

THINK ACT

BEYOND MAINSTREAM

POTENTIALISTS

FRONTRUNNERS

HESITATORS

TRADITIONALISTS

INDUSTRY 4.0

The new industrial revolution
How Europe will succeed

MARCH 2014

Roland Berger
Strategy Consultants

THE BIG 3

 **40%**

is the share of worldwide manufacturing (a total of EUR 6,577 bn) held by emerging countries. They have doubled their share in the last two decades. As part of traditional industrial economies, Western Europe has lost over 10% of manufacturing value added, from 36% to 25%
p. 4

 **1,350 bn**

To assume a leading role in Industry 4.0, Europe will have to invest EUR 90 bn a year over the next 15 years – a total of EUR 1,350 bn
p. 15

 **20%**

Traditional industrial policy will not provide enough support for value creation in Europe. To reach the goal of 20% industrial value added (from 15% today), we propose a new agenda for shaping a vision of Industry 4.0 in Europe
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Industry 4.0
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Europe's industry has lost ground in the past two decades. Now the cards are being reshuffled. There is a chance that Europe will increase its dwindling industry share from 15% up to 20% of the region's value added.

Industry plays a central role in the economy of the European Union, accounting for 15% of value added (compared to 12% in the US).¹⁾ It serves as a key driver of research, innovation, productivity, job creation and exports. Industry generates 80% of the EU's innovations and 75% of its exports. Including its effect on services, industry could be considered the social and economic engine of Europe. Yet European industry has lost many manufacturing jobs over the last decade, and is facing tougher competition from emerging markets. The ghost of "deindustrialization" currently haunting European governments and the European Commission is galvanizing them into action.

European industry is fundamentally diverse: While the German and Eastern European industrial sector is gaining market share and seeing productivity grow rapidly, other EU states are on the road to deindustrialization. French and British industry in particular have seen their market share shrink drastically since 2000, followed by southern European industrial sectors such as Spain's.

Is this industrial fracture in Europe inevitable? Couldn't traditional industrialized countries on the road to deindustrialization focus on high value-added

service activities, leaving Germany and Eastern Europe to be the industrial powerhouse of Europe? We don't think so. There is a compelling case for Europe to strengthen and develop its industry in all of its countries.

1. The world's two industrial fractures

The global industrial footprint has changed dramatically over the past 20 years. In the early 1990s, the world's manufacturing value added stood at EUR 3,451 billion in 1991. Over 60% of that could be attributed to six major industrial nations – the US, Japan, Germany, Italy, the UK and France. At that time, emerging countries only produced 21% of the manufacturing value added. **A**

This gap is even more striking when looking at the evolution of industrial jobs in different countries. The number of manufacturing jobs in China and Brazil increased by 39% and 23% respectively, whereas in Germany this figure decreased by 8%, in France by 20% and in the UK by 29%.

All of the traditional industrialized countries experienced a decline in manufacturing employment due to

1) This publication refers to EU 28 and uses the European Commission's definition of "industry" as "manufacturing", excluding mining, construction and energy.

three main factors. Firstly, the major productivity gains achieved in mature economies over the last few decades. Secondly, the loss of market share to newly emerging competitors. And thirdly, outsourcing of activities such as logistics, facility management, maintenance and different types of professional services to the service industry. This outsourcing often resulted in the relocation of the activity. With this outsourcing trend now coming to a close, increased productivity and international competition are the main drivers of the decrease in industrial employment. But while some traditional industrialized countries have adapted to this new situation, others have not.

THE FIRST FRACTURE appeared with the rise of emerging countries. This incursion was led by BRIC (Brazil, Russia, India and China), but European countries such as Poland, Romania and the Czech Republic soon followed. Between 1990 and 2011, manufacturing value added saw robust growth, up to around EUR 6,577 billion. Over that period, the traditional industrialized countries saw their average manufacturing value added increase by 17%, while in the emerging industrial countries it increased by 179%. The emerging countries now represent 40% of the total manufacturing value added worldwide.

A SECOND INDUSTRIAL FRACTURE recently appeared among the traditional industrialized countries. A few have retained high industrial value added despite the significant decline in jobs: Germany, Italy and Switzerland have kept their industrialization rate (manufacturing value added as a percentage of total value added) around 20% over the past 10 years. Others, however, saw both industrial employment and value added fall. This is the case for France, whose rate of industrialization has decreased from 15% in 2001 to 11% in 2011. Spain and the UK followed the same trend. **B**

These two fractures cut right across Europe, making the continent's industry extremely diverse. And regarding the future strategy for industrial value creation, Europe seems to be drifting apart as opposed to moving in one direction.

Traditional industrialized countries such as Germany, Sweden and Austria capture important value added

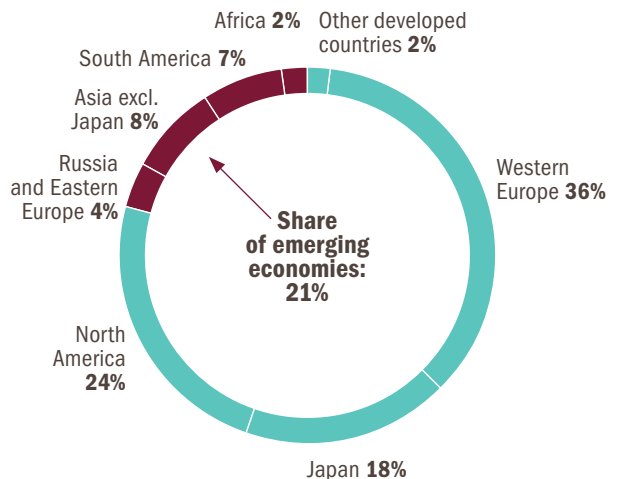
A

FIRST FRACTURE: THE RISE OF THE EMERGING ECONOMIES AS INDUSTRY PLAYERS

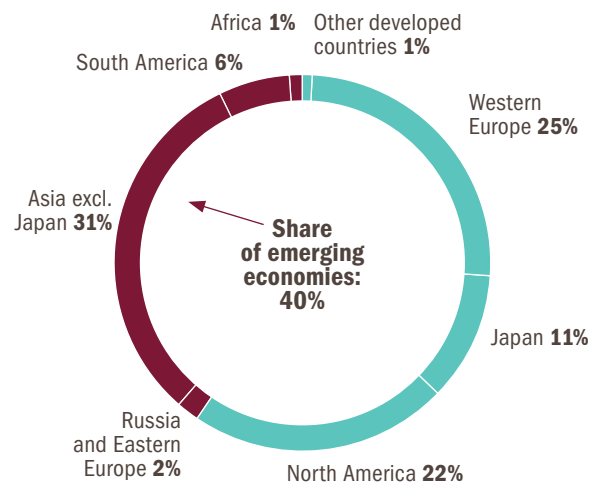


Manufacturing value added¹⁾

1991
EUR 3,451 bn



2011
EUR 6,577 bn



1) UNCTAD data in constant 2005 USD, converted into EUR (2005 exchange rate)

■ Traditional industrial economies ■ Emerging economies

in key sectors. But Europe also has several industrialized countries on its eastern side, such as Poland, Romania and the Czech Republic, where industry's role in the economy has always been strong (over 20% of the national value added). Their main advantage used to lie in low-cost manufacturing, and the value added per job is still lower than in traditional industrialized countries. But recently established plants in these territories are brand new, highly automated, and will enable the rapid development of high value-added activities. Meanwhile, France, the UK, Spain and Belgium are facing considerable decline in industrial employment and value added.

Europe is now at a crossroads. Countries clearly need some industry. But Europe as a whole has to determine what the new pattern of industrialization among its member states should be.

2. Why does Europe need industry?

Industry is a core element of the value chain. When plants move to a new location, they often take with them expertise and employment in high value-added sectors: development (product and process design), sales and marketing. To maintain high-quality services in an area, an innovative and creative manufacturing industry is critical. The trend toward deindustrialization in some European countries puts Europe at risk of losing high-value activities.

Industry is critical to ensure a balanced labor market and skills pyramid. The ratio of skilled jobs is higher in industry, whereas the production of services is often characterized by a concentration of highly skilled jobs (engineering, consulting, information technology, research, etc.) or, conversely, low skilled jobs (tourism, distribution, etc.). Deindustrialization weakens the European middle class, because it moves the focus away from mid-salary jobs. The structural change will cause a mismatch of supply and demand on the labor market. In the long run this polarizes society.

