KETS OBSERVATORY PHASE II

Cyber-Physical Production Systems
Report on promising KETs-based product nr. 7

Contract nr EASME/COSME/2015/026
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CYBER-PHYSICAL PRODUCTION SYSTEMS
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Executive summary

The current report aims to provide stakeholders with an analytical base helping to strengthen cross-regional cooperation mechanisms to boost the deployment of Key Enabling Technologies in Europe. The report specifically aims to highlight the value chain structure, key players and constraints for the domain of cyber-physical production systems (CPPS), and more specifically cyber-physical systems for production monitoring, with a particular attention to the less developed regions in Eastern and Southern Europe. It also addresses the key strengths and potential of the EU regions, as well as promising business opportunities and key risks and challenges. Finally, the report elaborates on specific policy recommendations with both immediate focus and longer-term orientation.

CPPS have the potential to significantly improve the competitiveness of the European manufacturing sector. Based on the integration of software and manufacturing equipment, cyber-physical systems for production monitoring can enable companies to achieve high-precision and zero-defect manufacturing and to benefit from substantial efficiency and productivity gains. At a wider scale, the large uptake of cyber-physical production systems by manufacturing companies would lead to a strong impact on growth and job creation. However, although large companies have already started digitalising their production processes, manufacturing SMEs are still relatively lagging behind and represent key potential end-users of CPPS.

Despite the significant benefits that CPPS can bring, the European value chain is still emerging. CPPS technologies are already mature and available on the market, but the uptake of such solutions by manufacturing SMEs still remains limited. Different key constraints have been identified in this regard. Firstly, as CPPS integration requires changes in the way manufacturing companies organise their work internally, there is a crucial need to further elaborate guidelines and tools, such as standards shared by most of the industrial players. Secondly, key players across the value chain would need to further collaborate in order to ensure the horizontal integration of production systems required by CPPS and to provide customised systems adapted to all manufacturing companies, and in particular to SMEs. Finally, one the key constraints lies in the top management teams of manufacturing companies that are often reluctant to engage into a long-lasting and complex transformation of production processes.

Although, Europe has a leading position in automation and digitalisation of the manufacturing sector at the global level, the uptake of CPPS is not even across EU regions. Although Western European regions are already well-engaged in the digitalisation of their industry, Southern and Eastern European regions still relatively lag behind this transformation. However, less mature regions display a strong potential thanks to key competitive advantages such as notably a cheap and qualified labour force, a strong manufacturing industry and a dynamic ICT sector.

Several measures could be implemented in order to support the large-scale uptake of CPPS notably in Southern and Eastern European regions. In particular, Regions should play a pivotal role notably by supporting the establishment of local Digital Innovation Hubs and the further creation of demonstration and testing facilities which would foster the bottom-up uptake of CPPS. Other measures with immediate focus include the further development of demonstration and testing facilities, the implementation of awareness-raising activities towards SMEs and the strengthening of SME access to EU public-private partnerships. Identified long-term measures include
inter alia financial support to manufacturing SMEs, ensuring the upskilling of the workforce as well as strengthening the support to R&D in the field of CPPS standards.
1. Introduction

The current report has been developed in the context of the second phase of the KETs Observatory initiative. The KETs Observatory represents an online monitoring tool that aims to provide quantitative and qualitative information on the deployment of Key Enabling Technologies1 (hereafter “KETs”) both within the EU-28 and in comparison, with other world regions. Specifically, the KETs Observatory represents a practical tool for the elaboration and implementation of Smart Specialisation Strategies in the EU regions.

1.1 Background

A key challenge for the EU competitiveness policy is to enable European industry to move to the higher end of the value chain and position itself on a competitive path that rests on more innovative and complex products. For many KETs, this implies a focus on more integrated technologies with the potential of connecting several KETs.

To this end, one of the key tasks of the KETs Observatory implies identifying and describing “promising KETs-based products” and their value chains, and recommending specific policy actions to help the EU industry stay ahead of global competition. Promising KETs-based products here can be defined as emerging or fast-growing KETs-based products with a strong potential to enhance manufacturing capacities in Europe. Such products correspond to KETs areas where Europe has the potential to maintain or establish global industrial leadership - leading to significant impacts in terms of growth and jobs.

1.2 Objectives of this report

In the context of the second phase of the KETs Observatory, in total, 12 promising KETs-based products have been selected for an in-depth analysis of their value chain, the associated EU competitive position and the corresponding policy implications. The selection of the topics stems from a bottom-up approach based on active engagement of regional, national and EU stakeholders through the S3 Platform for Industrial Modernisation2.

This report presents the results of the abovementioned in-depth analysis for one of the selected top-priority topics, namely cyber-physical production systems (CPPS), and more specifically cyber-physical systems for production monitoring, with a particular attention to the less developed regions in Eastern and Southern Europe. The analysis is based on desk-research and in-depth interviews with key stakeholders. The report aims to provide relevant stakeholders with an analytical base helping to establish or strengthen cross-regional cooperation mechanisms to boost the deployment of KETs in Europe.

1 Namely Nanotechnology, Micro-/Nanoelectronics, Photonics, Industrial Biotechnology, Advanced Materials and Advanced Manufacturing Technologies
2 http://s3platform.jrc.ec.europa.eu/industrial-modernisation
1.3 Target audience

The report aims to provide key market insights for cyber-physical production systems and identify key directions for action in order to maintain Europe’s competitive position on the global market. The report specifically targets the EU, national and regional policy makers and business stakeholders who are currently involved in or consider engaging in cross-regional cooperation mechanisms. The report may also be relevant for other key stakeholder groups including academia, as well as different support structures such as cluster organisations, industry associations and funding providers.
2. Key product facts

In the current section, we provide a brief introduction to cyber-physical production systems, with a particular emphasis on cyber-physical systems for production monitoring. We also elaborate on the market potential and the importance of these systems for EU competitiveness.

