INDUSTRY 4.0 – A COMPARISON OF THE STATUS IN EUROPE AND THE USA

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STATUTORY DECLARATION

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

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List of Abbreviations

BCG	Boston Consulting Group
CPS	Cyber physical systems
ERP	Enterprise resource planning
GDP	Gross domestic product
ICT	Information and communication technology
IIoT	Industrial Internet of Things
IoT	Internet of Things
IT	Information technology
R&D	Research and development
SM	Smart manufacturing
SMLC	Smart Manufacturing Leadership Coalition

ABSTRACT

Industry 4.0 is a highly discussed topic. Many experts try to predict the outcome of the fourth industrial revolution. Some say, that the United States has an advantage over Europe since the information and communication technology will play a key role. Others praise Europe's efforts and refer to the strong production technology companies. It is easy to lose track of the current status of research and the implementation of Industry 4.0 due to the high number of papers being published every month. Gaining an overview about the current efforts in Europe and the United States is one of the goals of this paper. Furthermore, some recommendations are derived based on the efforts done in these regions. Current research paper as well as newspaper articles and studies led to following conclusions. Europe has a slight advantage due to good preparation and some high funding through the European Union. Additionally, some big companies are using their leading position and developing production technologies, which will lead to smart factories – the goal of Industry 4.0. Europe should not forget that the research is just one side of the coin. The implementation, especially in small and mid-sized companies, needs more support and concerns need to be discussed. It can be seen that Europe is not missing out on the fourth industrial revolution. The United States is also aware of the next change in production and also funds research and development of these technologies. Main drivers in the United States are information technology companies like Google and IBM, but there is a lack of preparation found. Industry 4.0 needs to be a more known issue in the US and therefore needs more attention from the media. A defined term and a structured approach would also help in the implementation. The highest return on investment could be achieved if both regions combine their core competencies on an equal footing, since Industry 4.0 needs high-tech production technology as well as newest information and communication technology.

1. INTRODUCTION

Industry 4.0 is a current highly discussed topic. Every month, many research papers are published and many newspaper articles discuss this topic. The media is full of interviews with analysts who try to increase awareness not to miss this change. Even top-politicians like the federal chancellor of Germany, Angela Merkel, are publicly addressing the European industry not to fall behind and not to rely to much on their past success. (cf. dpa Deutsche Presse-Agentur GmbH, 2014) At the same time, they are praising businesses from the United States of America (USA) for their leading position. US Software companies, like Google Inc., are mainly responsible for this appraisal.

Are European businesses really missing out on this change and are there any variations in different countries regarding the current status of the implementation in businesses? These questions and the resulting opportunities are part of the following paper. It is based on research papers, newspaper articles and studies. First, the author will provide necessary definitions and have a basic look on Industry 4.0, what it means and which technologies it involves. Next, the current status of the USA and Europe will be discussed. It involves the implementation of Industry 4.0 in businesses as well as the understanding of these technologies. Lastly, a conclusion will be done which includes recommendations for necessary actions in terms of research, collaboration, and the implementation.

The goal of this paper is to evaluate the potential for the manufacturing industry in the USA and in Europe and to derive information about opportunities and risks in a competitive situation. The findings could provide businesses with needed information about the competitors and the real state in the industry. It will help them to decide where their current position is and what needs to be done next. Further it will be a short introduction to the topic *Industry 4.0* for everybody who wants to learn more about Industry 4.0 and what the possible benefits are.

2. IMPORTANT TERMINOLOGY

The following part will discuss the term Industry 4.0 and technologies involved. It will give a short insight on this topic and provide a good foundation to understand the meaning for each business of it.

2.1. Historic Background

When talking about industry and especially manufacturing, it is important to understand how it evolved and what led to the current state. In the beginning, everything was done barehanded and only with muscular strength. Since then humanity went through many changes. The most important turning points in history were the three industrial revolutions.

The first industrial revolutions took place from about 1760 to round about 1830. It was the mechanization of production where the manufacturing process changed from hand production to machines. An increasing number of these machines were powered by steam power. The efficiency of water power increased as well. It is also the time, where coal started to replace bio-fuels and wood. This industrial revolution started in Great Britain and was adapted by Europe and the US years later. The main driver of this change was the textile industry. This led to a change of the daily lives of the average population. Their income and living standard started to a continuing growth, even though these positive consequences occurred slowly. (cf. Editors of Encyclopædia Britannica, 2014b) Robert E. Lucas Jr., an American economist and winner of the 1995 Nobel Memorial Prize in Economic Sciences described the consequences of the first industrial revolution in his book *Lectures on Economic Growth* as follows: (cf. Editors of Encyclopædia Britannica, 2014a)

> *"for the first time in history, the living standards of the masses of ordinary people have begun to undergo sustained growth“ (Lucas, 2002, p. 109)*

Shortly after the mechanization of production, the second industrial revolution started. This transition took place between 1840 and 1870 and is also known as the technological revolution. Railroads and new manufacturing plants with a large iron and steel production characterized it. More and more machinery could be

found in the facilities and the factory electrification started. The opportunity to deliver huge amounts of goods from one place to another with the help of railroads and the capability of machinery combined with electric power lead to the production line and mass production. One of the best-known examples for mass production is Henry Ford's Ford Motor Company, which implemented mass production techniques in the late 1910s. The second industrial revolution did not just start in the United States, but also in Britain and Germany. Another important role in this change was taken by Japan as well. The result of the changes was a rapid industrial development and further growth of the standard of living. (Mokyr & Strotz, 1998)

In between late 1950s and late 1970s the digital revolution took place. This is also called the third industrial revolution. Digital technology was the driver of this change, which started with the first computer Z1 build by Konrad Zuse. (cf. Rojas, 2014) Another important driver was the communication technology. Today's factories use digital logic circuits and the technologies like computers and the Internet, which are based on these circuits. This digital revolution was also the beginning of the Information Age. The resulting manufacturing processes and its complexity was only manageable due to good information and communication technology (ICT), which was implemented in *"approximately 90 percent of all industrial manufacturing processes"*. (cf. Kagermann, Wahlster, & Helbig, April 2013, p. 13) These show that information technology (IT) will have a leading role now and in the future of manufacturing.