Industry and services are two sides of the same coin. Although some argue that services may eventually replace manufacturing, this is unlikely as the two

sectors are closely intertwined. Manufacturing creates value in the service sector (e.g. product-related services such as maintenance, business-related services such as accounting, or restaurants, hotels, etc.). 40% of jobs in the European manufacturing sector are service-related, and on average, services make up about a quarter of all inputs bought by EU industry. On the flipside, new services, e.g. in the cloud economy, are changing manufacturing and adding more value in the sector. Deindustrialization in some European countries is therefore a cause for concern because it affects more than just industry – it could impact European competitiveness as a whole.

An industrial imbalance creates a rift in trade policies. Ultimately the growing gap between European countries in terms of industrial performance has an impact on European international trade relationships. On one side of the gap are countries with a strong industrial sector, which are dependent on exports and keen on open borders, and on the other side, countries with a weak industrial sector that are more inclined to put up barriers to protect themselves.

Innovation, automation and sophisticated processes are at the root of industrial success strategies and have proven to be critical in maintaining a leading position. Therefore, looking toward the future is critical. Reindustrialization needs to be much more than simply rebuilding structures of old-fashioned manufacturing that vanished some time ago. Imitating the successful business models of countries such as Germany, Sweden or Austria is not a viable solution for the rest of Europe either. A successful approach to reindustrialization should take into account the changing environment and align processes, production and products to the new situation. And Europe's industrial future has to be envisioned and designed to cross borders.

B

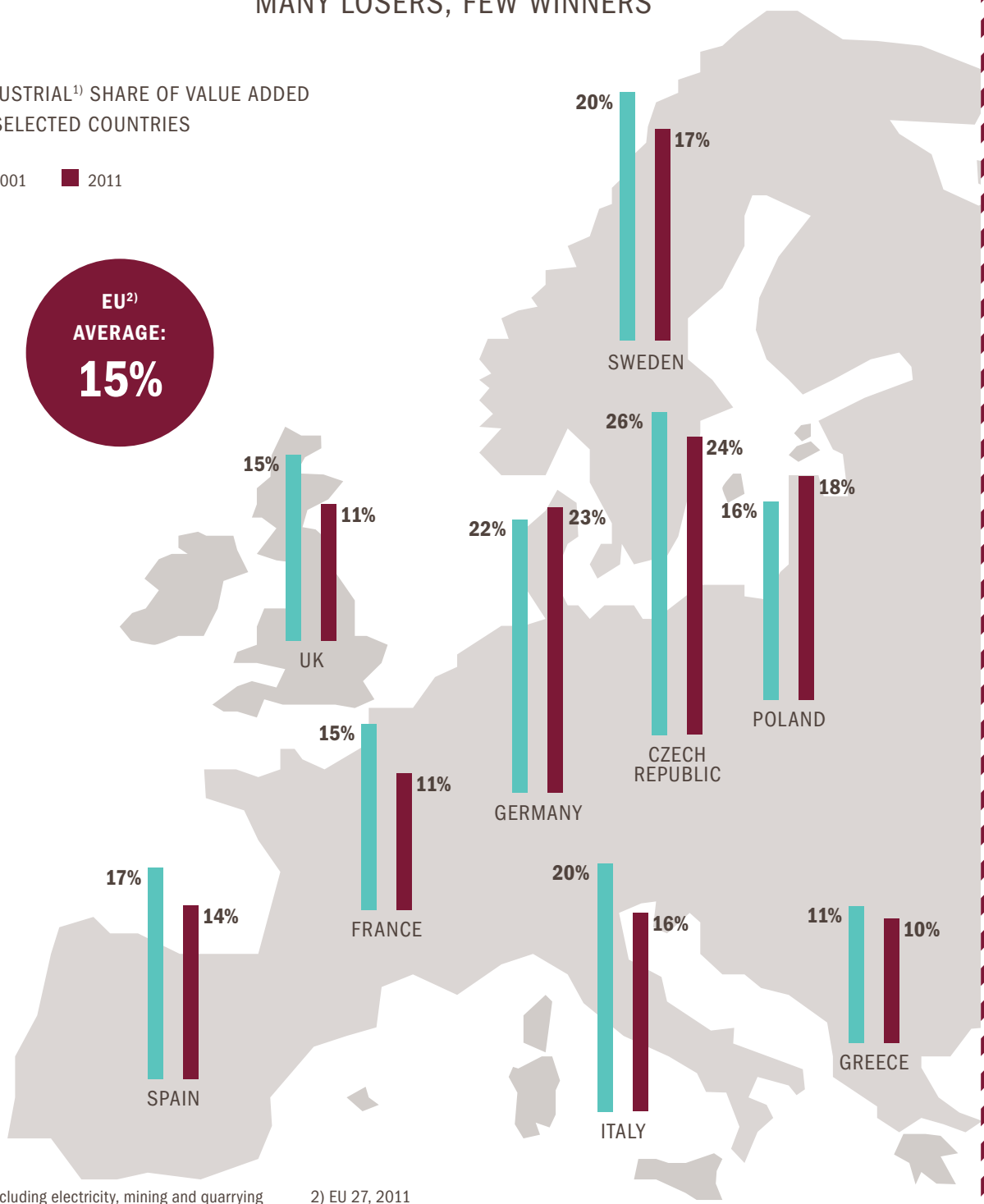
EUROPE – A DIVERSE PICTURE

MANY LOSERS, FEW WINNERS

INDUSTRIAL¹⁾ SHARE OF VALUE ADDED
IN SELECTED COUNTRIES

■ 2001 ■ 2011

EU²⁾
AVERAGE:
15%



1) Excluding electricity, mining and quarrying

2) EU 27, 2011

Source: UNCTAD

The fourth industrial revolution is already on its way. Revolutions are fast, disruptive and destructive. And there is no going back. Industry 4.0 will be an answer to the challenges lying ahead.

Since the beginning of the 21st century, we have been experiencing a digital transformation – changes associated with innovation in the field of digital technology in all aspects of society and economy. Some experts say that what we have seen so far accounts for a tenth of what is still ahead. This trend is also affecting the way goods are manufactured and services are offered.

1. The fourth industrial revolution and Industry 4.0

Western civilization has already witnessed three industrial revolutions, which could also be described as disruptive leaps in industrial processes resulting in significantly higher productivity. The first improved efficiency through the use of hydropower, the increasing use of steam power and the development of machine tools. The second brought electricity and mass production (assembly lines), and the third and most recent further accelerated automation using electronics and IT.

The fourth industrial revolution is already on its way. However, while some areas will see fast and disruptive changes, others will change slowly and steadily – a more "evolutionary" pace. In either case, there is no going back. This time, physical objects are being seamlessly integrated into the information network. The Internet is combining with intelligent machines,

systems production and processes to form a sophisticated network. The real world is turning into a huge information system.

"Industry 4.0" provides the relevant answers to the fourth industrial revolution. It has to be differentiated from smaller concepts such as the "Internet of things", "maker movement" or "factory 4.0". Industry 4.0 emphasizes the idea of consistent digitization and linking of all productive units in an economy. Let's take a look at the key characteristics of the new industrial landscape:

