosch IoT Suite	https://bosch.io/
Cisco	United States of America	Industrial IoT solutions for digital manufacturing, Factory networking	https://www.cisco.com/
Clear Blade	United States of America	IoT solutions for manufacturing	https://www.clearblade.com/
HCL Technologies Limited	India	IoT solutions; product: IoTWoRKS	https://www.hcltech.com/Internet-of-Things-IoT
HQSoftware	Estonia	IoT solutions	https://hqsoftwarelab.com/
Huawei	China	Industrial IoT, ICT-production systems	https://e.huawei.com/
IBM	United States of America	Industrial IoT solutions	https://www.ibm.com/
Intel	United States of America	IoT solutions	https://www.intel.com/
Microsoft	United States of America	Industrial IoT; product: Azure Industrial IoT	https://azure.microsoft.com/en-in/
Mocana	United States of America	IoT solutions for manufacturing	https://www.mocana.com/
Oracle	United States of America	IoT solutions for smart manufacturing	https://www.oracle.com/internet-of-things/
PTC	United States of America	Industrial IoT solutions; Digital Manufacturing	https://www.ptc.com/
SAP	Germany	IoT; product: SAP Internet of Things	https://www.sap.com/index.html
Schneider Electronics	France	IoT solutions and architecture; product: EcoStruxure	https://www.se.com/ww/fr/
ScienceSoft	United States of America	Industrial IoT solutions, Smart factory solutions	https://www.scnsoft.com/
Software AG	Germany	IoT solutions for manufacturing	https://www.softwareag.com/
Telit	United Kingdom	IoT solutions for manufacturing	https://www.telit.com/
Wind River	United States of America	Industrial IoT solutions	https://www.windriver.com/
Zebra Technologies	United States of America	IoT solutions for manufacturing	https://www.zebra.com/

Source: Fraunhofer ISI



Robotics for ICT Manufacturing

As was described in the introductory part, industrial robots play a crucial role for the ICT manufacturing. At present, many core ICT manufacturing operations are being managed by robots that help ICT manufactures to streamline processes, increase efficiency and reduce errors. Automation providers offer solutions for production systems and automated material handling. Some companies have partnered with suppliers of specialised electronics manufacturing machines to be able to provide more customised technologies.⁴⁶

Robot providers increasingly focus on R&D activities to integrate AI techniques and develop advanced sensors⁴⁷ that make technologies smarter. Automation technologies that enable a greater adaptability are on the rise and in great demand. The industrial robotics market is highly fragmented and competitive.⁴⁸ The major players often follow strategies, such as mergers and acquisitions, to maintain their position in the market.⁴⁹ Table 4 offers an overview of some central robotic technology providers.

Table 4: Robotics for ICT Manufacturing players

Company	Headquarters	Link to Advanced Manufacturing Technologies	Website
ABB	Switzerland	Collaborative robots	https://global.abb/group/en
Comau Spa	Italy	Industrial automation, collaborative robots, IoT-services	https://www.comau.com/en
Delta Electronics	Taiwan	Electronic components, robotics	https://www.deltarf.com/
Fanuc Corporation	Japan	Value-chain optimisation, smart systems applications	https://www.fanuc.eu/bg/en/industrial-automation/electronics
KUKA AG	Germany	Collaborative robots, automation, Industry 4.0 solutions	https://www.kuka.com/
Mitsubishi Electric Corporation	Japan	Collaborative robots, factory automation	https://us.mitsubishielectric.com/fa/en
Precise Automation	United States of America	Collaborative robots, industrial automation	http://preciseautomation.com/
Rethink Robotics GmbH	Germany	Value Chain Automation, smart collaborative robots	https://www.rethinkrobotics.com/
Siasun	China	Collaborative robots, electronic assembly	http://www.siasun.com/
Techman Robots	Taiwan	Intelligent robots for electronics assembly, smart factory solutions	https://www.tm-robot.com/
Yaskawa Electric Corporation	Japan	Collaborative robots	https://www.yaskawa-global.com/

Source: Fraunhofer ISI

⁴⁶ Roland Berger Focus (2018). The Race for Efficiency. Industry 4.0 and its impact on electronics assembly.