Today, the use of digital cellular phones, tablet computers and cloud computing is probably showing the next step. These technologies will lead to the fourth industrial revolution, which is summarized by the term Industry 4.0. This phrase is mainly used in Europe to represent the fourth industrial revolution. (cf. Benzie, 2014)

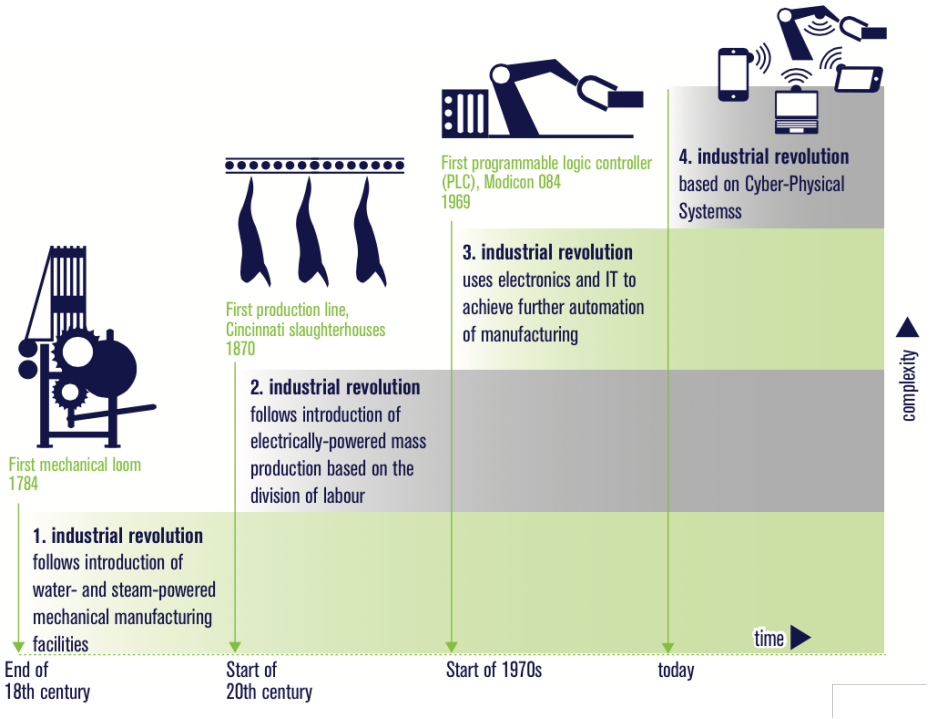

Figure 1: The Four Industrial Revolutions (Kagermann, Wahlster, & Helbig, April 2013, p. 13)

2.2. Industry 4.0

As mentioned in the last part, Industry 4.0 is term which stands for the fourth industrial revolution. It was mentioned for the first time in 2011 during the Hanover Fair. Since then, the German government took this term and turns it into a strategy project for Germany's businesses. One year later – also at the Hanover Fair – a working group on Industry 4.0 presented their *recommendations for implementing the strategic initiative industrie 4.0* as a final report to the German government. Siegfried Dias, manager at the Robert Bosch GmbH, and Henning Kagermann, former chairman of the Executive Board and Chief Executive Officer of SAP AG, chaired this working group. (Plattform Industrie 4.0, 2014)

The term Industry 4.0 is not well known outside of Europe. This does not mean that other nations did not realize the change and the importance of it for businesses and its competitive position. Similar to the German efforts, there is the so-called Smart Manufacturing Leadership Coalition (SMLC) in the USA with the goal of a collaboration between businesses in the smart manufacturing industry in research an development (R&D). (cf. SMLC, n/a)

> *"The SMLC is a non-profit organization committed to overcome barriers to the development and deployment of Smart Manufacturing (SM) Systems through an implementation agenda for building a scaled, shared infrastructure called the Smart Manufacturing Platform (SM Platform). SMLC activities are built around industry-driven development, application and scaling of a shared infrastructure that will achieve transformational economic-wide impact, manufacturing innovation and global competitiveness." (SMLC, n/a)*

The result of the fourth industrial revolution will be a so-called intelligent factory, or smart factory. Cyber physical systems (CPS) and the Internet of Things (IoT) will be key technologies to reach this goal. (cf. Kagermann, Wahlster, & Helbig, April 2013, p. 13-15)

2.3. Smart Factories

Smart products, health, mobility, and logistics are future goals of production and the consequence of our connected world. When focusing on manufacturing, the processes done with smart networks and smart systems will have a great impact. Smart manufacturing (SM) is done with intelligent software combined with smart tools. The benefits of such smart factories are numerous: (cf. Kagermann, Wahlster, & Helbig, April 2013, p. 19)

> *"Industrie 4.0 is focused on creating smart products, procedures and processes. Smart factories constitute a key feature of Industrie 4.0. Smart factories are capable of managing complexity, are less prone to disruption and are able to manufacture goods more efficiently. In the smart factory, human beings, machines and resources communicate with each other as naturally as in a social network." (Kagermann, Wahlster, & Helbig, April 2013, p. 19)*

In practice, the end-to-end ICT-based manufacturing plant, which already includes external information about logistics – inbound and outbound – production as well as marketing, will have additional potential in tracking of processes and involve closer cooperation between partners such as suppliers as well as customers. (cf. Kagermann, Wahlster, & Helbig, April 2013, p. 14)

2.4. Cyber Physical Systems

Moore's law predicted the speed of the technological development in today's society. Recent computers become smaller and smaller while at the same time being able to run a higher and higher amount of calculations per second. This leads to objects and products with embedded computer systems. These are able to perform tasks, which were unimaginable 20 years ago. When talking about CPS, these systems can be seen as the physical part. Combined with the connection to the cyber world, it becomes possible to control the physical entity according to the situation needed. The National Science Foundation CPS Summit defines CPS as follows: (cf. Parvin, Hussain, Hussain, Thein, & Park, 2013, p. 928-929)

> *"Cyber-physical systems (CPS) are physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core. This intimate coupling between the cyber and physical will be manifested from the nano-world to large-scale wide-area systems of systems. And at multiple time-scales." (National Science Foundation CPS Summit, n/a)*