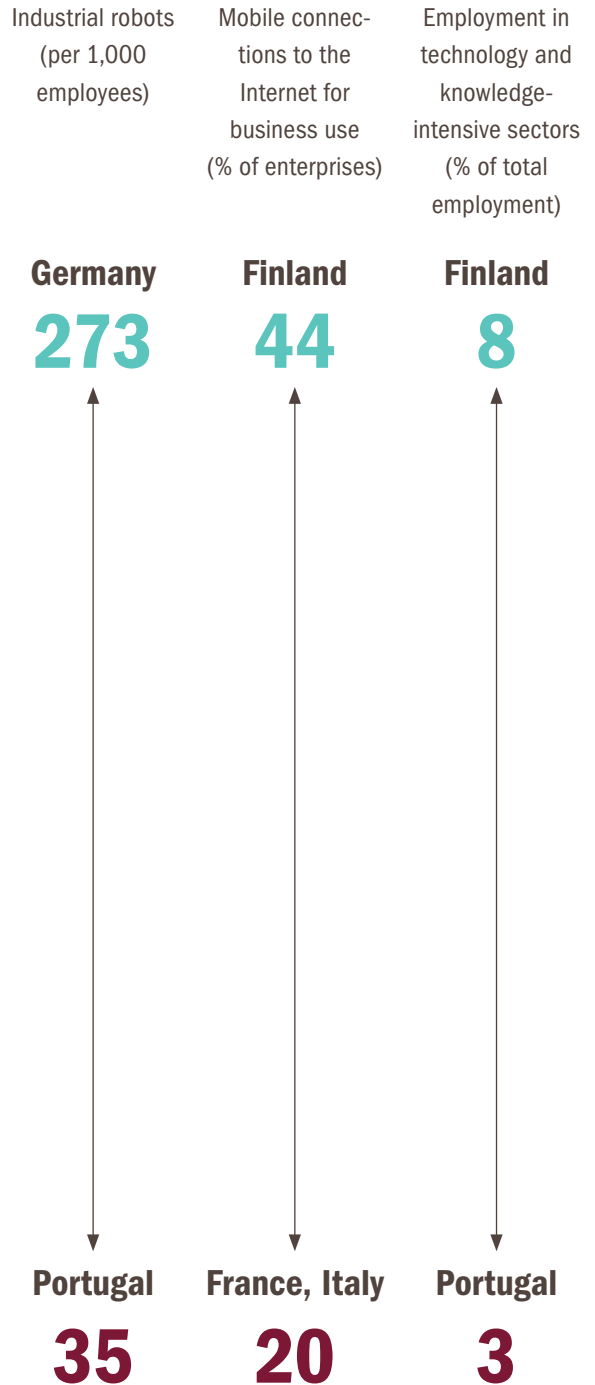
CYBER-PHYSICAL SYSTEMS AND MARKET-PLACE. IT systems today are already at the heart of the production system. In Industry 4.0, those systems will be far more connected to all sub-systems, processes, internal and external objects, the supplier and customer networks. Complexity will be much higher and will require sophisticated marketplace offerings. IT systems will be built around machines, storage systems and supplies that adhere to a defined standard and are linked up as cyber-physical systems (CPS). These can be controlled in real time. The plants and systems of the future will have clearly defined, similar interfaces. Using these technologies will make it possible to flexibly replace machines along the value chain. This enables highly efficient manufacturing in which production processes can be changed at short notice and downtime (e.g. at suppliers) can be offset.

SMART ROBOTS AND MACHINES. Robots already replaced human workers in the last revolution. The number of multipurpose industrial robots developed by players in the Industry 4.0 supplier segment and used in European manufacturing has almost doubled since 2004. In countries such as the Czech Republic or Hungary, the rise is even more impressive. In the future they will become intelligent, which means able to adapt, communicate and interact. This will enable further productivity leaps for companies, having a profound change on cost structures, skills landscape and production sites. Smart robots will not only replace humans in simply structured workflows within closed areas. In Industry 4.0, robots and humans will work hand in hand, so to speak, on interlinking tasks and using smart sensed human-machine interfaces. The use of robots is widening to include various functions: production, logistics, office management (to distribute documents). These can be controlled remotely. If a problem occurs, the worker will receive a message on his mobile phone, with link to a web cam, so he can see the problems and give instructions to let the production continue until he comes back the next day. Thus, the plant is operating 24 hours/day while workers are only there during the day. No more night shifts, and productivity skyrockets.

BIG DATA. Data is often referred to as the raw material of the 21st century. Indeed, the amount of data available to businesses is expected to double every 1.2 years. A plant of the future will be producing a huge amount of data that needs to be saved, processed and analyzed. The means employed to do this will significantly change. In France, 63% of plant managers consider cyber security to be crucial to their competitiveness. Innovative methods to handle big data and to tap the potential of cloud computing will create new ways to leverage information.

NEW QUALITY OF CONNECTIVITY. While at the beginning of the 21st century connectivity was a feature of only the digital world, in Industry 4.0 the digital and real worlds are connected. Machines, workpieces, systems and human beings will constantly exchange digital information via Internet protocol. This means

INDUSTRY 4.0 DATA SPOTLIGHTS I
Top and bottom positions¹⁾, 2012



1) Analysis of the 15 EU countries with the highest GDP

Source: IFR, Eurostat

physical things will be linked to their data footprint. Production with interconnected machines becomes very smooth: one machine is immediately informed when the part is produced in another machine, as well as the conveyor or the logistic supply robot. Machines automatically adapt to the production steps of each part to manufacture, coordinating almost as in a ballet to automatically adjust the production unit to the series to be manufactured. Even the product may communicate when it is produced – via an Internet of things – and ask for a conveyor to be picked up, or send an e-mail to the ordering system to say "I am finished and ready to be delivered". Plants are also interconnected in order to smoothly adjust production schedules among them and optimize capacity in a much better way.

ENERGY EFFICIENCY AND DECENTRALIZATION. Climate change and scarcity of resources are megatrends that will affect all Industry 4.0 players. These megatrends leverage energy decentralization for plants, triggering the need for the use of carbon-neutral technologies in manufacturing. Using renewable energies will be more financially attractive for companies. In the future, there may be many production sites that generate their own power, which will in turn have implications for infrastructure providers. In addition to renewable energy, decentralized nuclear power – e.g. small-size plants – is being studied as a way to supply big electro-intensive plants, thus providing double-digit energy savings.

VIRTUAL INDUSTRIALIZATION. There is nothing more difficult than launching a new plant or a new product in an existing plant: hours of adaptations, trials, pre-series testing requiring a high-caliber launch team and numerous unexpected cost overruns. A day lost through a standstill of production means a huge revenue loss for many businesses. Industry 4.0 will use virtual plants and products to prepare the physical production. Every process is first simulated and verified virtually; only once the final solution is ready is the physical mapping done – meaning all software, parameters, numerical matrixes are uploaded into the physical machines controlling the production. Some initial trials have made it possible to set up an automotive

part production unit in three days – as opposed to the three months it requires today. Virtual plants can be designed and easily visualized in 3D, as well as how the workers and machines will interact.

C FACTORY 4.0 gives an overview of the firm as an interconnected global system on a microeconomic level. Our graph depicts the key factors: outside the factory we see a 4.0 supplier network, resources of the future, new customer demands and the means to meet them. Inside the factory, we envision new production technologies, new materials and new ways of storing, processing and sharing data.

2. Industry 4.0: What is changing for companies?

We are describing the big picture of a profoundly transformed industry landscape. Will it be a threat or an opportunity? Both, as it turns out. Manufacturing companies in the traditional sense will surely remain in the market. But established players will undoubtedly change their organizations, processes and capabilities in whole or in part during the industrial revolution. And there will be new competitors with radically new industrial business models. New transforming technologies such as the Internet or mobile phones have not been successful just because they were new, but because they were also followed by a societal transformation. The Internet as a technology did not invent social networks, but social networks developed thanks to the Internet, and also enabled it to develop further. The same thing will happen with Industry 4.0, by bringing new functionalities that will change the rules of the game for the industry players.

The development will proceed at different rates in different industries. Here we have tried to identify some cross-industry implications:

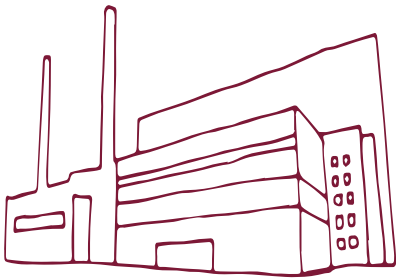
OUTPUT: PERSONALIZED, LOCAL PRODUCTION AND MASS CUSTOMIZATION. Industry 4.0 brings more freedom and flexibility into the production process. So it will become possible to create products tailored to segment-by-one customer needs at relatively low marginal cost. Also distribution processes for