⁴⁷ <https://www.fortunebusinessinsights.com/industry-reports/industrial-robots-market-100360>

⁴⁸ <https://www.mordorintelligence.com/industry-reports/industrial-robotics-market>

⁴⁹ <https://www.futuremarketinsights.com/reports/industrial-robots-market>



Artificial Intelligence and Advanced Data Analytics

Artificial Intelligence and Advanced Data Analytics are further key advanced technologies with high relevance for the ICT manufacturing companies. AI technology enables the ability of the manufacturing ecosystem to learn and adapt to changing environments, which represents additional value and offers new advanced opportunities to companies. The speed and the complex nature of the tasks in the ICT manufacturing are further factors that encourage the use of advanced AI technologies. However, the actual adoption of the technology is still in the nascent stage due to the presence of several challenges that hamper its implementation.⁵⁰ Table 5 gives an overview of some key players that provide AI and data analytics solutions to manufacturing companies.

Table 5: AI and Data Analytics solutions for manufacturing processes

Company	Headquarters	Link to Advanced Manufacturing Technologies	Website
AIBrain Inc.	United States of America	Artificial Intelligence; product: AICoRE	https://aibrain.com/technology/
Alphabet	United States of America	Artificial Intelligence; product: DeepMind	https://deepmind.com/about
Aquant Inc.	Israel	AI-driven data management and performance optimisation	https://www.aquant.io/platform/
Bright Machines	United States of America	Artificial Intelligence platform for digital manufacturing, computer vision, adaptive robotics	https://www.brightmachines.com/
Cisco	United States of America	Artificial Intelligence solutions, productivity optimisation	https://www.cisco.com/
Flutura Decision Sciences & Analytics	India	Artificial Intelligence and IoT-platforms	https://www.flutura.com/
General Electric Company	United States of America	Artificial Intelligence, knowledge management, data analytics	https://www.ge.com/
General Vision	United States of America	Artificial Intelligence, machine learning	https://www.general-vision.com/
Micron Technology Inc.	United States of America	Artificial Intelligence Platform 'FWDNXT'	https://www.micron.com/
Mitsubishi Electric Corporation	Japan	Artificial Intelligence; product Maisart	https://de.mitsubishielectric.com/en/
Nvidia	United States of America	Artificial Intelligence for manufacturing, machine learning, real-time simulation, software provider	https://www.nvidia.com/
Oracle Corporation	United States of America	Artificial Intelligence, data-driven cloud applications	https://www.oracle.com/artificial-intelligence/
Progress Software Corporation	United States of America	Artificial Intelligence, connected data	https://www.progress.com/
Rethink Robotics GmbH	Germany	Value Chain Automation, smart collaborative robots	https://www.rethinkrobotics.com/

⁵⁰ <https://www.gminsights.com/industry-analysis/artificial-intelligence-ai-in-manufacturing-market>



Company	Headquarters	Link to Advanced Manufacturing Technologies	Website
Rockwell Automation Inc.	United States of America	Artificial Intelligence for manufacturing, IoT solutions, performance optimisation	https://www.rockwellautomation.com/
Sight Machine	United States of America	Artificial Intelligence, machine learning, predictive maintenance, performance optimisation	https://sightmachine.com/
SparkCognition Inc.	United States of America	Artificial Intelligence, quality control, predictive maintenance	https://www.sparkcognition.com
UBTECH Robotics Corporation	China	Artificial Intelligence, robotics, computer vision for AI learning	https://www.ubtrobot.com/?ls=en
Vicarious Inc.	United States of America	Intelligent Robotics, Intelligent Automation, Robots-as-a-service, Vision-guided AI	https://www.vicarious.com/

Source: Fraunhofer ISI

2.3 Linkages along the value chain

To successfully implement Advanced Manufacturing Technologies is a challenging task for many manufacturing companies as it requires a broad range of advanced and interdisciplinary skills. To solve this challenge, a close cooperation between industry, technical and scientific partners from different domains that work together in interdisciplinary teams is essential.⁵¹ Also the development of Advanced Manufacturing Technologies, making these developments more customised, and facilitating a faster and more effective integration into manufacturing systems require close linkages and knowledge sharing between technology providers and users. The interoperability is another critical issue where collaboration plays a major role.