2.1 Introduction to the product

Cyber-physical production systems (CPPS) refer to the increasing integration of and interaction between the virtual and physical worlds in manufacturing systems. They are characterised by embedded computers monitoring and controlling physical production processes, usually with feedback loops where physical processes also affect computations and vice versa. In other words, CPPS use computations and communication deeply embedded in the production process (e.g. within manufacturing equipment), which add new capabilities to the production system by interacting with physical processes\(^3\). Such systems imply the increasing use of data and digital control of production, and provide their services in a semi-autonomous and networked manner. In sum, CPPS entail the digitalisation of production processes.

When applied within a manufacturing plant, CPPS are systems based on the integration of several key distinct components:

- Embedded systems such as sensors and actuators, which, integrated within production machines and tools, can capture physical data and affect production processes\(^4\).
- IT systems (i.e. software) which serve for the integration of the monitoring systems and the remote-control of all components.
- Communication infrastructures based on high-bandwidth networks enabling data exchanges between all CPPS components.

One of the key characteristics of cyber-physical production systems is their interoperability: all CPPS components can easily interact with the other components of the system (i.e. sensors, machinery, IT systems etc.). CPPS interoperability is based on the vertical integration (i.e. from sensors, machines to the management level of the company) as well as on the horizontal integration (i.e. between manufacturers, suppliers, and providers of support services) of production processes.

More specifically, this analysis mainly covers cyber-physical systems for production monitoring, which are here understood as a sub-set of CPPS. These specific systems carry out functions such as the continuous monitoring of the condition and performance of the manufacturing system at process, component and machine levels and are characterized by autonomous diagnosis capabilities and context-awareness. This involves advanced metrology, calibration and sensing, signal processing for a wide


\(^4\) Sensors record qualitative and quantitative measurement of the environment physical properties (e.g. temperature, humidity, sound etc.) and convert these measurement into a format that can be processed digitally. Actuators convert digital values into mechanical movements, thereby producing an effect on the environment. Extracted from: Acatech (2015), “Living in a networked world: Integrated research agenda CPS”, Acatech study.
such systems are mostly developed in the following fields: high-speed production monitoring technologies, optomechatronic technologies for process monitoring and quality assurance, as well as overall equipment efficiency measurement and management systems. Benefits associated with cyber-physical systems for production monitoring are considerable. By improving detection, measurement and monitoring of the production process and thus achieving high precision and zero-defect manufacturing, they can significantly increase the performance and reliability of manufacturing systems. They can substantially improve the quality of production and of final manufactured products. CPPS can also bring strong efficiency and productivity gains to manufacturing companies, therefore leading to a reduction of production costs. Indeed, overall, companies foresee a reduction of their operational costs by 3.6% thanks to the digital transformation of mechanical engineering. In sum, cyber-physical systems for production monitoring can play a pivotal role in increasing the competitiveness of the EU manufacturing industry.

2.2 Relevance to grand societal challenges

The digitalisation of the EU manufacturing sector will contribute to efforts towards the development of a smart, green and inclusive economy, as pursued by Europe 2020 strategy. The large-scale uptake of CPPS by European manufacturing companies would lead to fundamental impact on ‘growth and jobs’ which are a prerequisite for social sustainability, addressing the needs of citizens and the environment. Although the net effect of the integration of CPPS on future employment is difficult to quantify, it can be assumed that by enhancing the market responsiveness and competitiveness of European manufacturing companies and their suppliers, the large-scale uptake of CPPS would retain production industries and the dependent supply and services industries in Europe. It will in turn favor job creation for skilled and highly skilled workers. Indeed, the digitalisation of production processes leads to the emergence of new and more complex tasks requiring the greater intervention of workers with technical and engineering skills. Overall, following the large-scale uptake of CPPS, while the numbers of jobs for machine and plant manufacturers, assemblers, metal workers, and warehouse workers would tend to decrease, the number of jobs for

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6 Based on interview data.
machine operators, technicians, engineers and managers would increase\textsuperscript{12}. In particular, CPPS would contribute to the following two societal challenges\textsuperscript{13}:

- Energy and resource-efficient manufacturing processes: the integration of CPPS will lead to more performant and optimised manufacturing processes, thereby reducing unnecessary resource consumption, and will enable companies to better control and monitor their production.
- Socially sustainable, safe and attractive workplaces: the large-upscale of CPPS will lead to the automation of easy and repetitive tasks. It will reduce the number of jobs requiring to perform routine tasks and physically demanding labour. Workers’ tasks will therefore focus more on creative, human-added value activities (critical thinking, collaboration etc.)\textsuperscript{14}.

\subsection*{2.3 Market potential}

The market potential for cyber-physical systems for production performance monitoring is substantial both at the European and global levels.

Firstly, all European manufacturing SMEs are key potential end-users of CPPS. Customised CPPS can support all types of production processes and plants, they can therefore be deployed in all manufacturing companies across Europe. Also, industry is one of the key pillars of the European economy: the manufacturing sector in the European Union accounts for 2 million enterprises, 33 million jobs and 60\% of productivity growth\textsuperscript{15}. However, European companies, and mostly SMEs, are relatively lagging behind the digital transformation of their production process: while 71\% of European companies consider that they expect to achieve advanced levels of digitalisation by 2020, today, only 28\% of them have managed to achieve such transformation\textsuperscript{16}. Manufacturing SMEs are key targets as, in 2015, they accounted for 44\% of the value added and 59 \% of total employment in the EU manufacturing sector\textsuperscript{17}.