C

FACTORY 4.0

THE FULLY CONNECTED WAY OF MAKING THINGS

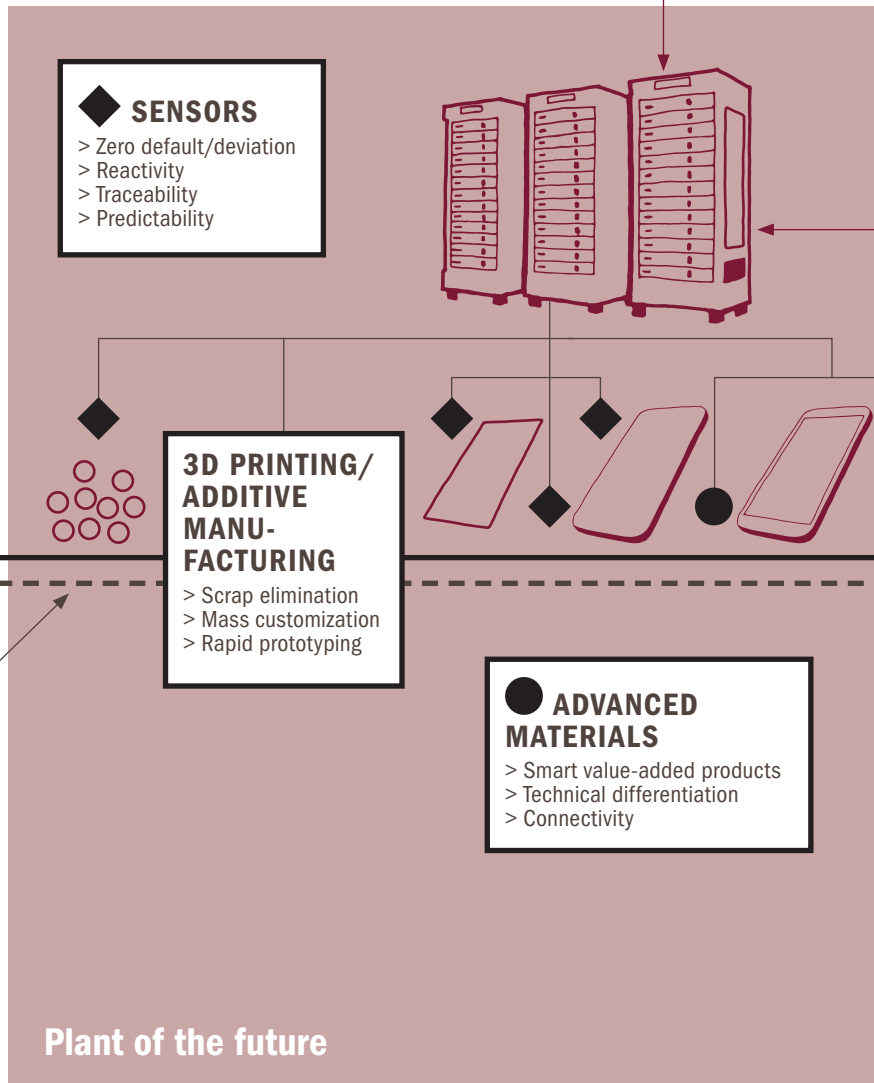
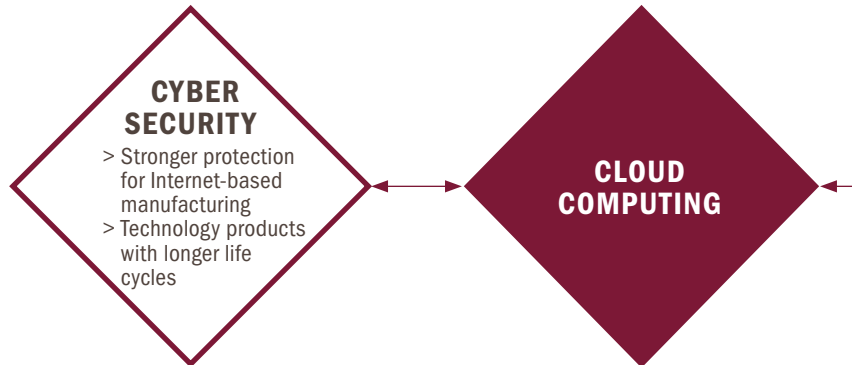
Industry 4.0 is based on new and radically changed processes in manufacturing companies: Factory 4.0. In this concept, data is gathered from suppliers, customers and the company itself and evaluated before being linked up with real production. The latter is increasingly using new technologies such as sensors, 3D printing and next-generation robots. The result: production processes are fine-tuned, adjusted or set up differently in real time.

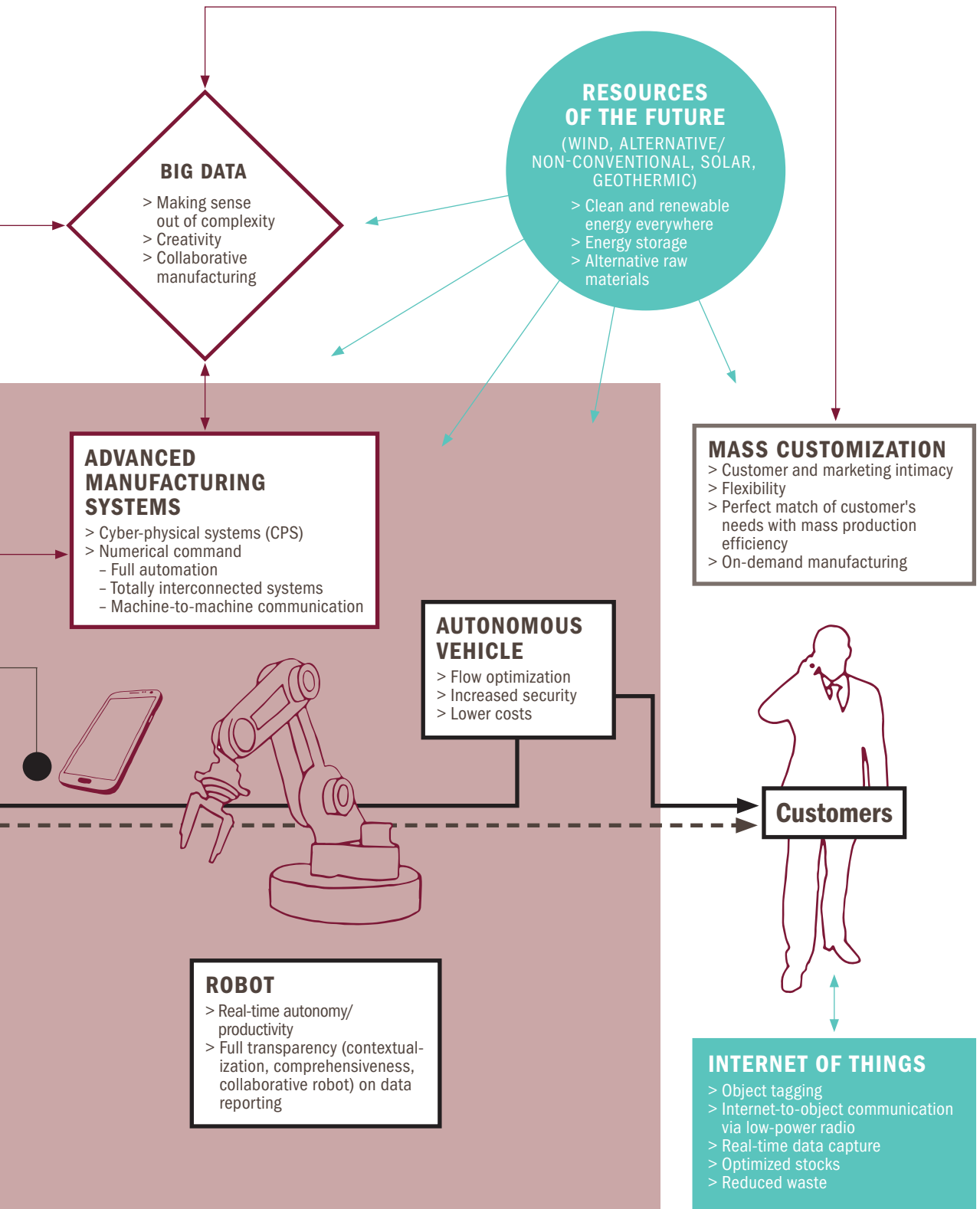


Suppliers

LOGISTICS 4.0

- > Fully integrated supply chain
- > Interconnected systems
- > Perfect coordination





spare parts or not too complex customer goods might get easier, if nothing but data has to be transferred while the physical production can be done locally. This becomes visible in the broadening of 3D printer usage: The market for 3D printers and related services rose to EUR 1.6 billion in 2012, and is estimated to rise to about EUR 4.4 billion annually by 2017. This approach can become a game changer if you think about producing in a high- or a low-cost country. A 3D printing plant can become economically viable and competitive in a high-cost country, by being less sensitive to labor cost while still providing the proximity necessary for affordable personalization.