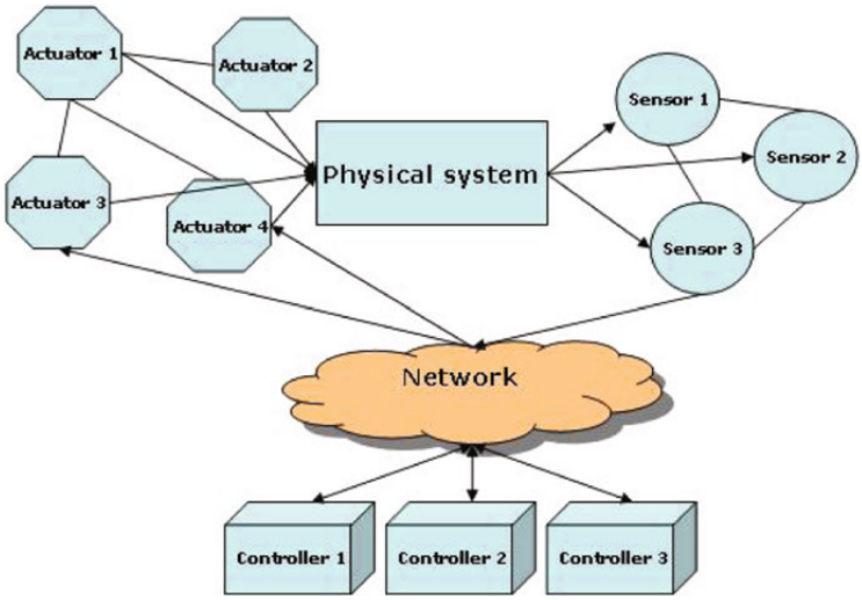

Figure 2: CPS Architecture (Parvin, Hussain, Hussain, Thein, & Park, 2013, p. 928)

2.5. Internet of Things

The term IoT has a wide range. People without a technological background think about smart watches or the ability to turn on the light in the house via their smartphone. But there is much more behind the IoT and this is the reason why many people divide this term into smaller parts. Patrick Moorhead, President and Principal Analyst at Moor Insights & Strategy describes smart watches and similar devices as the Human Internet of Things, while the basis for businesses and manufacturing is described as the Industrial Internet of Things (IIoT). (cf. Moorhead , 2013) Other sources divide the IoT first into the IoT and also into the Internet of Services. (cf. Kagermann, Wahlster, & Helbig, April 2013, p. 13) In general, a good definition for the IoT is as follows:

> *"Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts". A different definition, that puts the focus on the seamless integration, could be formulated as "Interconnected objects having an active role in what might be called the Future Internet" (Bassi & Horn, 2008, p. 6)*

2.6. Difference between Cyber Physical Systems and the Internet of Things

After reading the definitions of CPS and the IoT it may be difficult to see the difference between this two technologies. Imre Horvath from the Delft University of Technology describes the IoT as an infrastructure, which collects information and controls itself and other things in the physical space, while CPS *"creates synergy among the entities of the physical and cyber space, by integrating analogue and computational hardware, middleware, and cyberware."* (Horvath, 2014) This means, that the IoT will connect different products to each other, for example a smart watch with a smart phone. (cf. Baum, 2013, p. 42-45) CPS in contrast uses the connection to the cloud and sensors to actively adjust a physical thing to a current state. (cf. Russwurm, 2013, p. 30-31)

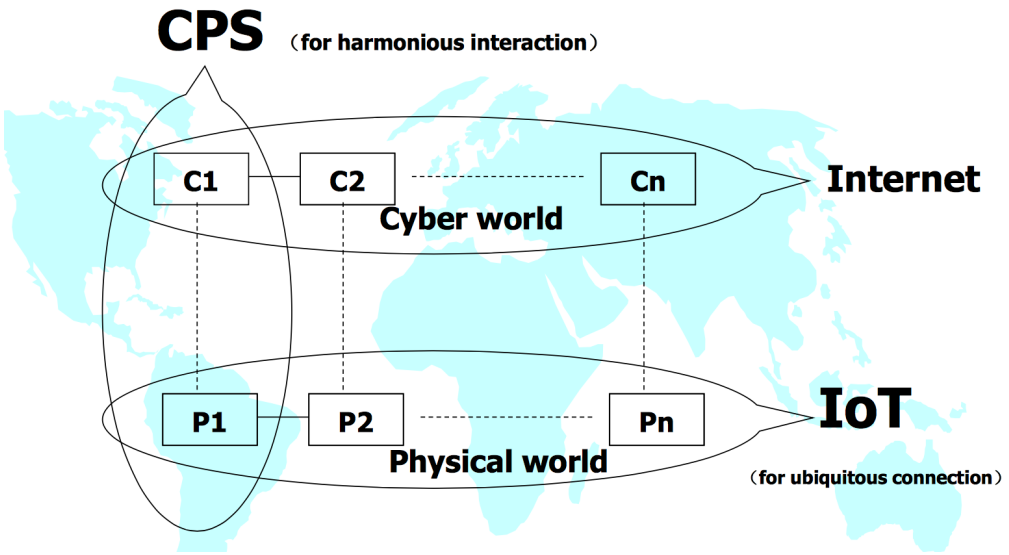

Figure 3: Difference between CPS and the IoT (Chen, 2010, p. 10)

3. CURRENT INITIATIVES

The following chapter will highlight some of the current initiatives in USA and in Europe. Such initiatives could be established by the government or made up by different and sometimes even competing companies.