More specifically, it should be noted that the market potential for CPPS in Southern and Eastern Europe is particularly strong. Indeed, manufacturing companies in these countries are in general lagging behind Western Europe regarding the transformation of their production processes. For instance, although Western European companies have already started digitalising their production systems, the industry, mostly SMEs, in Southern and Eastern Europe has not yet fully achieved the automation of its manufacturing processes\textsuperscript{18}. However, such less developed regions, and particularly Eastern Europe, benefit from a highly dynamic and growing manufacturing sector that

\begin{thebibliography}{9}
\bibitem{Ref13} Ibid
\bibitem{Ref14} For instance, the programme "Made Different"-Belgium’s Industry 4.0 policy- puts a great emphasis on the key role played by workers in the digital transformation of a manufacturing company. It notably defines a “human-centered production” as a key pillar of factories of the future. Available at: http://madedifferent.be/en/
\bibitem{Ref15} EU Commission webpage on ‘Digitising European Industry’. Available at: https://ec.europa.eu/digital-single-market/en/digitising-european-industry
\bibitem{Ref18} Based on interview data.
\end{thebibliography}
today plays a central role in European supply chains. For instance, in 2015, the manufacturing sector was the fastest-growing sector in Central and Eastern Europe, achieving a 7.4% growth\textsuperscript{19}. In particular, the automotive sector is notably a key pillar of such activity as almost 23% of the manufactured cars in Europe were produced in CEE regions\textsuperscript{20}.

Secondly, the large-scale integration of CPPS in manufacturing systems will significantly reshape and redefine companies’ organisations and production processes and lead to the emergence of new support services such as maintenance and IT-related services. In other words, smart manufacturing will lead to the emergence of profoundly new business models. By taking a leading position in the field of CPPS, Europe will also have a forerunner position at the global level in all support services related to CPPS integration, thereby boosting its future exports\textsuperscript{21}.

2.4 Importance for the EU competitiveness

In the domain of CPPS, Europe is one of the leaders at the global level in all parts of the value chain, including research, production of machinery and development of software.

With an estimated 36% share of the world market, the European Union is the world’s largest producer and exporter of machinery, and estimations show that 3 million employees are active in the sector\textsuperscript{22}. The EU mechanical engineering sector is expected to grow at around 3.8% over the next ten years\textsuperscript{23}. In terms of software development, the EU is also one of the global industrial leaders. In 2014, the software industry in the EU directly contributed around 250 billion EUR to the EU’s GDP and employed more than 3 million people\textsuperscript{24}. European software companies are particularly innovative and invest strongly in software R&D- accounting for almost 12.7 billion EUR in 2013\textsuperscript{25}.

EU manufacturing industry is central to the EU economy with a value added reaching around 15% of GDP in 2015\textsuperscript{26}. However, in the last decades, it started losing grounds to the tough competition from emerging markets, notably through an ever-greater pressure to reduce production costs. Engaging in the digitalisation of the EU manufacturing sector notably through the adoption of CPPS is an opportunity that cannot be missed if Europe wants to gain a significant competitive advantage\textsuperscript{27}.

\textsuperscript{20} Ibid.
\textsuperscript{21} Based on interview data.
\textsuperscript{23} Ibid.
\textsuperscript{25} Ibid.
\textsuperscript{26} Strategic Policy Forum on Digital Entrepreneurship (2016) “Big data and B2B digital platforms: The next frontier of Europe’s industry and enterprises”, European Commission.
\textsuperscript{27} Ibid.
3. Value chain analysis

The current section addresses the value chain structure, key players, as well as the key identified constraints. The value chain is based on strong linkages between the software industry and the mechanical engineering sector. It can still be considered that the uptake of CPPS is still emerging throughout Europe. Indeed, although technology needed to build CPPS is today relatively mature, there is still a lack of common standards providing guidelines for the straightforward CPPS deployment into already operating production plants. Systems provided by large companies are already available on the market but are nonetheless too costly and not necessarily adapted to a large number of manufacturing companies, such as SMEs in particular. The results of the analysis presented below illustrate the importance of the European dimension for CPPS, and underline the need for developing regional innovation ecosystems as well as cross-regional partnerships.

3.1 Value chain structure

Figure 3-1 presents the value chain structure for cyber-physical production systems for production performance monitoring, based on the three following dimensions: (1) value-adding activities; (2) supply chain; and (3) supporting environment.

Five key value adding activities can be identified in the value chain. R&D and production foster the development and uptake of technologies that directly lead to the reduction of manufacturing costs, and include activities such as: testing and piloting of an innovative open-source software or the application of a new customised CPPS within a SME production plant. The emergence of new business models is also noteworthy, as relevant actors along the value chain tend to increase their collaboration through partnerships. Also, new support services, tailored to end-users' needs are emerging, such as, for instance, in the maintenance sector. The pro-active promotion and awareness raising by public authorities for the greater uptake of smart manufacturing technologies at European, national and regional levels equally play a crucial role.

Figure 3-1: Value chain model for cyber-physical systems for production monitoring
The second layer outlines the key steps of the supply chain following the input-output model. The main inputs of the supply chain come from two distinct industries, namely the IT and mechanical engineering industries. The input of the IT industries is mainly based on the development of software adapted to the management and control of manufacturing companies’ production process. The input of the mechanical engineering industries comprises two types of manufacturing equipment: machines (e.g., lasers, mold machines, machine tools etc.) and automation components (e.g., sensors, actuators, CNC controllers).