PROCESS: NETWORKED MANUFACTURING AND CLUSTER DYNAMICS. Businesses will operate in dispersed locations, drawing on skills spread across their empires. Groups of suppliers concentrated in small areas help ideas flow more freely. One of the opportunities lies in a phenomenon called "industrial democracy", meaning that the blurring frontiers between the information and physical worlds may lower entry barriers for smaller or more specialized companies. In some areas, the distribution of power between multinationals and SMEs or very focused market players may shift. The challenge for business lies in the assumption that the complexity of production and supply networks will grow significantly. This type of approach could lead to "mobile manufacturing units": small and autonomous manufacturing cells that could be shipped in some countries to locally develop production for the local market without building a full plant. This type of game changer could modify the approach of industrial foreign direct investment with regards to emerging markets and localization needs.

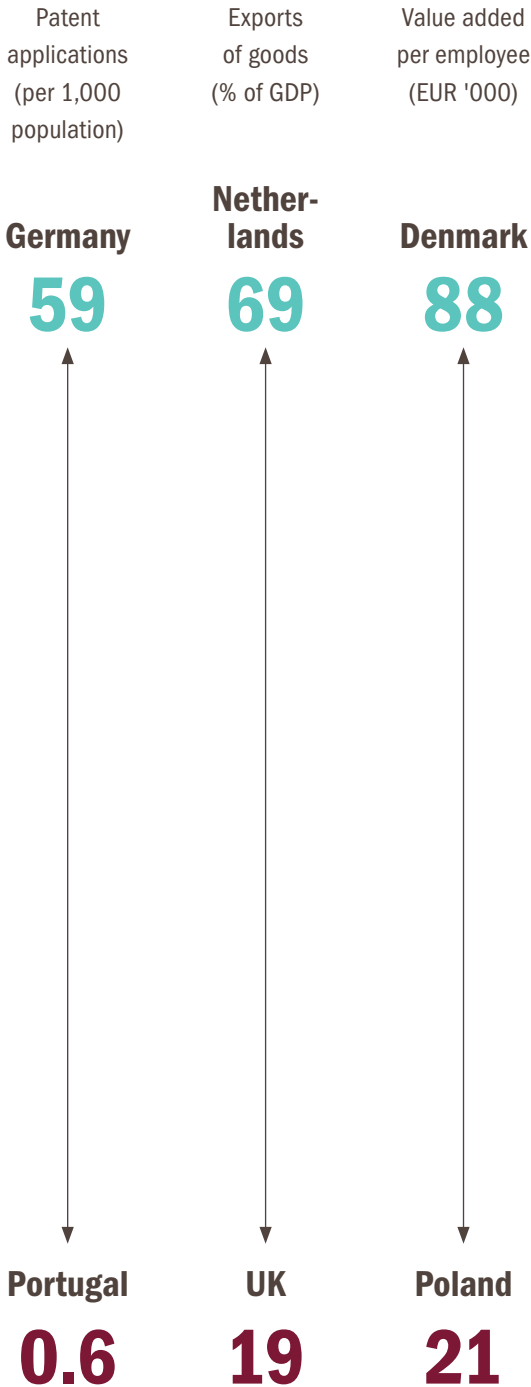
BUSINESS MODELS: FRAGMENTATION OF THE VALUE CHAIN. In a complex and intertwined manufacturing network, the roles of designers, physical product suppliers and the interfaces with the customer (contractor) will change. The first step is the fragmentation of the value chain. We have seen this before in monolithic industries like music or the media: After fragmentation, countless small entrants have lower barriers to entry. As business leaders rethink and

restructure their value chains new challenges in regard to cost and profit ownership arise. Where will the high margins be in the future? In the design, in process handling or in customer data expertise? New business models could also be created if the "long tail" philosophy that was brought up by the Internet can be extrapolated to the Internet of things.

COMPETITION: CONVERGING FRONTIERS. Traditional industry boundaries are becoming blurred, as are the boundaries between industrial and non-industrial applications. Going forward, the focus will be on industrial working methods, including the reproducibility not only of identical products but also of services. Services can be mass-produced too. High-quality digital (outsourced) services and a fail-safe, comprehensive digital infrastructure are becoming the fundamental prerequisites for successful Industry 4.0. And there will be even closer dovetailing between IT/telecommunications firms and traditional manufacturing companies. The former might in some cases become the new industry leaders. The most recent examples: Facebook is acquiring a stake in the drones business and Internet giant Google is entering the biotech sector and researching new methods of combating age-related diseases. In Industry 4.0, the supplier hierarchies/pecking orders are likely to change. Today, physical machine and tooling suppliers harvest the biggest margins with their industry clients. But in a cyber-physical system world, these suppliers will lose importance. Instead, suppliers of sensors, IT and software might take their place in Industry 4.0, while machine and tooling companies shift down to tier 2.

SKILLS: INTERDISCIPLINARY THINKING IS KEY. The dominant technologies of Industry 4.0 will be IT, electronics and robotics. But it will also embrace other knowledge areas such as biotech and nanotech. It is to be expected that businesses in Industry 4.0 need both enhanced social and technical skills. There will be a shift toward design thinking instead of production thinking. Corporate cultures with continuous training and development in the workplace and lifelong learning are becoming a core competency. A lot of collaborative and cross-cultural competencies will be re-

INDUSTRY 4.0 DATA SPOTLIGHTS II
Top and bottom positions¹⁾, 2012



1) Analysis of the 15 EU countries with the highest GDP

Source: World Bank, UNCTAD

quired to be able to work in network environments sustainably. On the technical side: connecting the network will mean a lot of standardization. Therefore, the technical competency profile will be rather T-shaped and interdisciplinary than specialized. Analytics specialists, engineers and programmers will have to be able to think across business models, production processes, machine technology and data-related procedures. New job titles will emerge such as data scientist and cyber safety guards.

GLOBALIZATION: LIGHT FOOTPRINT. The organization of the future will concentrate on selected hotspots, rather than a comprehensive global presence. There will be open production sites ("makerspaces") and clusters. Firms will not necessarily have to sustain huge production sites to operate cost-efficiently. Sometimes it will be cheaper to transfer data and produce locally on a small scale. Organizations will be set up in a much more decentralized and flexible way.

3. How much does Europe have to invest?

Industry 4.0 is an opportunity to change the economic rules of the industry, especially to overcome the deindustrialization trends faced by some European countries. In the current industry setup, there are ways to maintain Europe's competitive edge compared to low labor cost countries: selecting high added-value products or activities, having modern and automated production units with critical size and implementing manufacturing excellence practices. With Industry 4.0 the demand for highly qualified services will increase activities to support this more complex industry.

From an economic point of view, if industry wants to offer incentives to investors it has to go about it in a different way due to its risk profile. We assume investors expect a return on capital employed (ROCE) of 15% as an average for European industry. In the box "Traditional Industry" on the horizontal axis (see figure on page 14), we find countries achieving this with activities that require low capital intensity and low value-added products. The countries here with low labor costs

are leveraging a labor-intensive workforce and more manual processes. Those are rare in Europe. Nevertheless, this box contains France, Spain and the UK. Due to underinvestment over the years, their industrial assets have progressively lost their value. At the same time, labor costs are high. Therefore, profitability is declining and competitiveness is decreasing. **D**

In the box "Industry 4.0", we find countries with state-of-the-art production processes. They are more competitive (due to automation and scale effects) and can afford higher margins, which pay off their capital needs.

The graph on the right shows the positioning of Europe in general as well as France and Germany in 2012. Germany is positioned with an even higher ROCE than 15%. Therefore, the profit generated will help the country to invest its employed capital in the future industry technologies. By contrast, France currently earns much lower margins from its industry, preventing it from investing and thus eroding the capital employed.

If the European economy can achieve a strong position within Industry 4.0, divestment is no longer a threat. Industry 4.0 requires investments. But Industry 4.0 also substantially increases capital productivity, as mentioned above with the potential benefits (mass customization, networked manufacturing, etc.) which optimize the way capital is leveraged. Europe's economy will be able to move upward along this curve – meaning firms that invest more capital will be more profitable.