3.1. USA

In the USA the whole terminology *Industry 4.0* is not very popular. Not many people know what this term means and are confused when they first hear about it. This is also the reason why there are so many different names, which try to explain this whole change behind Industry 4.0. But this does not mean that in the US no one pays attention to the change. On the contrary, there are many US companies currently working on the next industrial revolution even though they do not call it the same. The government realized that it has to pave the way for this movement and even support the research. Until now, IT companies provided manufacturing businesses with good enterprise resource planning (ERP) software. From the viewpoint of Industry 4.0, manufacturing plants with a high integration of ERP systems are already the first step towards a smart factory. But the communication is limited inside of the company. In the future this will need to change. Data exchange needs to be done with suppliers as well as the customers. This needs a mutual basis and many US companies are working on it. (cf. Weiss, 2014)

A good way to get a clue on what is going on in an economy, is to study the innovational strength of different countries. Since 2005, the management consulting firm Boston Consulting Group (BCG) conducts a yearly study on the most innovative companies. Taking a look on the list of the 50 most innovative companies of 2014 reveals that seven out of ten companies are based in the US. When looking at the first 20 companies, 14 US companies can be count and only two European ones – both of them based in Germany. The BCG also ranks coming companies and its predicted opportunities in the future, where five out of ten companies are based in the US. (cf. Wagner, Taylor, Zablit, & Foo, 2014, p. 7-9)

EXHIBIT 2 | The 50 Most Innovative Companies of 2014

1 to 10		11 to 20		21 to 30		31 to 40		41 to 50	
1	Apple	11	Hewlett-Packard	21	Volkswagen	31	Procter & Gamble	41	Fast Retailing
2	Google	12	General Electric	22	3M	32	Fiat	42	Wal-Mart
3	Samsung[1]	13	Intel	23	Lenovo Group	33	Airbus	43	Tata Group
4	Microsoft[2]	14	Cisco Systems	24	Nike	34	Boeing	44	Nestlé
5	IBM	15	Siemens	25	Daimler[3]	35	Xiaomi Technology	45	Bayer
6	Amazon	16	Coca-Cola	26	General Motors	36	Yahoo	46	Starbucks
7	Tesla Motors	17	LG Electronics	27	Shell	37	Hitachi	47	Tencent Holdings
8	Toyota Motor	18	BMW	28	Audi	38	McDonald's	48	BASF
9	Facebook	19	Ford Motor	29	Philips	39	Oracle	49	Unilever
10	Sony	20	Dell	30	SoftBank	40	Salesforce.com	50	Huawei Technologies

Source: 2014 BCG Global Innovators survey.
[1]Includes all Samsung business groups (including electronics and heavy industry).
[2]Includes Nokia.
[3]Includes Mercedes-Benz.

Figure 4: The 50 Most Innovative Companies of 2014 (Wagner, Taylor, Zablit, & Foo, 2014, p. 8)

EXHIBIT 3 | Half of the Top Up-and-Coming Companies Are Based in the U.S.

1	Xiaomi Technology		6	Oxo	
2	WhatsApp		7	Great Wall Motors	
3	Square		8	GungHo Online Entertainment	
4	Rakuten		9	Oculus VR	
5	Wipro		10	Splunk	

Source: 2014 BCG Global Innovators survey.

Figure 5: Up-and-Coming Companies (Wagner, Taylor, Zablit, & Foo, 2014, p. 9)

Some of these companies listed above established the Industrial Internet Consortium (IIC) in March 2014. These companies are Intel, Cisco, General Electric, IBM and AT&T. Furthermore, this group is open for other companies to contribute as well and has currently more than 100 members. Their goal is *"to bring together the organizations and technologies necessary to accelerate growth of the Industrial Internet by identifying, assembling and promoting best practices."*. (Industrial Internet Consortium, n/a) Only the five companies who established this consortium have an annual turnover of more than 470 billion dollars, which show the possibilities of this consortium. Additionally, the US government invests more than 100 million dollar into the research for CPS. (cf. Riemenschneider, 2014)

Despite this consortium, many of these companies have their own projects in their specific areas of business. Intel is building an intelligent system framework, where they develop on intelligent and embedded systems. IBM has its smarter planet strategy and General Electric published a white paper on the Industrial Internet. (cf. Rath, 2013)

The fourth industrial revolution also needs a lot of development in software. In this area, US companies are leading. Almost any big and well-known software company has its root in the US and they realized their opportunities as well. Google is currently calling for research proposals. They plan to offer grants for research in the open web of things. (cf. Sawers, 2014) Their goal is to:

> *„To further the development of open standards, facilitate ease of use, and ensure that privacy and security are fundamental values throughout the evolution of the field, we are in the process of establishing an open innovation and research program around the IoT. We plan to bring together a community of academics, Google experts and potentially other parties to pursue an open and shared mission in this area." (Cerf, Want, & Senges, 2014)*

The National Institute of Standards and Technology (NIST) from the US Department of Commerce hosts the Advanced Manufacturing National Program. Universities, manufacturing companies as well as representatives from federal agencies with manufacturing related missions are part of this program. They even call the upcoming technology a *"Revolution in Manufacturing"*. The goal is to

enhance technology transfer in manufacturing industries as well as helping the companies to overcome barriers. (cf. Advanced Manufacturing Portal, n/a) NIST „allocated 100 million dollars of funding to provide technical support to domestic manufacturing industry“. (Kagermann, Wahlster, & Helbig, April 2013, p 70) The US government also financially supports this program. For this purpose, the Obama administration increased the funding for advanced manufacturing by 19 percent to 2.2 billion dollars in 2013. (cf. Kagermann, Wahlster, & Helbig, April 2013, p. 70) The following year, US President Barack Obama announced new actions to strengthen US manufacturing. This includes additional 300 million dollars to ensure competitiveness of US manufacturing businesses and much more. (cf. Office of Press Secretary, 2014)

All of these actions sound promising. Many companies as well as the government are investing much money to further encourage the development of new technologies in manufacturing. But there are also voices, which try to warn the US not to fall behind Europe in the next change. Reporter Patrick Thibodeau, who writes about government IT policies among other things, recently manifested his concerns that the US government is not investing enough in CPS and IoT development. As mentioned in the paragraph before, the current investments announced by the White House will definitely bring the US much closer to the needed funding in order keep the development of CPS on a level to ensure competitiveness.

The provided numbers show, that the US is a strong economy and therefore high financial resources. It has a big effort in developing new technologies and many highly innovative companies. The US software industry and many other companies are getting together and combine their strengths in developing new technologies. Another hint, which represents the importance of US based manufacturing, is that some companies try to bring back their production to the US. One example is Apple, who is currently starting to make more and more products in the US and thereby investing a lot of money in manufacturing. (cf. Garside, 2013) The US government also realized the importance of CPS for the future of manufacturing and is raising needed funds for R&D. All of these programs combined help the US economy to be a serious competitor in the fourth industrial revolution.