In the EU, such cooperation works usually well in advanced countries with a rich tradition in developing Advanced Manufacturing Technologies and established collaboration and interaction practices and structures between technology providers, users and relevant intermediaries, like Germany, France, Belgium, Austria, the Netherlands, Italy and Scandinavian countries. The situation is quite different in many 'new' EU countries that are still witnessing structural weaknesses, such as weak collaboration links between businesses and academia and the overall deficits in innovation performance as well as the uptake of Advanced Technologies. The EU takes a great deal of efforts to address these challenges: thanks to European initiatives there is a growing number of business intermediaries and institutions in these countries aimed at facilitating cooperation, knowledge exchange, commercialisation of research results and providing financial and consulting services to help companies implement and use advanced technologies. Many EU programmes (e.g. in the context of Horizon 2020) aim directly at bridging the gap between specific challenges of manufacturing companies, especially SMEs, and solution providers and at facilitating the adoption of advanced manufacturing technologies, encouraging relevant players to work together and develop collaborations between SMEs and large companies.

As it was previously mentioned, due to the high dynamic and growing complexity in the technology market and competitive rivalry among existing technology providers, companies themselves often pursue partnering strategies (for example with innovative start-ups) to source complementary technologies. Apart from this, large players often consolidate their market position through acquisitions and mergers.

⁵¹ Rosenberger et al. (2019). Capturing Industry 4.0 Use Cases for Interdisciplinary Implementation. In: A SemI40 Project Prospective. Industry4.0 from Evolution to Revolution. SemI40 Consortium. [HTTP://WWW.SEMI40.EU](http://www.semI40.eu)



Section 3

3. Analysis of EU competitive positioning

Overall, it is difficult to characterise the EU-27 in the context of advanced manufacturing technologies on a general basis. There are significant disparities across firms and individual territories in the EU. On the one hand, there is a number of EU countries, like Germany, Austria, Scandinavian countries, that have a rich heritage in Advanced Manufacturing drawing on established ecosystems and a pro-active public policy that supports the update and upgrade of manufacturing technologies. On the other hand, the EU involves a range of countries that have little tradition in such policies and display a lower readiness for the adoption of Advanced Manufacturing Technologies.

Figure 5 provides an overview of the key strengths, opportunities, challenges and risks associated with the adoption of Advanced Manufacturing Technologies by the ICT manufacturing companies in the EU countries.

Figure 5: Strengths, opportunities, challenges and risks for the advanced manufacturing technologies and robotics value chain



Source: Fraunhofer ISI (Note: the figure contains abbreviations: AMT - Advanced Manufacturing Technologies, CEEC - Central and Eastern European Countries, FDIs - Foreign Direct Investments).

3.1 Strengths

The EU excels in technological competencies related to the Advanced Manufacturing Technologies. There is a large number of Technology Centres⁵² and R&D organisations engaged in activities in the area of Industry 4.0 technologies and carry out different lines of R&D with high relevance for the industry. Numerous higher education institutions offer specialised study programmes to train highly skilled professionals, equipping them with an in-depth understanding of different advanced technologies and the capabilities required to efficiently deploy or develop them further. The EU features high level of differentiation of skills, incremental innovations and creativity, combining the high tech with artisan ingenuity.

There is **a number of initiatives in the EU countries**, such as Industrie 4.0 in Germany, Production 2030 in Sweden, Industrie du futur in France, Factories of the Future in Belgium, Industry 4.0 in Czechia, Industrie 4.0 Österreich in Austria, Industria 4.0 in Italy and Industria Conectada 4.0 in Spain. These EU countries have a lead role in adoption of advanced manufacturing technologies. They have elaborated and implemented dedicated strategies that include a wide scope of activities aimed at encouraging and fostering the adoption of digitalised advanced technologies in the manufacturing sector. They are based

⁵² See the mapping of European Technology Centres at: <https://ati.ec.europa.eu/technology-centre/mapping>



on a broad stakeholder involvement with a particular focus on SMEs integrating different policy fields like vocational education and training.⁵³