Product development leads to the integration of heterogeneous hardware and software components ensuring the deep interaction of information and physical systems (i.e. interaction of all components from embedded sensors, to the company’s control and data centers). This system integration results into cyber-physical systems for production performance monitoring such as high-speed production monitoring systems, optomechatronic systems or overall equipment efficiency measurement and management systems. In order to be effective when installed in the production plant, the development of cyber-physical systems needs be tailored to fit the end-user’s specific production requirements.

The application scope of CPPS for production monitoring is extensive, covering all manufacturing sectors, as they can be integrated in all original equipment manufacturers’ plants (OEM), regardless of their size. Although market potential is considerable, the uptake of CPPS still remains marginal. Indeed, large companies are already well-engaged in the uptake of cyber-physical systems, yet manufacturing SMEs are significantly lagging behind.

Finally, the third dimension highlights six pillars necessary to the creation and existence of the entire value chain. They include R&D demonstration facilities, digital and communication infrastructures, innovation ecosystems facilitating the collaboration of all relevant actors along the value chain, common standards and architectures enabling the widespread uptake of CPPS in manufacturing, access to finance as well as a skilled workforce.

3.2 Key players

The key actors of the value chain of cyber-physical systems for production performance monitoring can be clustered into the following main groups:

- **Research and development centres**: These organisations play a crucial role in R&D related to the development of standards, architectures, open platforms and smart manufacturing equipment. They typically offer testing and prototyping services. They can also provide additional consulting services, in particular

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28 A Computer Numerical Control (CNC) controller is a microcomputer aims to execute the commands into actions by the specific machine tool it is associated to.
30 "Innovation ecosystems” are complex structures formed by the interaction of the participating community within an environment. A healthy ecosystem is one, which participants can thrive and grow, it self-regulates and adapts as the market needs evolve. The community consists of industry participants, start-ups, competence centres, research institutions, technical and business services.” ICT Innovation for Manufacturing SMEs (I4MS), available at: http://i4ms.eu/i4ms/i4ms_concepts.php
related to business development. Such organisations are in general composed of universities as well as research and technology organisations (RTOs).

- **Software developers**: These companies are of different types as they include start-ups, SMEs and large manufacturers specialised in software, platforms and interface (e.g. human-machine interface) development. The latter often develop proprietary solutions, comprising integrated software and hardware (see below ‘system integrators’). However, a vast community of SMEs and start-ups is also fast growing in this sector, that are notably at the origin of the development of open-source software for manufacturing. Such companies are characterised by their better access to finance than manufacturing companies as they are less capital-intensive.

- **Manufacturing equipment providers**: These companies are in general composed of mid-caps and SMEs positioned at the beginning of the industrial supply chain. Such companies are specialised in the production of manufacturing equipment such as machine tools. European producers, and in particular German companies, are among global leaders in the field and have a specific focus on high-end machines with relatively long production cycles.

- **‘System integrators’**: System integration is today mainly carried out by large manufacturers that provide proprietary solutions and systems that encompass both hardware and software components. However, such systems are not necessarily adapted to all production needs, and in particular to manufacturing SMEs, but mainly designed to support larger manufacturers (e.g. in the automotive industry)\(^\text{31}\). An alternative solution, more adapted to manufacturing SMEs, does not lie in one specific actor but rather in partnerships across key value-chain actors in the form of innovation ecosystems. Such partnerships are able to provide customised solutions to manufacturing SMEs.

- **End-users**: Cyber-physical systems for production monitoring have a considerable market potential as they can be integrated in any manufacturing plant. Therefore, end-users comprise both large manufacturing companies as well as SMEs. However, as stated in Section 2.3, as manufacturing SMEs are in this case study considered as key target as they are relatively lagging behind the digitalisation of their production process.

The table below presents some illustrative names of relevant companies. The list should by no means be considered exhaustive.

**TABLE 3-1: Mapping of key market players**

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<thead>
<tr>
<th>Research &amp; Development</th>
<th>Production</th>
<th>Partnerships</th>
<th>Policy Support</th>
<th>Services</th>
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<tr>
<td>RWTH Aachen University (Germany) Politecnico Milano (Italy) Mondragon University (Spain) Fraunhofer IPA (Germany) DFKI</td>
<td>IoT North (Poland)</td>
<td>Industry 4.0 (Germany) Industrie du Futur (France)</td>
<td>Fraunhofer IPA (Germany) INESC TEC (Portugal) Innovalia Association (Spain) IMECC OÜ (Estonia) Institute of Electronics and</td>
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<td>Politecnico Milano (Italy)</td>
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<td>Fraunhofer IPA (Germany)</td>
<td>CICERO Digital innovation Hub (Italy)</td>
<td>Průmysl 4.0 (Czech Republic)</td>
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\(^{31}\) Based on interview data.
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<th><strong>Value chain analysis</strong></th>
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<td><strong>Software developers</strong></td>
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3.3 Key constraints

Several key constraints have been identified in the value chain for cyber-physical systems for production performance monitoring.

**Lack of common standards for the integration of CPPS**

In practice, CPPS integration requires profound changes in the way companies structure and organise their work internally. In order to achieve the wide uptake of CPPS in the manufacturing sector, there is a crucial need to further develop guidelines and tools in the form of standards and open platforms altogether defined and shared by all industrial players.