3.2. Europe

When talking about Europe, it is hard to make a general statement because of the differences in each country. There are countries with a higher concern and more effort to push forward the next industrial revolution than other countries. While taking a look on the share of industry on a country's gross domestic product (GDP) in the last couple of years, it becomes clear that Europe had some difficulties in the past to keep production domestic. The only western European country capable of increasing its industry share on the GDP was Germany. (cf. Spath, Ganschar, Gerlach, Hämmerle, Krause, & Schlund, 2013, p. 15) More than 90 percent of German businesses say that the manufacturing location in Germany will still be important in the next five years as well. (cf. Spath, Ganschar, Gerlach, Hämmerle, Krause, & Schlund, 2013, p. 40)

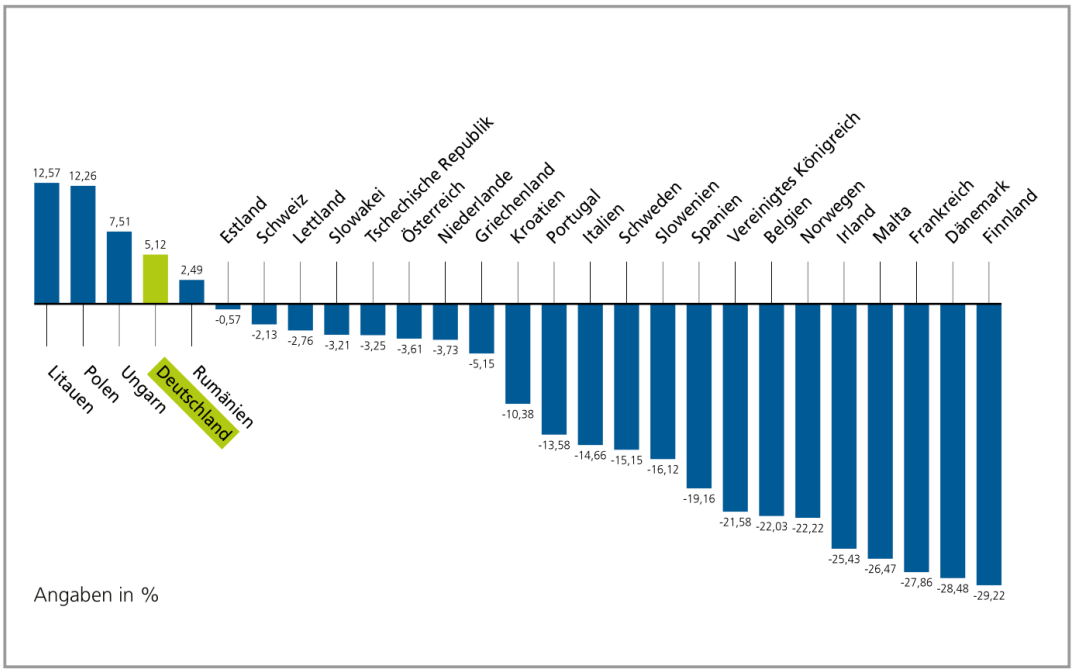

Figure 6: The difference of the industry share on the GDP in Europe between 2001 and 2012 (Spath, Ganschar, Gerlach, Hämmerle, Krause, & Schlund, 2013, p. 15)

This also shows the importance of the industry in Germany and additionally, that Germany is an interesting location for many companies. Another indicator is the fact that *"60 percent of Germany's manufacturing sectors are in medium-high technology or high-technology product areas, which mainly reflects the great strengths of Germany's 'Mittelstand'."*, compared to the US, where only 40 percent of their manufacturers are

high-tech ones. (cf. President's Council of Advisors on Science and Technology, 2014, p. 5) But this does not mean that all of these companies understand what a CPS is and what impact it will have on the industry. A study revealed that 60 % of the interviewed companies do not understand the depth of CPS and only 4.2 percent use CPS in their production. (cf. Spath, Ganschar, Gerlach, Hämmerle, Krause, & Schlund, 2013, p. 114-115)

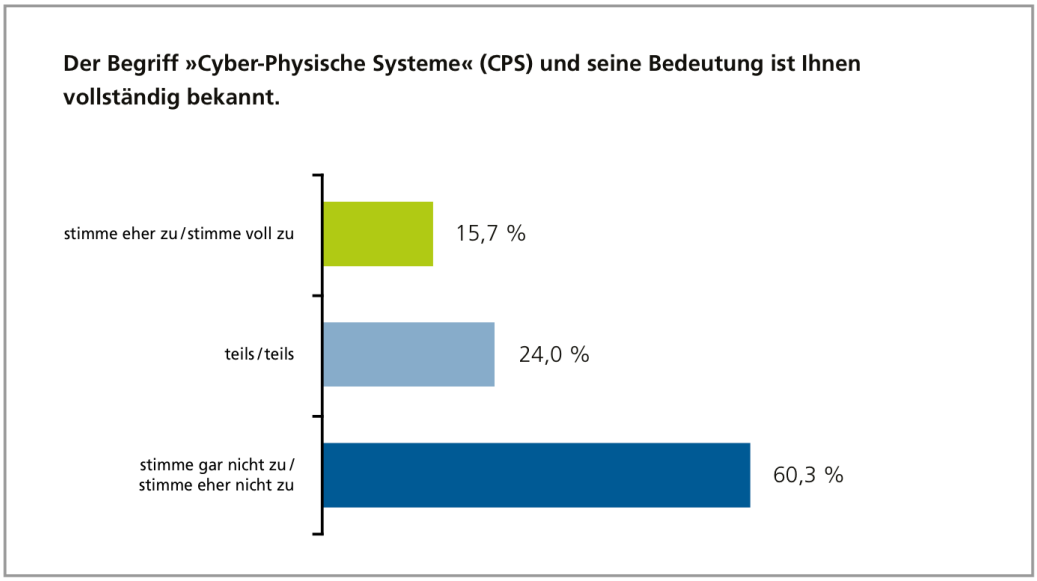

Figure 7: Knowledge about CPS and its opportunities (Spath, Ganschar, Gerlach, Hämmerle, Krause, & Schlund, 2013, p. 114)