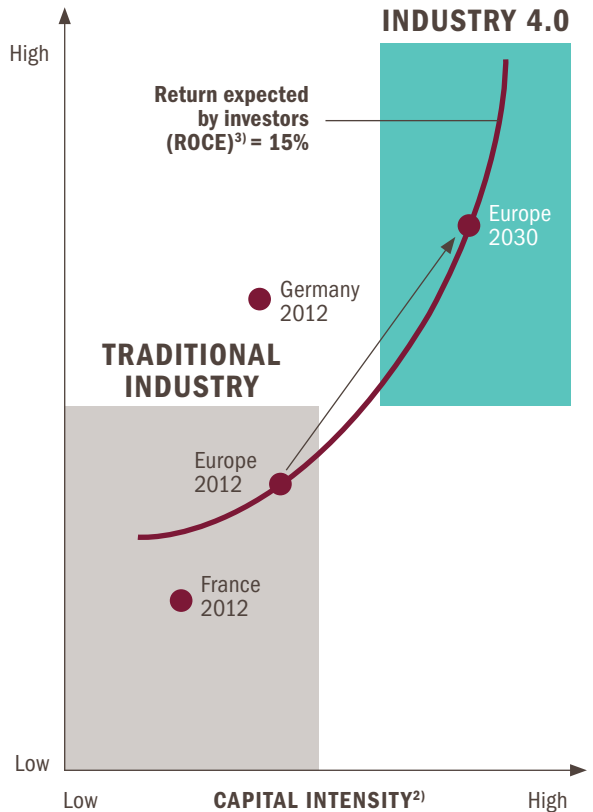
Europe has to act now. In 2012, the EU Commission set the goal of boosting manufacturing's share of GDP in Europe from 15% to 20% by 2020. This objective is quite challenging, because advanced manufacturing economies such as Germany, Poland and Austria will not be able to boost their shares much more. Even in China, manufacturing only accounts for 30% of the economy – and this figure is declining. Against this backdrop, reaching the 20% goal in Europe would mean that countries such as the UK and France, which for decades have been shutting down their industries and are now at around the 10% mark, would have to reestablish manufacturing on a huge scale in less than seven years.

D

INDUSTRY 4.0 WILL INCREASE PROFITABILITY AND CAPITAL INTENSITY

Dimensions of economic impact

PROFITABILITY¹⁾

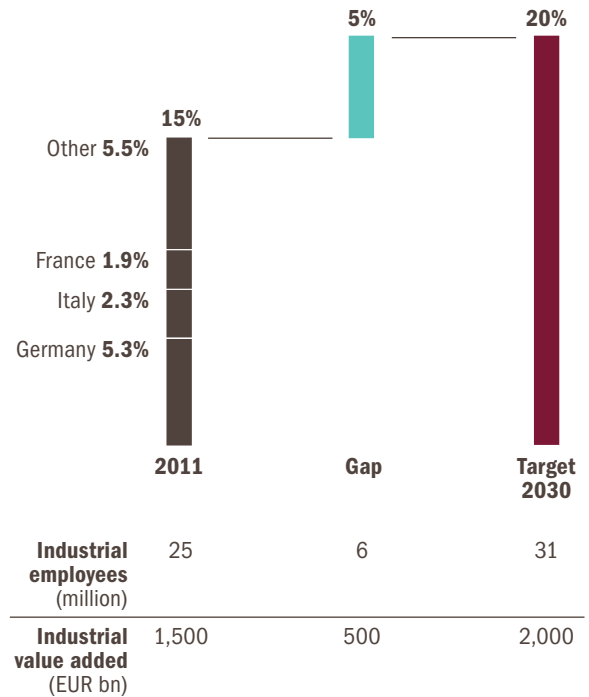


- 1) EBIT as % of value added;
margin: Low = below 5%, High = above 20%
- 2) Capital employed/value-added;
margin: Low = below 0.5, High = above 1.3
- 3) ROCE = profitability x capital intensity

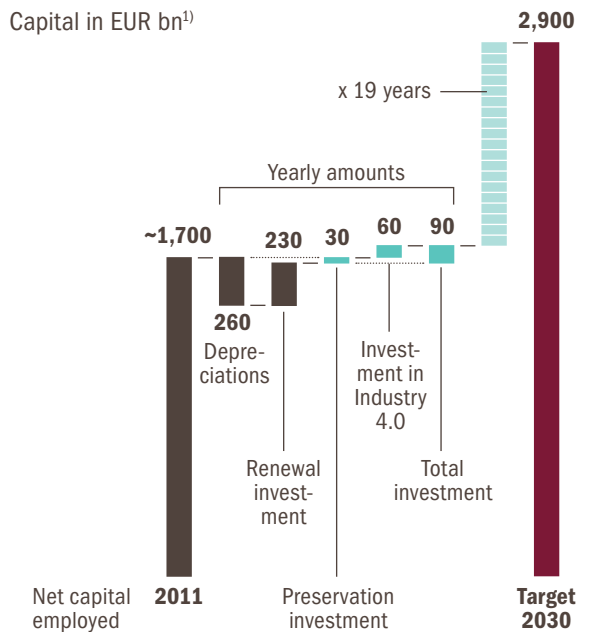
E This target is certainly not achievable considering today's situation (Industry 3.0). Instead, it can only be achieved by taking part in the fourth industrial revolution. Reaching 20% means that Europe has to create EUR 500 billion in value added and 6 million jobs (provided current GDP growth and inflation remain the same). These figures look huge, as this amount is about double the size of the French industry. However, looking at the bigger picture and including all value-added services generated by Industry 4.0, the objective could be achieved by 2030. More concretely, it doesn't mean that a product currently manufactured in China will be manufactured by a European worker: it will be manufactured by a European robot or machine, which is programmed by a European engineer. Opportunities for new jobs could be: working in engineering centers, IT centers, virtual laboratories, big data centers, or in a control tower of a plant network, but probably not inside a plant.

🔴 How much investment does Industry 4.0 require? As shown below, the calculation of the objective in terms of ROCE and profit helps in evaluating the investment amount. Currently, the industrial investment level in Europe is EUR 30 billion lower than the level of depreciation, meaning that assets are slowly losing value. Therefore, in order to achieve the goal by 2030, European firms must keep investing about EUR 90 billion per year to generate the necessary additional value added. This would add up to EUR 1,350 billion over the next 15 years. This amount is not so large at the European level, and is far below numerous investment activities of European politics, such as the bailout programs for indebted member states.