Firstly, manufacturing companies’ production management systems are today mostly based on the ISA-95/IEC62264 defined by the International Electrotechnical Commission (IEC). According to this standard, manufacturing companies are organised into a five-level hierarchical model also known as ‘automation pyramid’. However, this globally accepted standard proves to be limited to steer the integration of CPPS as it does not sufficiently cover their heterogeneity in terms of hardware and software integration, as well as because it has significant limitations regarding the increased complexity of modern networked automation systems.

The definition of new standards, widely agreed on by industrial players and taking into account the deployment of CPPS, is therefore highly needed to support the progressive adaptation and transformation of companies’ production systems. Indeed, most manufacturing companies that aim to integrate CPPS in their production process already have operating manufacturing plants. In other words, integrating CPPS requires the stepwise adaptation of the existing production system. In order to

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successfully implement commonly shared and standardised migration paths (i.e. technical guidelines) towards the digitalisation of production process.\textsuperscript{34}

However, despite these limitations, stakeholders report that several EU-funded projects, notably supported by the ECSEL JU\textsuperscript{35} or the Factories of the Future public-private partnership have made significant progress towards the development of new standards\textsuperscript{36}. They also consider that the European Union benefits on these topics from a great pool of expertise, which is nonetheless too fragmented to effectively pave the way for standardised and common solutions across Europe\textsuperscript{37}.

**Value chain players need to collaborate within innovation ecosystems**

As stated in Section 2.1, CPS interoperability requires the horizontal integration of the production system (i.e. along production networks). Therefore, one of the key constraints of the value chain is to bring all the relevant industries together. Although Figure 3-1 depicts a linear supply chain, in practice, key players are nonetheless often involved in ecosystems characterised by a complex interplay of relationships. Such collaborative environments particularly prove crucial to support the uptake of CPPS by manufacturing SMEs, which, in general have limited funding and a lack of expertise in R&D. Such partnerships ensure the cost-effective development of systems that are customised to the specific needs of SMEs, and ensure a continuous support to end-users throughout the different phases of product development, from system design and implementation as well as to the provision of support services. Finally, stakeholders consider that manufacturing SMEs are in many cases defined by their local or regional-based activity: having close access to innovation regional ecosystems would therefore significantly attract them. In this regard, EU regions play a great role in developing and fostering these innovation regional ecosystems, notably through the set-up of Digital Innovation Hubs (See Section 4.3).

The EU project “Business Experiments in Cyber-Physical Production Systems” (BEinCPPS), implemented in the frame of the I4MS initiative (i.e. ICT innovation for Manufacturing SMEs), is notably a good example of the development of regional innovation ecosystems\textsuperscript{38}. In total, 5 regional Digital Innovation Hubs (DIH), made of competence centres, manufacturing enterprises and IT SMEs have been established across Europe\textsuperscript{39}. These DIHs mainly aim to experiment new open CPPS platforms for manufacturing SMEs and support the development of solid business models and partnerships across I4MS value-chains and EU regions.

**Full commitment from end-users´ top management is required**

According to stakeholders, the integration of CPPS within manufacturing plants is a rather complex operation which requires time to ensure the effective overhauling of


\textsuperscript{36} Such projects include inter alia BEinCPPS (I4MS- http://www.beincpps.eu/ ), MANTIS (ECSEL JU- http://www.mantis-project.eu), SCorPiUS (H2020- http://www.scorpius-project.eu ) etc.

\textsuperscript{37} Based on interview data.

\textsuperscript{38} I4MS website: http://i4ms.eu/

\textsuperscript{39} The BEinCPPS digital innovation hubs have been established in the following regions; Lombardy (Italy), Basque Country (Spain), Rhône-Alpes (France), Norte (Portugal) and Baden-Württemberg (Germany). Available at: http://www.beincpps.eu/
well-established production processes⁴⁰. Such transformation, made of gradual and progressive adjustments implies the voluntary mobilisation and full commitment of management teams over the long-run.

However, such efforts may appear burdensome to companies, in particular SMEs, which in general lack of the adequate expertise and operate under tight margins, thus not allowing them for major uncertainties at decision-making/strategic level⁴¹. This is notably the case in Southern and Eastern regions, where stakeholders report that manufacturing SMEs are in general not aware of the potential benefits brought by the digitalisation of production systems⁴². Therefore, one of the main barriers to a full exploitation of CPPS remains a rather conservative industry, relatively reluctant to change. Stakeholders report that particular efforts need to be made to raise awareness among SME management teams, and to provide them with dedicated support.

⁴⁰ Based on interview data.
⁴² Based on interview data
4. Analysis of the EU competitive positioning

The current section analyses the position of Southern and Eastern European regions with regard to cyber-physical systems for production monitoring. It elaborates on their potential, key risks and challenges as well as opportunities. Europe covers most of the value chain but its highest potential lies in the development of software platforms and in the definition of new models for CPPS integration. The greatest strengths of Europe are based on its technological leadership and on a favourable policy framework. Although Western European regions are considered as main leaders in the field, a great and yet untapped potential lies in Southern and Eastern European regions.

4.1 Strengths and potential of Southern and Eastern European regions

In this sub-section, we address the strengths of Southern and Eastern European regions, their key competitive advantages and Europe’s expected global position in 2030 as well as regions that could be in the lead.

Europe’s technological leadership and supporting policy environment

According to stakeholders, Europe is one of the leaders in automation and digitisation in manufacturing at the global level. Indeed, this is notably due to the fact that large European companies are fully committed in taking a leap forward towards Industry 4.0 as they consider that advanced manufacturing technologies are key to unlock future competitiveness. European CEOs of mid-caps and large companies notably rank the achievement of ‘smart factories’ as their top priority in this field. In this regard, German OEMs remain the main European frontrunners and drivers of the digital transformation of the European manufacturing sector.