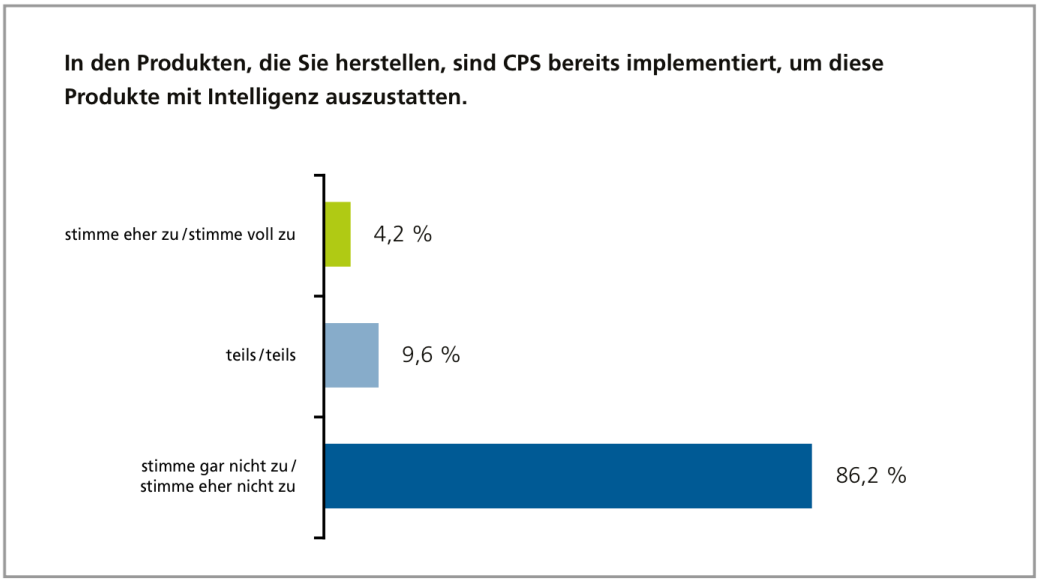

Figure 8: CPS in Production (Spath, Ganschar, Gerlach, Hämmerle, Krause, & Schlund, 2013, p. 115)

The German government, some universities as well as some big and well-known companies are working hard to make smaller companies aware of the next industrial revolution. A report with *recommendations for implementing the strategic initiative Industrie 4.0* was sponsored by the German government (cf. Kagermann, Wahlster, & Helbig, April 2013) and publicly announced at the Hanover Fair in 2013. Since then the term Industry 4.0 is on everyone's lips. The university RWTH Aachen established the cluster of excellence Integrative Production Technology for High-Wage Countries and does its research together with many industrial partners like BMW, EADS, ThyssenKrupp Steel AG, and many more. (cf. RWTH Aachen, 2014) Furthermore, there are organizations like the Federal Association for Information Technology, Telecommunications and New Media, the German Engineering Association, and the German Electrical and Electronic Manufacturers' Association who are working hard in their fields on the implementation of the vision of Industry 4.0 in Germany. Siemens is already producing first machinery for the next industrial revolution at its manufacturing plant in Amberg. A part of the production there is already done by their own so-called Simatic process control technology and stands for the future factory. Representatives from the USA and China already came to visit this plant. (cf. Visser, 2014)

Barcelona, Spain, is also a big place for the future of the IoT. It hosted the IoT World Forum in 2013 and became one of the top players in this area. There will also be a Startup boot camp this year to further encourage and accelerate IoT based companies and innovations. (cf. O'Hear, 2014) The US company Cisco invested in Barcelona. With 30 million dollars they restored the facility and build an innovation center, which will *"provide a platform for research, technological development and new market opportunities."* (Middleton, 2014)

The whole discussions about Industry 4.0 are not ignored by the United Kingdom (UK) even though they do not have a well-written document with strategies as Germany and the US has. David Willetts, science minister in UK, declared that robotics and autonomous systems were one of the eight great technologies that the government supports. The UK realized the importance and announced a research award over 15 million pounds *"to increase the strength and productivity of research."*. (Shead, 2013) Current production challenges the UK

faces can be solved by the use of Industry 4.0. The fourth industrial revolution can thereby benefit from some of UK's strengths. This is also the reason, why Brian Holliday from Siemens urges the UK to invest in digital and smart factories. Additionally, he suggested, that Germany and the UK should establish a joint technology initiative and work together to further strengthen the industry in Europe. Additionally, this project should get funds by the European Union (EU) and grow to a pan-European research project. Current research in the UK is done by different organizations as the electronic systems community (ESCO) and the automation trade association (GAMBICA). Near Coventry, a manufacturing technology center is build by Siemens and Hewlett-Packard. This is UK's first digital factory and is used as a showcase for Industry 4.0. (cf. Nathan, 2014) All of this is only possible, because of the extra 45 million pounds funding boost UK's government announced. This increases the amount of UK funding to more than 70 million pounds. (cf. BBC, 2014)

Austria also benefits from the German initiatives in Industry 4.0. The media adapted discussed topics. This led to a similar understanding of the next industrial revolution as German businesses have. Additionally, the Austrian government grants a funding of 250 million Euros for local business to adapt necessary changes for Industry 4.0. (Staudacher, 2014)

Europe is a very diverse place. Some countries are already working hard on the vision of Industry 4.0 and thereby investing a lot of money in research. Groups are formed which combine strengths of different companies. Other countries are less involved in it. Eight percent of all employees in Finland work in technology and knowledge-intensive sectors, while in Portugal only three percent work in these sectors. 69 percent of the GDP in Netherland were exports of goods, while in the UK only 19 percent of the GDP were exports. These and other numbers show the differences and challenges in Europe. Thinking about the possible benefits makes clear, that investing into technologies regarding Industry 4.0 will have a high return on investment. (See figure 9) (cf. Blanchet, Rinn, von Thade, & De Thieulloy, 2014, p. 7-15) The European Union tries its best to support countries and businesses that are willing to invest in and research on CPS and the IoT. Since 2014, there is a EU framework program for research and innovation called *Horizon 2020*. This program

offers funding opportunities for three sections. Firstly, for excellent science to support the exchange of scientific and research infrastructure. Secondly, for industrial leadership and lastly, for societal challenges as for example health, energy, and transport. Total investments amount to more than 80 billion euro and include 20.3 billion euro for industrial leadership. (cf. ZVEI, n/a)