E THE GAP THAT NEEDS TO BE BRIDGED¹⁾
Industry share as a % of total value added



HOW MUCH EUROPE NEEDS TO INVEST
Capital in EUR bn¹⁾



1) Constant depreciation assumed
Source: UNCTAD; Eurostat; Roland Berger

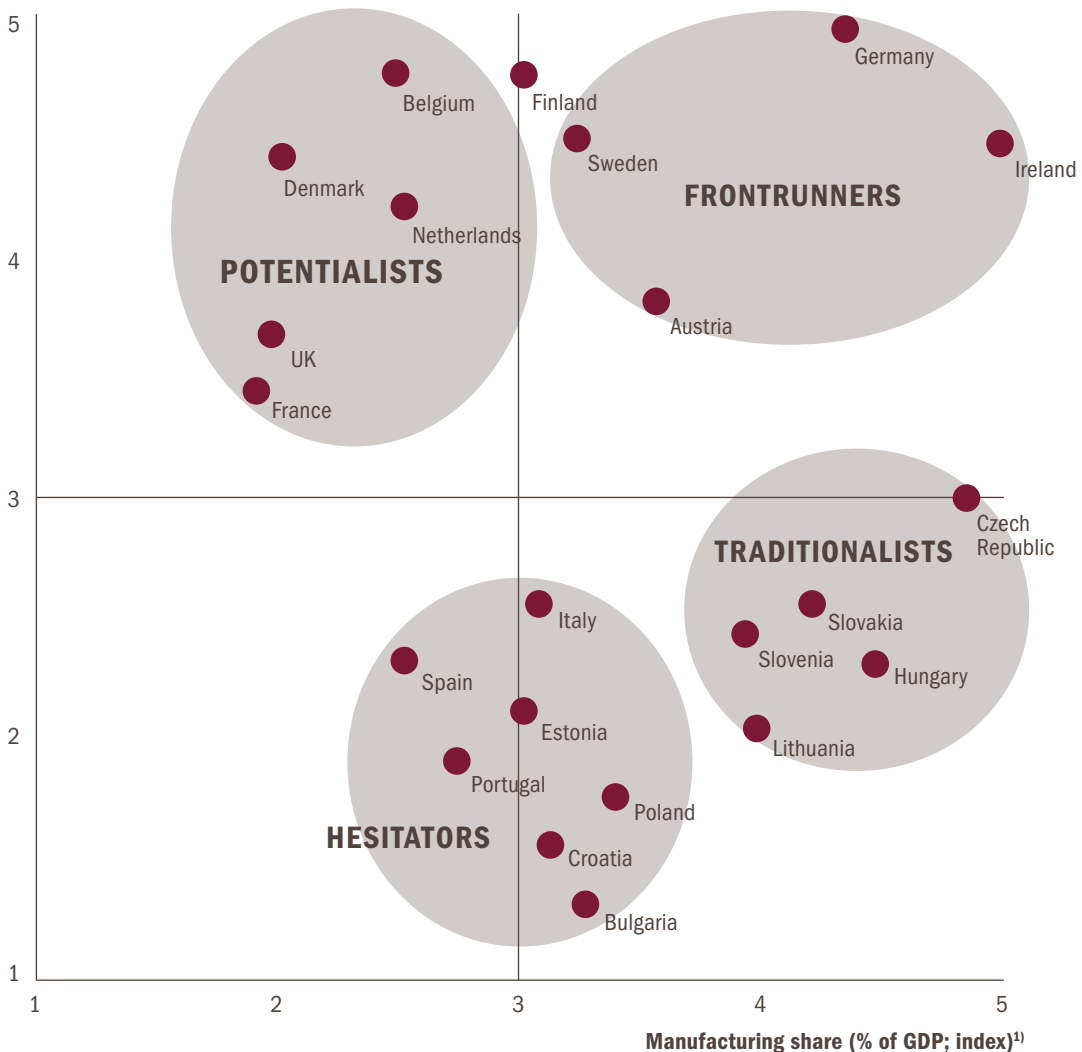


READINESS CHECK FOR EU

OUR ANALYSIS REVEALS FOUR DIFFERENT CLUSTERS

The RB Industry 4.0 Readiness Index is represented on the vertical axis. We calculated it as follows: first we bundled production process sophistication, degree of automation, workforce readiness and innovation intensity into a category we called "industrial excellence". Then we combined high value added, industry openness, innovation network and Internet sophistication into a category we labeled "value network". Each category was measured using a 5-point scale, with "5" indicating that a country is excellently prepared for the Industry 4.0 landscape. The combination of these two categories determines a country's position in the RB 4.0 Readiness Index. The horizontal axis represents the traditional industry measure – the manufacturing share.

**RB Industry 4.0
Readiness Index¹⁾²⁾**



1) 1 = low, 5 = high

2) Adjusted for outliers Cyprus, Latvia, Luxemburg, Romania, Greece

3. Is Europe ready? The RB Industry 4.0 Readiness Index

We have shown that industrial (r)evolution will change the game for industrial users, infrastructure suppliers and technology providers. New aspects need to be considered: how open is the economy? Will it be able to adapt to converging industries? How excellent are innovation networks? How qualified, flexible and interdisciplinary are employees in order to trigger Industry 4.0 within their companies?

To gain some initial insight into these questions, we created an **"RB INDUSTRY 4.0 READINESS INDEX"** for the EU's key industrial countries.

The matrix roughly divides the European economies into four major groups. The Frontrunners are characterized by a large industrial base and very modern, forward-looking business conditions and technologies (Sweden, Austria and Germany). Ireland is a special case: several big pharmaceutical producers contribute to the country's relatively small GDP, which makes them manufacturing champions. Ireland also has a large IT service sector (readiness).

The Traditionalists are found mainly in Eastern Europe. They still thrive on their sound industrial base, but few of them have thus far launched initiatives to take industry into the next era. The third group, the Hesitators – a mixture of southern and eastern European countries – lacks a reliable industrial base. Many of them suffer from severe fiscal problems and are therefore not able to make their economies future-proof.

The Potentialists are an interesting cluster. Their industrial base has been weakening over the past few years. Here we find countries such as France and the UK, which looked somewhat desperate in our analysis on pages 4 and 14. That may be true when looking at all the historical data. But in the corporate sector, we find indications of a modern and innovative mindset. They just have to find the right way to tap their potential.

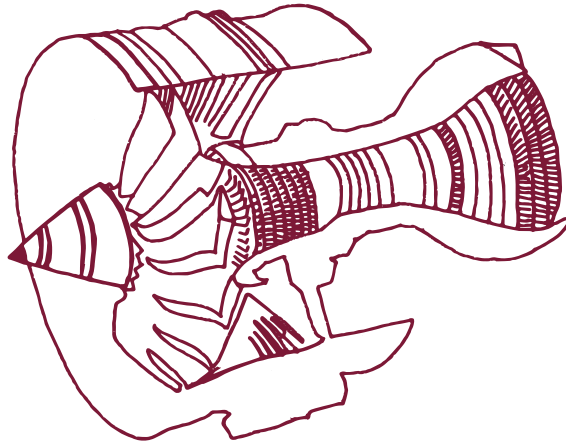
4. A look at best practices of Industry 4.0

We have identified three groups of players: Industry 4.0 technology suppliers, infrastructure providers and industrial users. Technology suppliers such as Siemens, Kuka or Dassault provide key production technologies like collaborative robots or telemaintenance systems. Infrastructure providers such as telecoms or SAP deal with supporting structures and services – for example cloud computing, big data storage and processing. Industrial users are traditional global manufacturing firms such as VW or BASF. They use technologies like rapid prototyping or energy-smart buildings to optimize their production processes.

Those groups of players are essential for making Industry 4.0 happen. As they move into Industry 4.0, companies have to be able to respond more quickly and flexibly to customer demand and fast-changing customer specifications. This change is clearly visible in logistics, for example. But companies in mechanical engineering, medical engineering and engine production are also taking their first successful steps toward setting up intelligent production processes and customized products.

PIONEERS OF INDUSTRY 4.0

HOW THE NEW MANUFACTURING LOGIC IS GAINING GROUND



Several enterprises have developed innovative ideas to shift the activities of their business units to Industry 4.0. Many others are expected to follow. Below are some examples from different countries that show how they turn production into a smarter, more virtual, more connected and more decentralized system.

TRUMPF

German toolmaker Trumpf, an Industry 4.0 supplier and worldwide market leader of laser systems, has put the first "social machines" to work. Each component is "smart" and knows what work has already been carried out on it. Because the production facility already knows its capacity utilization and communicates with other facilities, production options are automatically optimized. Customers can receive pictures of the machines in real time during the production process and have the chance to provide feedback very early on, which can help to build even better machines.

SIEMENS

German manufacturing giant Siemens, an industrial user, is implementing an Industry 4.0 solution in medical engineering. For years, artificial knee and hip joints were standardized products, with engineers needing several days to customize them for patients. Now, new software and steering solutions enable Siemens to produce an implant within 3 to 4 hours.

ROLLS-ROYCE

British aero-engine manufacturer Rolls-Royce, an industrial user as well, is gearing up to use 3D printing technology to produce components for its jet engines. Some of these parts have very long lead times due to the tooling process involved, and it can take 18 months to fill an order. 3D printing would shorten this process considerably, and also make it possible to manufacture more lightweight parts.

DASSAULT SYSTÈMES

French software provider Dassault Systèmes is pushing the integration of product development and production. This initiative's core is a 3D platform designed as a common work environment for the company, where designers and engineers can, for instance, simulate new products jointly and in real time. The connected 3D environment can also be used via cloud computing.

3 Europe is in better shape to embrace the new industrial world than many people think. Our roadmap for Europe lays the groundwork for an Industry 4.0 environment. Here's how companies and politicians can contribute.

The target for Europe to reach 20% manufacturing share of GDP for its industry is sending the message that Europe's future depends on manufacturing. This vision of a new industrial Europe is precisely the right one. We think that in the future, quickly switching over to Industry 4.0 will be a major competitive advantage for an economy over its global competitors. Europe as a whole is in better shape to embrace the new industrial world than many people think. Besides its solid industrial base, many countries are in a good position (equipment, knowledge, expertise, networks) for converting to Industry 4.0, as our RB Readiness Index shows.

European companies have a chance to develop a competitive edge here. The US has deindustrialized to a great extent and moved toward a service and high-tech economy. China has invested a lot in Industry 3.0. The country is busy rebalancing the economy towards more sustainable growth. But it is heading toward Industry 4.0 as well: The Chinese government recently formed the China 3D Printing Technology Industry Alliance. Japan is probably the most advanced country in this field, especially in robotics and automation. A pilot plant operated by a mechanical engineering company in Yokohama employs humanoid robots with 80% of the productivity of a human worker. The fact that the company has not laid off staff members is a clear sign

that Japan is moving toward automation in response to the rapid aging of its population – 40 million people fewer in 2050. However, it is important for all European players – governments and industry alike – to set off for the new era at the same time.