Further, **there are a lot of programmes and initiatives at the EU level**, for instance under the Horizon 2020 programme, that were introduced aiming at fostering the adoption of Advanced Technologies in industries - including the ICT manufacturing sector⁵⁴ - in the European countries. They have led to building of knowledge and innovation communities, public-private-partnerships, the identification of projects of European interest, thematic initiatives for enabling and industrial technologies dedicated to the advancement of these technologies.⁵⁵ The European Union actively promotes international cooperation in the field of Advanced Manufacturing Technologies and synergies between companies and academia. In addition to the more supply-oriented initiatives, the European Commission has gradually integrated a lead user market approach to stimulate the demand for adoption and diffusion of novel technologies. Recent proposals of the European Commission on the European industrial and innovation policy led to the establishment of the dedicated platforms (e.g. the European Platform of National Initiatives on Digitisation and digital industrial platforms). In parallel, the EU makes different funding sources available, such as from the European Fund for Strategic Investments and the European Structural and Investments Funds. The modernisation of industry and integration of advanced technologies also constituted important building blocks of the EU Regional and Cohesion Policy for the period 2014–2020. In addition, regions are encouraged to collaborate through the Smart Specialisation Platform for Industrial Modernisation (S3P-Industry) in areas relating to digital technologies and Industry 4.0.⁵⁶ The 2020 New Industrial Strategy of the European Commission initiated and reinforced a range of new programmes and initiatives to boost the development and adoption of advanced technologies for green and digital transition of industries. This involves provision of considerable resources for R&D, infrastructure and skills, initiatives aimed at fostering the deployment of Advanced Technologies and helping overcome existing challenges and risks, creating of regulatory environment and stimulating network activities for a better support of firms, especially SMEs.⁵⁷

Standards are essential for the adoption of new technologies enabling comparability and inter-operability across firms, regions and countries and are a key requirement to facilitate the networking. During the last decade, many **EU-led initiatives have been implemented to foster the European Standardisation System (ESS)**.⁵⁸

The further obvious strength is that the **ICT manufacturing sector in many EU countries is effectively at the forefront of the Industry 4.0 implementation**, which provides advanced opportunities for companies involved in related activities and strengthens their competitive advantage.

3.2 Opportunities

There are a lot of advantages and opportunities for the European ICT manufacturing related to the broad deployment of Advanced Manufacturing Technologies. They open **new opportunities for productivity and efficiency gains** through automation and optimisation of operational and business processes, enable the flexibilisation and mass customisation allowing cost efficient flexible and customised production of complex ICT components and assembly, higher quality of products and acceleration of manufacturing processes. Real or near real time control and interconnectivity allows much faster reaction to problems, changes in demand and other factors. Furthermore, **the adoption of Industry 4.0 technologies enables new business models** that provide new growth opportunities to companies. The technologies may also help **improve the environmental impact of companies** through optimised use of resources (e.g. more energy efficient operation of machinery, waste reduction) and **increased innovative capability** through new technological possibilities in manufacturing. Further, advanced manufacturing technologies can also help make logistics and customer services faster, more efficient and customer-centric.⁵⁹

Advanced Manufacturing Technologies might also **foster innovation** by allowing manufacturers to create new kinds of products that cannot be easily realised with conventional technologies and

⁵³ Eurofound (2019). The future of manufacturing in Europe,

⁵⁴ One example is the ongoing Semi40 project <http://www.semi40.eu/> focusing on smart production and cyber-physical production systems for electronics manufacturing involving leading industrial partners, SMEs as well as the research institutes and universities from five EU countries. It is so far one of the largest Industry 4.0 projects.

⁵⁵ Dosso (2020). Technological readiness in Europe. EU policy perspectives on Industry 4.0.

⁵⁶ Dosso (2020). Technological readiness in Europe. EU policy perspectives on Industry 4.0.

⁵⁷ For a detailed overview, see: European Commission (2021). Annual Single Market Report 2021. Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe' recovery.

⁵⁸ Dosso (2020). Technological readiness in Europe. EU policy perspectives on Industry 4.0.

⁵⁹ <https://www.i-scoop.eu/industry-4-0/>



processes⁶⁰ on the one hand and to accelerate product development and product optimisation on the other.

A lot of opportunities arise from the uptake and broad use of digitalised Advanced Manufacturing Technologies for countries of Central and Eastern (CEECs) Europe to raise their level of productivity, which still significantly lags behind the productivity level of advanced EU-countries. These technologies are expected to make considerable contribution to reducing the productivity gap between 'old' and 'new' EU countries⁶¹ **and support the catching-up process in manufacturing sectors.**