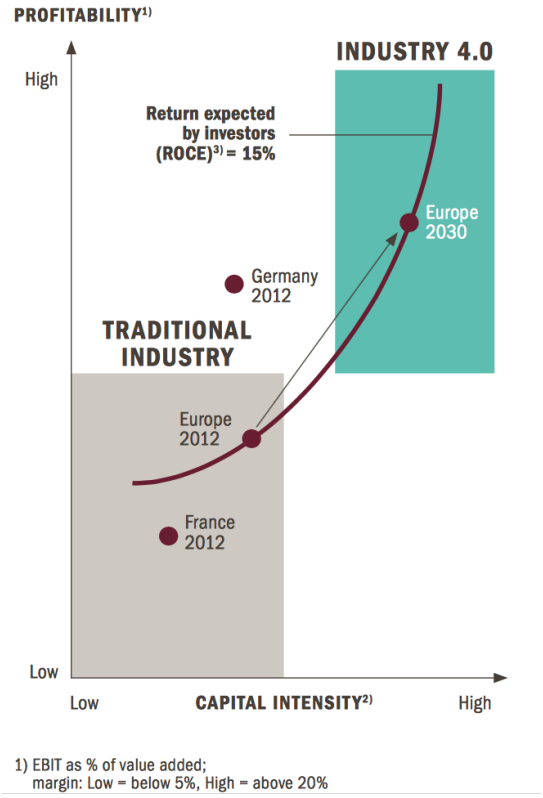

Figure 9: Expected Profitability of the European Industry (Blanchet, Rinn, von Thade, & De Thieulloy, 2014, p. 14)

4. INTERPRETATION

It can be seen, that both regions – Europe and USA – realized the importance of the change for its industry. Both have companies, which are developing new technologies and both governments support them with needed funds. Even universities started their research in CPS and the IoT. The goal is to strengthen the industry in each specific region and to ensure competitiveness in the future. In the past, USA was known for a strong manufacturing industry. It was the home of the big three – Ford, Chrysler, and General Motors. In the last couple of years, these and many other companies suffered due to a strong competition and the rise of low-wage countries like China and India. Today, the USA has seen the potential of new

technologies for its businesses and tries to get back its power. World leading sectors of the USA became IT companies – like Google, IBM, Cisco, and many. Since the whole technology behind Industry 4.0 is based on automation and communication between machines, the IT is one the keys to make the next industrial revolution possible and clearly an advantage for the US. During the past glory days of the USA; it was an example for German businesses. (Fraunhofer-Gesellschaft, 2014) Since then, German businesses made their way to the top in some industry sectors. Especially car manufacturing and the mechanical engineering branch are key sectors in Germany. Recently, the German car industry realized the important role of IT in the future and started collaborating with US companies to make the future car a smart product. (Deutsche Presse-Agentur, 2014)

Germany has done one very important part with the report of the *Industrie 4.0 Working Group*. This report is more than just recommendations for implementing the strategic initiative Industry 4.0. It gives the whole change a name, where everybody understands what is meant with it. There is less confusion because this term combines CPS and IoT, or more precise – it combines the CPS and the IIoT. Furthermore, this report was well advertised. The media wrote many articles about it and almost any German citizen heard this term, even if he or she may not really understands what it means. This helps making people aware of this process and highlights the importance. This report can also be seen as a guideline for implementation. It shows a well-considered way, how the future industry could become reality. All of this allows to bundle and organize competencies and to act in concert. Other European countries as well as the USA should also consider organizing their efforts more. UK for example, uses the term *Industry 4.0* provided by the German report as well and adapts it to its economy. It is always good to have a special term to describe the whole change. It could help decreasing uncertainties and misunderstandings while discussing topic since everybody has a clear understanding of what the terms stand for. Organizing R&D actions will lead to a more efficient progress and fewer inventions need to be done twice. Every company or institution could focus on a specific part of what needs to be done. This will lead to an efficient implementation of the next industrial revolution.

This report, the awareness of German businesses as well as the leading position of Germany's economy in the mechanical engineering sector give Germany a little advantage over other countries. The EU tries to push other countries as well. The cooperation between Germany and the UK is a first step to lower differences in the EU. It also combines different key competencies and lets Europe be a little step ahead. But the USA is close and it also has some good strategies on how to become the world leader after the next industrial revolution. The IT sector in the US has great opportunities and these companies are using their power to find new technologies and further extend their field of business. This shows, that even with a slight advantage Europe should be aware of the US and its capabilities. This means that the financial support is needed and must not be minimized. The financial funds of the US government seem insufficient in contrast to the Horizon 2020 program, which is currently the world's largest funding program. (cf. Kagermann, Wahlster, & Helbig, April 2013, p. 71)

The next thing where Europe needs to work on is the acceptance of these new technologies in the population and specifically the mid and small-sized companies. More than 98 percent of Europe's businesses are small or mid-sized. (Vetter & Köhler, 2014, p. 2)

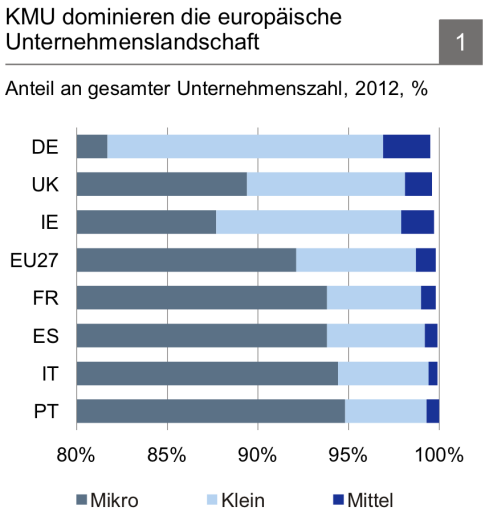

Figure 10: Percentage of Small and Mid-Sized Companies in Europe (Vetter & Köhler, 2014, p. 2)