Europe’s technological leadership is the result of a supporting policy environment at European, national and regional levels. Indeed, the establishment of pan-European Public-Private Partnerships (PPPs) such as the ECSEL Joint Undertaking and the Factory of the Future PPP, as well as European project such as I4MS, play a key role in defining European roadmaps and strategies, providing financial support to research and pilot lines, as well as in ensuring collaboration between academia, industry and public authorities across Europe. Moreover, national Industry 4.0 initiatives have been recently implemented in most EU Member states with a view to supporting the digitalisation of their industry. Such national initiatives have been first implemented in Western Europe, with programmes such as Industry 4.0 (Germany), Industrie du Futur (France) or Smart Industry (Netherlands), that have so far produced significant results towards the digital transformation of manufacturing companies, through, inter alia, the uptake of CPPS. However, Southern and Eastern Member

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44 Ibid.
45 Based on interview data.
46 http://www.ecsel-ju.eu/web/JU/local_index.php The Electronic Components and Systems for European Leadership Joint Undertaking (ECSEL JU) was created in 2014, following the merge of ARTEMIS and ENIAC JUs.
48 “ICT Innovation for Manufacturing SMEs (I4MS), available at: http://i4ms.eu
States have also recently put in place similar initiatives such as Průmysl 4.0 (Czech Republic), IPAR 4.0 National Technology Platform (Hungary) or Indústria 4.0 (Portugal) with similar ambitious objectives. Finally, EU regions in general also show a strong commitment to develop tailored regional policy tools: Almost 90% of regions either prioritised ICT or advanced manufacturing in their smart specialisation priorities. Some EU regions have also developed their own regional Industry 4.0 initiative (e.g. Basque industry 4.0). The involvement of EU regions, and notably from Southern and Eastern Europe, proves also pivotal in order to reach and support manufacturing SMEs, as stakeholders consider that their core business activity is often well-anchored in a local territory.

Europe’s global position in 2030

Stakeholders suggest that most of the value chain can be covered by European companies. The European Union is notably the world’s largest producer and exporter of machinery and remains one of the leaders in the production of automation components. However, Europe’s greatest potential lies in the development of software platforms and integration of cyber-physical production systems. By shaping the new reference architectures and developing the open platforms that would be widely used and considered as global industrial standards, Europe could indirectly ensure its leading position in machinery exports as well as become a global frontrunner in CPPS support service providers (i.e. IT consulting, maintenance etc.). The United States, Japan as well as China are Europe’s main competitors in the field due to their strong positions in software and hardware products and systems, and have developed dedicated policy support to advance fast towards the development of CPPS.

Key competitive advantages of Southern and Eastern European regions

At the European level, the following key competitive advantages for the large-scale uptake of CPPS were identified:

- Leading position in all segments of the value chain;
- Strong and stable environment for R&D;
- Large companies that are among worldwide innovation leaders in the field and that act as forerunners to the uptake of CPPS by other companies.
- Trust and good collaboration among all actors of the value chain; in particular through the establishment of innovation ecosystems;
- A large internal market ensuring a great market potential.

More specifically, Southern and Eastern European regions benefit from the following key competitive advantages:

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52 http://www.spri.eus/es/basque-industry/
54 Based on interview data
55 Ibid.
Analysis of the EU competitive positioning

- Supporting policy frameworks in particular at national level;
- A cheap and qualified labour force;
- A strong manufacturing industry which represents a key pillar of European supply chains;
- A dynamic ICT sector (notably with a growing number of start-ups and companies in the sector).

Regions that could be in the lead

At the moment, leading regions in cyber-physical systems for production monitoring are mainly concentrated in Western Europe. They include inter alia, several German, Dutch, French and Scandinavian regions, as well as Flanders (Belgium)57.

However, significant discrepancies can be observed between Southern/Eastern and Western EU regions. The former regions tend to show limitations in terms of building up innovation ecosystems, and in providing support to manufacturing companies towards their digital transformation of the industry. Stakeholders note that while manufacturing companies based in Western Europe have started or are about to engage the digitalisation of their production processes, the industry in Southern and Eastern Europe remains in the process of achieving the automation of their manufacturing processes. Therefore, the adoption of a tailored pan-European approach proves key in order to overcome this profound digital gap between EU regions.

Despite existing challenges and discrepancies, several Southern and Eastern Europe regions emerge as digital frontrunners notably thanks to the adoption of dedicated policies and development of demonstration infrastructures. They include inter alia: Mazovia (Poland), Slovenian regions, Central Hungary (Hungary), Norte Region (Portugal) and the Basque country (Spain).

4.2 Key risks and challenges

The following key risks and challenges for Southern and Eastern European regions and regional stakeholders in the development and uptake of cyber-physical systems for production monitoring have been identified:

- **Limited access to funding for manufacturing SMEs:** Investing in CPPS represent high investment costs, that most manufacturing SMEs cannot afford58. There is therefore a crucial need to provide them with dedicated and long-term financial support (e.g. dedicated programmes and initiatives at national or regional level) as the transformation of production processes is a complex and long-lasting operation.
- **Lack of relevant skills in the workforce:** The smooth integration of CPPS into production lines leads to the redefinition of functions traditionally carried out by human workforce. Work in industry at all levels would increasingly consist of

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57 Ibid.
maintaining and supervising smart machines. It therefore requires the acquisition of new and complementary skill sets adapted to these innovative systems. In particular, there will not only be an increase in demand for digital skills but also for complementary skills, such as entrepreneurial, leadership and engineering skills. In order to address these needs, a particular emphasis should be focused on developing more trans-disciplinary university curricula (e.g. such as STEM disciplines), as well as trainings to ensure the upskilling of the workforce.