In addition to potential efficiency gains and optimisation of production processes, advanced technologies might have a large impact on the organisation of employment in companies. Apart from replacing repetitive or highly process-related tasks, they contribute to the **creation of new types of activities and fields of activity. New forms of cooperation between people and in interaction with machines** are also emerging. AI and advanced automation technologies offer great opportunities in many areas of ICT manufacturing where humans currently reach their limits due to high workload or a high degree of complexity. It is assumed that the support of human decision-making processes through algorithms will in future lead to significant changes in human work. In a medium and long term it can be expected that modern worker assistance systems will enable even more strongly that time-consuming and strenuous manual activities are carried out or supported by machines and human workers will receive more time for knowledge-intensive, creative or innovative activities.⁶²

Huge opportunities are linked to the **better use of the potential of big data along the ICT manufacturing supply chain and their analysis.**

3.3 Risks

Despite all the benefits, there are a lot of concerns and risks around innovative manufacturing technologies, which need to be adequately addressed. It is an undisputable fact that the automation and use of Advanced Manufacturing Technologies require new and more advanced skills. This will favour highly skilled jobs and lead to a reallocation of distribution between tasks, sectors and regions resulting in a **growing risk of income inequality and polarisation** disadvantaging particularly those who are not adequately trained or are not able to be re- and upskilled.

In production plants, programmed robotic arms and humans work side by side, so the technologies must be trustworthy for the safety of workers. However, the technology still has some **immanent safety risks for human workers** as it is yet not possible to technologically solve all potential insecurity factors that might occur. Additionally, **ethical and societal issues have been raised around the ability of AI systems** to learn and make decisions and the potential for inadvertent bias. Thus, there is a growing need to understand how algorithms work, so that if something goes wrong, a solution can be found, in order to avoid the problem occurring again.⁶³

Although there are mixed conclusions concerning the impact of automation on employment,⁶⁴ recent studies suggest that the **Central and Eastern European Countries are likely to be particularly impacted by the advanced digitalisation and automation** due to a large share of manufacturing in GDP on the one hand and a significant extent of basic and manual work that can be more easily automated, on the other. PricewaterhouseCoopers (2019)⁶⁵ points out that the transition will hit the employment in these countries during the so called third automation wave characterised by the increasing autonomy of the production systems that is going to occur in middle and long term (2030+). This might lead to an opposition to the use of these technologies.

The further risks for the ICT manufacturing sectors in the CEECs are associated with the **high dependency of the ICT manufacturing industry on foreign investment and high level of integration into the global value chain.** As such they are more exposed to external effects and developments as well as potential disruptions of the global value chain.

⁶⁰ <https://www.bcg.com/publications/2015/lean-and-manufacturing-production-why-advanced-manufacturing-boost-productivity>

⁶¹ Septimiu (2020). Transition to Industry 4.0 in the Visegrád Countries. Economic Brief 052.

⁶² Rosenberger et al. (2019). Capturing Industry 4.0 Use Cases for Interdisciplinary Implementation. In: A SemI40 Project Prospective. Industry4.0 from Evolution to Revolution. SemI40 Consortium. [HTTP://WWW.SEMI40.EU](http://www.semi40.eu)

⁶³ <https://etech.iec.ch/issue/2019-06/the-artificial-intelligence-technologies-behind-smart-manufacturing>

⁶⁴ See for example: Aghion et al. (2020). What Are the Labor and Product Market Effects of Automation? New Evidence from France. Research Briefs in Economic Policy No. 225.

⁶⁵ PricewaterhouseCoopers (2019). How will AI impact the Hungarian labour market?



Finally, the unprecedented transformative effects of advanced technologies require more agile and anticipatory governance⁶⁶ representing a particular challenge for many companies and policy makers connected to the high risk of not being able to address it adequately.

3.4 Challenges

Major challenges are associated with **high cost of investments** necessary for the acquisition and implementation of new advanced technologies as well for qualification measures. The high cost of investment required are especially challenging for SMEs.