G THE "NEW" INDUSTRY IS A KIND OF ECOSYSTEM. It will be difficult to manage the process centrally, but there will be reinforcing effects if the right levers are applied by the players in the system. Therefore it is crucial to communicate the idea that players in the corporate sector (technology suppliers, infrastructure providers and industrial users) and European governments will profit the most if their Industry 4.0 initiatives go hand in hand.

As shown in the chart below, Industry 4.0 will be adopted if all parties are focused on a common objective: policy makers and politicians, public and private experts, industry associations and large group infrastructure providers and of course end users. As opposed to industry in the last century, it is not possible to make a 4.0 industrial policy, in the sense that governments or the EU would decide what to do in this field, which technology to use, how much money to spend and who will be the future champions. This top-down era is over because complexity is too high, innovations come from bottom-up approaches, markets

G

NEW INDUSTRY 4.0 ROADMAP

Industry 4.0 will be implemented in three steps involving all players

STEP	ACTION	PLAYER
1. SET CONDITIONS FOR THE 4.0 ECOSYSTEM	Promote Industry 4.0 as a European idea	European and state policy makers
2. BOOST INDUSTRY 4.0 OFFERING	Accelerate innovation	Public and private partners, forming collaborative networks and/or innovation clusters
	Develop future champions	Equipment and infrastructure industry players and associations
	Establish a dynamic digital environment	Infrastructure providers and financing
3. PROMOTE FAST ADOPTION AS COMPETITIVE LEVER	Progressively transition to 4.0	Industrial users (pharmaceuticals, automotive, aerospace, manufacturing, etc.)

are risky, uncertain and volatile, and the winners of today can easily become the losers of tomorrow. Therefore, to put the 4.0 industrial ecosystem in place, all parties need to align and move in the same direction, but with an open approach, promoting entrepreneurship, risk taking, innovation and agility.

1. Set the conditions for the 4.0 ecosystem

A shared vision for policy makers and governments is needed. Industry 4.0 must be understood by governments and policy makers, and promoted as a priority for Europe. A political and economic agenda that focuses on old industrialized policies will not work for

Europe's "new" industry. Depending on the country, this type of policy includes strong protectionism, subsidies for business champions and industry-friendly tendering policies, to name just a few. In Industry 4.0 we try to think more systemic. European and government policy makers' role is to establish the framework, basically: transform the idea of Industry 4.0 into a European idea. This requires a common understanding of European industrial policies. Industry 4.0 must be prioritized and coordinated. To do that successfully, Europe needs a roadmap equipped with incentives and actions to support communication of the vision of Europe as an Industry 4.0 hotspot. Legislation should create an "infrastructure" for promoting entrepreneurship.

2. Boost Industry 4.0 offering and assume leadership

Developing leaders in Industry 4.0 solutions requires three success factors:

ACCELERATE INNOVATION. Industry 4.0 encompasses a broad set of technologies with a huge field for innovation and creative solutions. Pioneering business models will create new opportunities for adding value, but those will depend on breakthrough innovations for technology and the ability to bring them to market. This is an area where public and private partners have to collaborate closely. Pan-European collaborative networks or innovation clusters can be set up between countries, universities, research institutes and businesses, combining public and private research. Companies must regularly review their strategic alignment, which will result in new methods of entering new stages of the value chain. Based on this review, they can identify missing links inside and outside the company, foster elaboration of technology roadmaps across Europe and set up research communities.

Consistent investment in R&D programs is also crucial. Companies should identify cross-border partners (corporate and science) and collaborate with them on research projects. Supported by pan-European initiatives, innovative start-ups will profit from the new opportunities. The role of those Industry 4.0 innovation clusters would be to design best practices of Industry 4.0 solutions, technology concepts, develop technology roadmaps and enhance start-up development.

DEVELOP FUTURE CHAMPIONS. There are many European companies that are very well positioned as leaders in the various fields of Industry 4.0. However, technology is evolving rapidly. The danger is not keeping up with technologies required to offer integrated solutions. A champion in machine-tooling that does not build up Internet-of-things technologies will not be able to develop the new machine generation. Therefore, players must develop a technology strategy and close the gaps. Sometimes this will only be possi-

ble through mergers and acquisitions. We expect significant consolidation among the Industry 4.0 players. Sometimes the partners in a collaboration will come as a surprise: who would have thought that Google would buy Nest (thermostatic sensors for home appliances)? Like Google-Nest, many traditional players that produce tangible products will move into intangible new technology fields and buy software start-ups or Internet companies. Or vice versa, with engineering and CAD/CAM firms buying machine equipment firms. This type of move will reshuffle industry segmentation which is organized by physical sectors (machine & tooling, electrical equipment, software, engineering services).

It might be helpful to organize new Industry 4.0 associations to support the development of a strong offering. Last but not least, we need some pragmatism in the field of antitrust policies. European companies have to gain a strong competitive position in comparison to the US and Asia. It may be wise to let some strong players emerge and consolidate based on a robust European market.

ESTABLISH A DYNAMIC DIGITAL ENVIRONMENT. The digital aspect has become mission-critical for many products and services. Therefore, Europe's "new" industry needs a competitive environment that fosters dynamic telecommunications and Internet usage. Infrastructure providers can contribute in this field, not only by providing structures for power and telecommunications supply, but also by developing standards for data transfer and security procedures. Key fields to consider include cyber security, energy, telecommunications and the cloud. Pan-European digital infrastructure initiatives will be needed, to be managed by industry players or associations.

But Europe also needs a service infrastructure. It's not only digital services that are suffering from fragmented and nationally focused offerings in Europe, but also the key areas of energy, transportation and financing. This roadmap must be supported by a specific financing plan. This might include incentives for industrial users to invest in the transition to Industry 4.0 or funding for infrastructure development.

Besides infrastructure, this dynamic digital environment also needs to foster new talent. Unsufficient education policies and a lack of mobility in some countries mean Europe cannot fully capitalize on its skills pool. The new competency fields required by Industry 4.0 need to be embedded in education. This includes fields such as software programming, data analysis or scientific computing.

3. Promote fast adoption as a competitive lever

There are two ways to move into Industry 4.0: transforming existing (legacy) plants or making greenfield investments. Both require a strong change management approach. Industry 4.0 will probably penetrate the quickest through greenfield investments, coming either from new business opportunities. Also repatriation of manufacturing from developing countries to Europe could be a trend in Industry 4.0. But it will require a different setup. Fostering relocation of activities is a good lever to enhance transition to 4.0, create value added in Europe and develop qualified jobs. This may require investment programs or incentives.

The other approach is to progressively adapt the legacy manufacturing footprint. Transforming a legacy plant into a modern 4.0 factory has a significant social impact and requires a competency shift and new ways of working and manufacturing. Numerous actions are possible, but have to take social aspects into account. For instance, the French Robotics Association has launched its "Robocaliser" program. Since French unions still perceive robotization as a job killer, the program promotes the idea of using robots as a way to avoid delocalization.

Companies should consider seizing the opportunity to use 4.0 technologies by developing tailored manufacturing strategies that best leverage the new technologies. Industrial users that share European Industry 4.0 knowledge and build best practice communities will be key to a successful transition. This is a good opportunity to establish 4.0 tech shows in all end-user industries because the overall solutions will be ex-

tremely specific: 4.0 in the automotive industry won't be the same approach as in the railway or aviation sectors, simply because the production factors are fundamentally different. Companies will also have to allocate special investment for the transition, for example, by setting up phased programs to facilitate site reconfiguration. It will also be necessary to build up new skills, possibly by initiating special recruiting actions and training programs. Companies may want to consider incentivizing the launch of pilots as well.

Conclusion

The next industrial revolution lies directly ahead, and will likely prove to be a source of huge opportunities for European countries. Moving toward Industry 4.0 fits quite well with the European model: it makes it possible to preserve a sustainable industry, develop qualified employees, support energy transition and adapt to large-scale customization. It will also allow Europe to compete successfully with other regions in the world and promote the emergence of future European champions. But speed is of the essence – the time to move forward and capture this opportunity is now.