- **Relative lack of a pan-European approach**: As stated above, EU regions are not advancing at the same pace towards the digitalisation of their industry. In order to ensure the large-scale uptake of CPPS in Southern and Eastern European regions, there is a need to adopt a holistic approach taking into account these disparities. However, it is to be noted that recent efforts have been made by the European Commission with the launching in March 2017 of the European platform of national initiatives on digitising industry. This project brings together the 13 existing national initiatives to digitise industry and nine currently in preparation to improve the sharing of best practices across EU Member States. More specifically, further dedicated support to the development of Digital Innovation Hubs in Eastern European Member States has also been recently launched by the European Commission, in the frame of the project “Smart Factories in new EU Member States”.

- **Reluctance to change from manufacturing SMEs**: As SMEs often operate under tight margins, their top management can adopt a relative conservative stance towards the adoption of new digital technologies. In order to overcome this significant hurdle, a great emphasis should be put on awareness-raising as well as on demonstrating the benefits of the CPPS through showcases of success stories and result-driven pilot projects.

- **Limited digital infrastructures**: The development and expansion of fast and reliable internet connectivity is essential to deliver next generation digital mechanical engineering services. However, access to high-speed broadband services in Europe is still far from universal, in particular in less developed regions.

4.3 Opportunities for the Southern and Eastern European regions:

Opportunities for Southern and Eastern European are mainly two-fold:

- **Engaging in smart specialisation based on value chain needs**: As stated above, the value chain is mostly covered by European actors. However, there is a need to build on the strong points of each region (i.e. smart specialisation in software development, automation components or machinery) rather than trying to develop full value chains at the regional level. Southern and Eastern

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European regions can significantly foster the uptake of CPPS by building on their strengths and potential (See Section 4.1).

- **Developing innovation ecosystems at regional level**: In order to fully tap the wide uptake of CPPS in the manufacturing sector, and in particular by SMEs, it is necessary to develop local platforms, such as Digital Innovation Hubs (DIHs) functioning as one-stop-shop for SMEs, aiming to provide them with financial and technical support, and contacts to all relevant actors across the value chain, as well as local public authorities. In this regard, according to stakeholders, the five digital innovation hubs established in different EU regions in the frame of the project BEinCPPS (I4MS)\(^{63}\) can be considered as a model to follow. These DIHs have notably facilitated the uptake of new open CPPS platforms by local manufacturing SMEs.

Taking stock of Southern and Eastern European regions’ strengths and potential, the establishment of cross-regional partnerships need to be further encouraged. Firstly, such partnerships would enable the full integration of the value chain by bridging EU regions according to their smart specialisation. Secondly, it would provide these regions with a common platform where they can exchange best practices with more advanced regions on how to develop regional innovation ecosystems. This would eventually foster the development of a streamlined pan-European approach. Such cross-regional partnerships should take stock of the insights of previous successful experiences such as I4MS (i.e. notably BEinCPPS) as well as the regional partnership set up under the Smart Specialisation Platform on Industrial Modernisation on ‘Production Performance Monitoring Systems’/‘SME integration to Industry 4.0’\(^{64}\).

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\(^{63}\) [http://www.beincpps.eu/](http://www.beincpps.eu/)

\(^{64}\) Smart Specialisation Platform website: [http://s3platform.jrc.ec.europa.eu/sme-integration-to-industry](http://s3platform.jrc.ec.europa.eu/sme-integration-to-industry). Slovenian regions and Mazovia (Poland) are the origin of the partnership on ‘Production Performance Monitoring Systems’ which aims to support the uptake of CPPS for production monitoring by regional manufacturing SMEs, by developing a common platform to all participating local companies. The cross-regional collaboration would aim to confront results as well as to elaborate and disseminate best practices.
5. Policy implications

The current section aims to present specific policy recommendations on what needs to be done in order to strengthen the EU competitive position regarding this product in the coming years, and specifically on how to ensure the large-scale uptake of cyber-physical systems for production monitoring in Southern and Eastern European regions. The following recommendations are composed of a mix of potential measures to be implemented at European, national and regional levels.

5.1 Measures with immediate focus

The following measures with immediate focus have been identified:

- **EU coordinated actions supporting the further development of inter-regional cooperation partnerships and regional innovation ecosystems:**
  As stated in Section 4.3, Southern and Eastern European regions would greatly benefit from the development of inter-regional cooperation partnerships and regional innovation ecosystems. It would ensure the integration of the value chain at the EU level and foster the bottom-up uptake of CPPS within the manufacturing sector. Such initiatives should follow and take stock of existing successful projects, such as inter alia:
  - The regional partnership set up under the Smart Specialisation Platform for Industrial Modernisation\(^{65}\) and the Vanguard Initiative\(^{66}\) are good examples of effective and result-driven inter-regional cooperation.
  - The I4MS initiative, funded under the EU R&I programmes, which aims to enable and foster the collaboration of manufacturing SMEs across their value chains through the help of digital innovation hubs predominantly in cross-border experiments across Europe\(^{67}\).

- **Increasing the number of demonstration and testing facilities in less developed regions:** More pilot projects and demonstrations are needed to ensure the digitalisation of companies’ production processes. Indeed, before significant investments are made, SMEs require technology uptake support and pilot projects to reveal demonstrated results in improved productivity. Demonstration and testing laboratories are key components of regional innovation ecosystems. Although such facilities are becoming more common in Western Europe, less mature regions still relatively fall short of such installations. Having close access to such facilities will greatly reduce the financial risk for end-users, potentially attract local manufacturing SMEs, and ensure the development of more customised systems\(^{68}\).