The adoption of Advanced Manufacturing Technologies drives the demand for highly skilled workers. The data centrality and increasing data and data analytics intensiveness of production processes and growing role of AI require new skills - data scientists, data analysts and AI specialists. There is an intense competition for data and AI professionals among companies from different sectors and regions. Additionally, in the ICT manufacturing sector one of the most sought-after high-skills occupational profiles are those that combine engineering and other domain skills, like data analytics and AI. **Shortage in highly skilled professionals** constitutes a major challenge to the ICT manufacturing companies in the context of Advanced Manufacturing Technologies adoption and deployment. Alongside extensive knowledge of technical processes, skills that are highly relevant include independent decision-making and creativity. Decentralised production processes may require rapid intervention and problem solution oriented thinking in cases of dysfunction or other emergency cases. All European countries experience difficulties obtaining enough professionals with the necessary skill set. However, the Central and Eastern European Countries (CEECs) are particularly affected, as they additionally suffer from the outflow of scarce highly skilled workers and professionals to the high wage countries. Germany, Scandinavian countries, France, Ireland and Italy are among those who are continuously adapting their curricula and apprenticeship programmes to address new skill demands linked to changes in the technological development in general and the uptake of the advanced technologies in particular. However, **current education and training systems in many 'new' EU countries do not appear to be fully prepared to the coming technological changes** associated with a broad adoption of new technologies suffering from **disparities in educational outcomes and low supply of professionals in relevant STEM** (science, technology, engineering and mathematics) **disciplines and ICT specialists** in particular aggravated by a significant gender gap.

The adoption of Advanced Manufacturing Technologies in some European countries is still limited due to **missing or insufficient understanding of these technologies**. The ability to exploit the full potential from such technologies depends less from having the most advanced technologies, but from the capability to efficiently operate them. Consequently, companies often need partners that help them understand the potential these technologies are presenting and assist them by transforming their production lines and mastering the increasing complexities of technologies to be able to exploit the full potential of technologies. Also having access to testing capacities, such as testbeds for Advanced Manufacturing Technologies and experimental workplaces for testing innovative solutions and processes is highly significant for the ICT manufacturing companies, especially SMEs. These opportunities are still rather restricted in some European regions, particularly in the Eastern EU countries. Furthermore, firms in some CEECs - especially Romania and Bulgaria - often cannot rely on advanced interdisciplinary knowledge and expertise in related fields from domestic universities and research centres, as these are largely missing.

Moreover, the adoption of advanced manufacturing and automation technologies in particular can be furtherly restricted by **economic considerations and the abundance of cheap labour**, as the low-cost production remains economically advantageous to the companies located in the low wage countries. This is linked to the further challenge and risk of some low cost regions in the EU-27 of not being able to keep pace with increased product and quality demands.

The ability to collect, manage, analyse and use different types of data is essential for the exploitation of the potential of digital technologies in production. However, evidence suggests that **in some European regions there is still no widespread awareness of the importance of data for creating the value** and improving the efficiency of production processes. The main barriers are mainly managerial and cultural.⁶⁷

⁶⁶ Dosso (2020). Technological readiness in Europe. EU policy perspectives on Industry 4.0.

⁶⁷ Corò and Volpe (2020). Driving factors in the adoption of Industry 4.0 technologies. An investigation of SMEs.



Despite advantages the mobile or collaborative robots provide, they are presenting some deficits with regard to the **safety issues due to sharing the production floor with human workers or moving in their proximity**, which requires high level of protection from any threats that might occur. Along with other technological issues, the security aspect belongs to key areas that require further research and development.⁶⁸

The digitalisation of industrial systems increases the security vulnerabilities due to **possible security breaches in the cyber domain**. The increasing demand of extensive machine data acquisition for data analysis, as well as for the permanent connectivity of devices and remote maintenance, requires the improvement of various security measures of industrial equipment and networks, both at the hardware as well as at the software level. The production technology needs to be protected as effectively as possible from the manipulations in software and hardware.⁶⁹

There is also a **number of technological challenges** that restrict the adoption of Advanced Manufacturing Technologies. Not all Manufacturing Execution Systems (MES), which is a critical foundation for the Industry 4.0 application, are capable of supporting Industry 4.0, as Industry 4.0 requires advanced characteristics that many traditional MES do not have.⁷⁰ So, the manufacturing companies need to re-equip or upgrade their existing technologies necessitating high investments. In general, the Industry 4.0 technologies have not reached a high level of maturity. There is still a lot of technological challenges and gaps that need to be addressed.⁷¹

Despite some ongoing activities, the **standardisation and the lack of interoperability** represent further challenges linked to the adoption of Industry 4.0 technologies, as they require a high degree of interoperability of technologies, data and programs so that different machines, devices, tools and software programs can connect and communicate with each other. Lack of interoperability makes the integration of third-party equipment or software challenging.⁷²

One of the obstacles to the use of AI technologies in industrial processes is the **shortage of data in industrial applications**. The reason for this is that the events relevant for industrial applications, such as faults in equipment, disruptions in the production process, quality problems or hazardous situations, are usually rare. Empirical evidence shows that classical deep-learning methods can utilise their full potential only when sufficient data is available. However, the challenges cannot be addressed by generating and storing more data only, but must be also reflected on the algorithmic level.⁷³

Advanced Industry 4.0 technologies require advanced communication infrastructure - 5G. In international comparison, **many EU countries lag behind in terms of rolling out the 5G technology**. Apart from this, there are growing security concerns with regard to the established technology suppliers.