These companies often have difficulties and considerations regarding the next industrial revolution. Many of them are scared, because they do not really understand

what the consequences will be. Even Frank Bsirske, from the German union Verdi, says that the digitalization of production will cost many jobs. This scares people and lets the implementation of Industry 4.0 become slower. (Fockenbrock, 2015, p. 26) It is an opportunity for other regions like the USA to overtake Europe and gain competitiveness. Another concern of smaller German businesses is data security. As mentioned before, some German manufacturers already established collaborations with US IT businesses. Not just since the NSA leaks of Edward Snowden showed that the concerns should be taken serious. A connected world, where important production data is saved in the cloud provides great opportunities for hackers. Recently, the number of cyber attacks has increased on an all time high. Therefore, the security of future production systems should be guaranteed. (cf. Schöpf & Spitzenstätter, 2014, p. 33-38)

Another point of view could suggest a collaboration between the USA and Europe. Low-wage countries like China and India are gaining power. The competition with these countries makes it important to work as efficient as possible. Industry 4.0 is supposed to ensure an advantage for high-wage countries. The best way to benefit would be the collaboration of US IT businesses with European production technology. Prof. Reimund Neugebauer says, that such a collaboration could solve many problems of our society if both regions share its core competencies on an equal footing. (Fraunhofer-Gesellschaft, 2014) This could probably bring a really good solution to current problems and should be considered. The benefits of industry 4.0 for companies are numerous. The competitiveness is just one of them. Furthermore, businesses will become more flexible in manufacturing, mass customization will become more profitable and new business models will emerge. (Kagermann, Wahlster, & Helbig, April 2013, p. 5-8)

5. CONCLUSION

Both, USA and Europe have a great foundation to build on for the next industrial revolution. They realized the importance of Industry 4.0 for its economy. It will strengthen businesses and its competitiveness, thereby securing jobs and a high standard of living. This is only possible, because of the high investments Europe and the USA deploy for R&D. Both regions have companies, which are world leaders in

its branches. Europe has its strengths in production technology and the USA has some influential IT companies. These companies also help achieving the goals for the next industrial revolution.

5.1. Recommendations for the USA

When thinking about the USA and its efforts it can be seen, that some issues which lead to difficulties in the implementation can be traced back to the fact that there is no defined basis. There is no word specially describing the fourth industrial revolution. Almost any institution uses a term for Industry 4.0, which seems to fit best in their opinion. This leads to the problem that when trying to get information about Industry 4.0 it seems very confusing and unclear. In consequence, smaller businesses do not really understand the change and get scared since it seems to big and to chaotic to understand. This slows down the whole process of the implementation across USA's businesses. The USA should consider writing a public paper. It could be based on the model of the German paper about Industry 4.0 with a well-defined name for future actions. Another possible action should be a campaign in the media to make people more aware of this change. This informs citizens as well as businesses and leads to a decrease of fear. When people feel informed about the consequences of a change, they are more likely to adapt it.

Since the IT plays an important role in the next industrial revolution it should be a focus on these companies. They should get any help they need to be able to make their research. This does not just mean financial support but also includes legal barriers. Furthermore, these companies should consider establishing coalitions with production technology companies. Such coalitions would have almost any skills needed to further promote the next industrial revolution.

Lastly, the US government should be clear of their goals. The Horizon 2020 project form the EU includes funding, which is much higher than the investments done by the US government. If their goal is to become world leading in Industry 4.0, then they should consider investing more not to fall behind Europe. The other option would be to adapt technologies invented by foreign companies to its businesses. This option would be less consuming regarding financial resources but would also have the disadvantage of falling behind other countries.

5.2. Recommendations for Europe

Europe has a good basis, since most countries adapted the efforts done by the German government. Many countries accept the term Industry 4.0 and have an understanding of what it stands for. This term even builds the basis for a shared identity. Companies, universities and even countries – like Germany and the UK – established coalitions and use their strengths to develop the future factory. Siemens already uses a prototype of the future factory in Amberg, which is a good example for the expertise of European businesses.

Siemens is just one example for the strength of Europeans production technology sector. Europe world leading position in these technologies is a good foundation to develop new technologies, which will lead to the next industrial revolution. The only problem, which such companies face in Europe, is the advantage of the USA's IT branch. The most innovative companies are based in the US. The only way for Europeans production technology companies is to collaborate with US IT businesses – but this also leads to difficulties regarding data security and trustworthiness.

The term Industry 4.0 is also a highly discussed topic in the media. This leads to a broad acceptance of the topic. Many businesses get to know the change behind Industry 4.0 very early and thereby securing the possibility of a quick adaption in the future. Furthermore, feared consequences can be discussed openly in the media. Further actions should focus on concerns about data security – especially when collaboration with US companies – and job security. Future norms and standards should also be discussed to ensure the collaboration with smaller businesses in the future.

When discussing the question if Europe is missing out on the next industrial revolution all of the previous information has to be considered. They show that Europe is aware of the importance of it for European businesses and with its efforts to ensure future competitiveness Europe does not miss out on something. Even more, Europe has a slight advantage because it made necessary actions for the future. This is not a reason to lean back because the USA is in hot pursuit so further support of the EU is needed to ensure a world leading position. The opportunities both regions

could have by combining its core competencies are substantial. The US IT branch and European excellence in production technology could ensure the competitiveness of both regions in the future.

5.3. Next Steps

Future research papers on Industry 4.0 could additionally compare other regions like China, India, and Japan and its efforts in the next industrial revolution. These regions are some of the countries with the highest exports and a strong manufacturing industry. Additional research can be done by comparing not just countries and research with each other, but also by comparing different business sectors.

To make the dream of a smart factory come true, much more research has to be done. A standardized basis would lead to an efficient use of new technologies and should be established since Industry 4.0 will have an impact on almost any company. The provided funding could lead to a quick development of new standards and ensure a quick implementation of the next industrial revolution.

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