- **Implementing awareness-raising measures dedicated to manufacturing SMEs:** As outlined in Section 3.3, one of the key barriers to the full integration of the value chain lies in the conservative stance from the top management of manufacturing SMEs towards profound changes in their production systems. Also, stakeholders have reported that there is a relative lack of knowledge regarding the benefits associated with CPPS among manufacturing SMEs in

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\(^{65}\) Available at: http://s3platform.jrc.ec.europa.eu/

\(^{66}\) Available at: http://www.s3vanguardinitiative.eu/

\(^{67}\) Available at: http://i4ms.eu/

\(^{68}\) Based on interview data.
Southern and Eastern Europe. Therefore, a great emphasis should be put on raising awareness among SMEs in order to demonstrate to them in practice the concrete benefits of CPPS. Awareness-raising activities can mainly take two forms: the organisation of roadshows with the presentation of success stories, as well as the provision of tailored assessment tools such as free or low-cost mentoring services within SME premises (similar to the advisory services provided under the Belgian Made Different programme for example).

- **Strengthening SME access to EU Public-Private Partnerships (PPPs):** The ECSEL JU and the Factories of the future PPP play a pivotal role in financing R&D across Europe, defining its key strategic orientations at EU level, and supporting all relevant actors (industry, research and technology organisations, public authorities) in their efforts to bridge the ‘valley of death’. However, there is a need to ensure the greater involvement of SMEs from all sectors (software/IT, mechanical engineering etc.) in these European programmes. For instance, the share of funding dedicated to SMEs is lower in ECSEL JU (13%) than its level in the Artemis JU (19%), the previous EU PPP dedicated to embedded and cyber-physical systems. Such measures will notably improve the exploitation of EU-wide research by SMEs.

5.2 Measures with longer-term focus

The following measures with longer-term focus have been identified:

- **Enhancing digital infrastructures in less mature regions:** Southern and Eastern European regions do not have digital infrastructures that are as performant as Western European regions. However, companies' access to a high-speed broadband connection is a determining condition to ensure the large-scale uptake of CPPS. Therefore, investments in digital networks and infrastructures need to be upscaled in less developed regions. Both European Funds (e.g. such as notably the Connecting Europe Broadband Fund) and public investments at national level play a key role in this regard.

- **Providing financial support to manufacturing SMEs:** Manufacturing SMEs face immense difficulties to access the financial sources necessary to invest in CPPS. The establishment of adapted financial incentives will reduce the risks for companies and trigger greater integration of CPPS within their manufacturing plants. Taking stock of the positive achievements of existing initiatives such as I4MS, there is a need to further strengthen or develop cascading funds, which contrarily to H2020 funds, are directly accessible by SMEs at the level of regional innovation ecosystems. An easier access to funding would certainly facilitate the dissemination and integration of cyber-physical systems for production monitoring.

- **Addressing the skills-related challenges:**

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69 Based on interview data
70 http://www.madedifferent.be/
72 Based on interview data.
Policy implications

- There is a need to develop educational programmes in high education that fully take into account of the emerging requirements related to the integration of CPPS in the manufacturing sector. Such programmes should be based on cross-disciplinary courses (i.e. STEM disciplines for instance) enabling students to acquire a relevant set of skills.
- Further training schemes also need to be put in place in order to upskill the workforce in the manufacturing sector. Such support programmes should particularly target manufacturing SMEs.

• **Strengthening the support for R&D and research exploitation towards the development of CPPS standards and open platforms**: As indicated in Section 3.3, there is a great need to develop common standards, and open platforms that will ensure the large-scale uptake of CPPS by manufacturing companies. R&D and research demonstration need to be further supported in this field by national and H2020 funds, in particular through the ECSEL JU and the Factories of the Future partnership. However, stakeholders report that it will also be important to avoid the fragmentation of R&D activities across Europe, by putting a great emphasis on the re-use of project results and on projects cross-fertilisation.

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74 Based on interview data.
**Annex A: List of interviewees**

Table A-1: Overview of the interviewed stakeholders

<table>
<thead>
<tr>
<th>Nr</th>
<th>Name</th>
<th>Position</th>
<th>Organisation</th>
<th>Country</th>
<th>Stakeholder type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ales Hancic</td>
<td>Managing Director</td>
<td>TECOS</td>
<td>Slovenia</td>
<td>RTO - Representative of Slovenian regions in the S3 Platform</td>
</tr>
<tr>
<td>2</td>
<td>Oscar Lazaro</td>
<td>Managing Director</td>
<td>Innovaia Association</td>
<td>Spain</td>
<td>RTO - Member of BEinCPPS consortium (I4MS project)</td>
</tr>
<tr>
<td>3</td>
<td>Tomasz Szlazak</td>
<td>Vice-President of the Board</td>
<td>RCIT (Radom Center for Innovation and Technology)</td>
<td>Poland</td>
<td>RTO</td>
</tr>
<tr>
<td>4</td>
<td>Urko Zurutuza</td>
<td>Coordinator of the Intelligent Systems for Industrial Systems Research Group</td>
<td>Mondragon University</td>
<td>Spain</td>
<td>University - Leader of the ECSEL project MANTIS (Cyber-Physical System-based Proactive Collaborative Maintenance)</td>
</tr>
<tr>
<td>5</td>
<td>Cesar Toscano</td>
<td>Researcher</td>
<td>INESCTEC</td>
<td>Portugal</td>
<td>RTO - Member of BEinCPPS consortium (I4MS project)</td>
</tr>
</tbody>
</table>

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