⁶⁸ Haas, Sarah, Rainer Matischek, Benjamin Bara and Andreas Wallner (2019). Advanced Hardware-Based Security for the Industrial IoT. In: A SemI40 Project Prospective. Industry4.0 from Evolution to Revolution. SemI40 Consortium. [HTTP://WWW.SEMI40.EU](http://www.semi40.eu)

⁶⁹ Haas et al. (2019). Advanced Hardware-Based Security for the Industrial IoT. In: A SemI40 Project Prospective. Industry4.0 from Evolution to Revolution. SemI40 Consortium. [HTTP://WWW.SEMI40.EU](http://www.semi40.eu)

⁷⁰ Critical Manufacturing (2019). MES Challenges. In: A SemI40 Project Prospective. Industry4.0 from Evolution to Revolution. SemI40 Consortium. [HTTP://WWW.SEMI40.EU](http://www.semi40.eu)

⁷¹ Alcácer and Cruz-Machadoa (2019). Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. Engineering Science and Technology. Issue 22, pp. 899-919.

⁷² Roland Berger Focus (2018). – Industry 4.0 and its Impact on Electronics Assembly.

⁷³ BMWi (2019). Technologieszenario „Künstliche Intelligenz in der Industrie 4.0“. Working Paper.



Section 4

4. Conclusion & Outlook

4.1 Conclusion

The supply of cutting edge electronic components and systems plays an essential role for the innovativeness and competitiveness of major economic sectors and technologies and is crucial for the economic growth of the EU countries. As a core element of modern technologies and processes, innovative electronics are expected to be a key enabler for better environmental performance of those. The uptake and broad application of new manufacturing techniques and technologies has the potential to transform the ICT manufacturing companies of all kinds to help them become more innovative, responsive and cost-efficient in a highly dynamic and competitive global market. Innovative Advanced Manufacturing Technologies can also help improve the environmental impact of companies through optimised resource consumption and waste reduction. Strengthening the European manufacturing and the support of green and digital transformation of industries - including electronics - through the adoption of advanced technologies is therefore one of the central goals of the EU's industrial policy.

There is a broad range of Advanced Manufacturing Technologies that might deliver significant advantages in terms of productivity, efficiency gains and quality improvements to companies across the ICT manufacturing sector. These are primarily technologies that are referred to as Industry 4.0 or smart manufacturing and are characterised by Cyber-Physical Systems and smart machines that are interconnected and use data to communicate. Within these technologies, Advanced Robotics and Artificial Intelligence (AI) are becoming particularly important for the ICT manufacturing sector and expected to have an even greater impact in the future.

The EU-27 is a heterogeneous region representing a lot of strengths and opportunities associated with the adoption and impact of Advanced Technologies in the ICT manufacturing companies. However, despite all the benefits, there are a lot of challenges and risks around innovative manufacturing technologies, which need to be adequately addressed. To fully exploit their potential requires more than the availability of the technology. Companies need a comprehensive expertise that would allow them to implement and operate them efficiently and create value out of them.

4.2 Outlook

As was demonstrated in the report, Advanced Manufacturing Technologies hold huge potential for the ICT manufacturing. They are fundamentally changing the way companies are operating, products are designed, fabricated, used and serviced. The potential lies not only in the transformation of production facilities and processes, but also in chances emanating from new business models enabled by these technologies.

The EU has taken many initiatives to foster the modernisation of industrial sectors and to facilitate the adoption of new technologies. Nevertheless, more action and greater investments will be required to enhance the scope and intensity of the advanced technologies adoption and to better account for the industry- and region-specific contexts to enable a sustainable transition towards Industry 4.0.⁷⁴ This involves the improvement of companies' readiness to leverage technologies and better cope with existing challenges. Skills are an essential precondition for the successful implementation of advanced technologies. Technology advances offer numerous opportunities, but also considerable challenges for the future of workforce development. Investments in advanced manufacturing skills and strategies are necessary to improve the link between training and future industry needs and to strengthen skills to meet the requirements of future manufacturing. More efforts should be taken to encourage next generation into topics and disciplines associated with Robotics, Artificial Intelligence, automation, and advanced manufacturing techniques.

Furthermore, for the successful transformation of the ICT manufacturing in Europe the ensuring of data, cyber security and interoperability have an increasingly important role and need to be adequately addressed in the future.

Being the backbone of the EU's economy, SMEs are however confronted with a great deal of challenges and risks linked to the implementation of new technologies and their integration in the workflow. The

⁷⁴ Dosso (2020). Technological readiness in Europe. EU policy perspectives on Industry 4.0.



readiness of SME in the EU countries to adopt Industry 4.0 technologies and their capability to meet the challenges exist only in part. Many of them are still not prepared to implement the Industry 4.0 concepts. They need SME-customised implementation strategies and approaches involving SME-adapted advanced technology solutions.⁷⁵

At the same time, Industry 4.0 smart production systems require innovative solutions to improve the environmental sustainability of the manufacturing industry and the environmental performance of companies while enhancing their economic competitiveness. This takes a systematic approach from concept development of sustainable solutions and technology design, integration into manufacturing process, manufacturing of ICT products up to their delivery and re-cycling management concepts at the end of the product life cycle.

4.3 Covid-19 – impact on the ICT manufacturing and advanced technologies

The Covid-19 has caused unprecedented disruptive effects on the global economy and the manufacturing sectors. The crisis has led to the economic downturn in the ICT and the related sectors due to affected supply chain disruptions across the ICT manufacturing sector and the sharp drop in demand for ICT products by end-use markets. A large majority of electronics manufacturers and suppliers reported delays from suppliers due to the spread of corona virus.⁷⁶ Many SMEs and large manufacturing plants have postponed new technology upgrade in their factories owing to the crisis and in order to recover from the losses caused by the lockdown and economic slowdown.⁷⁷

The coronavirus pandemic has indirectly highlighted to the manufacturing sectors that Industry 4.0 technologies are necessary for the survival in a global marketplace and for dealing with extraordinary situations like the last crisis. Conversely, companies with a higher level of automation turned out to be more resilient to the crisis as technologies helped them operate with fewer workers on the shop floor and ensure ongoing operations without human interventions, or operate remotely. So the pandemic provides also a great opportunity for companies to reassess their technological gaps and put in place a technological transformation plan to be better prepared for future disruptions.⁷⁸

⁷⁵ Matt and Rauch (2020). SME 4.0: The Role of Small- and Medium-Sized Enterprises in the Digital Transformation.

⁷⁶ <https://www.ukelectronics.co.uk/coronavirus-impact-electronics-industry/>

⁷⁷ <https://www.marketsandmarkets.com/Market-Reports/artificial-intelligence-manufacturing-market-72679105.html>

⁷⁸ World Economic Forum (2020). The Impact of COVID-19 on the Future of Advanced Manufacturing and Production. Insights from the World Economic Forum's Global Network of Advanced Manufacturing Hubs.



Section 5

5. Annexes

5.1 List of interviewees

Interviewee	Position	Country
Balázs Barta	Managing Director, Pannon Business Network (PBN)	Hungary
Michael Hummel	Executive Vice President, ST Microelectronics SRL	Italy
Gerd Ohl	Managing Director, Limtronik GmbH	Germany
Eugen Raisch	Team Leader, KEBA Industrial Automation Germany GmbH	Germany
Roland Sommer	Managing Director, Plattform Industrie 4.0	Austria



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About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. It provides policymakers, industry representatives and academia with:

- Statistical data on the production and use of advanced technologies including enabling conditions such as skills, investment or entrepreneurship;
- Analytical reports such as on technological trends, sectoral insights and products;
- Analyses of policy measures and policy tools related to the uptake of advanced technologies;
- Analysis of technological trends in competing economies such as in the US, China or Japan;
- Access to technology centres and innovation hubs across EU countries.

More information about the 16 technologies can be found at: <https://ati.ec.europa.eu>

The project is undertaken on behalf of the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the European Innovation Council and Small and Medium-sized Enterprises Executive Agency (EISMEA) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

