

Industry 4.0 – Overview and Policy Implications

Philip Steden, Robert Kirchner

German Advisory Group

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Executive Summary I

Since 2011 “Industry 4.0” stands for the comprehensive digitization of industrial production. I 4.0 describes the 4th industrial revolution: intelligent and digital connected systems (connected machinery).

- Industry 4.0 represents a new level of controlling the entire value chain over the lifecycle of products
- At the center is the intelligent product (Internet of Things)
- Elements of Industry 4.0 are:
 - cyber-physical systems
 - IP-based networks
 - IoT-platforms
 - big data analytics
 - artificial intelligence
 - predictive maintenance
 - advanced robotics
 - Additive manufacturing and 3D printing

Executive Summary II

- In addition to technology aspects, business aspects of Industry 4.0 as well as educational aspects are just as important. Qualification is crucial.
- I 4.0, smart production and industrial artificial intelligence can have a positive net job effect. New skill-intensive job profiles evolve, other jobs are lower on demand.
- Economic policy should care about Industry 4.0 because it is a boost on productivity, allows new and better customized products as well as new disruptive business models.
- Policy areas to support the digitization of manufacturing industries are:
 - incentives for investments
 - technology transfer
 - information and networking opportunities
 - education and teaching
 - consulting services
 - economic development

Structure

Executive Summary

1. Introduction: what is Industry 4.0?
2. Which aspects belong to Industry 4.0?
 - 2.1 Elements of digitization and Industry 4.0
 - 2.2 Examples of Industry 4.0
3. What can be gained from Industry 4.0?
4. Lessons for economic policy
5. Industry 4.0 in Germany

Contacts

1. Introduction: Industry 4.0 is everywhere in the news

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ADVANCEDMANUFACTURING.ORG - THE LEADER IN #MFG NEWS AND TECHNOLOGY

Three Ways Industry 4.0 Is Forcing Manufacturers to Rethink Lead Times

August 10, 2018 by **Aaron Continelli** - President, Cre8tive Technology and Design

INDUSTRIE 4.0
Industrie 4.0
A change with potential for growth

78 billion Euro until 2025!



The Economist

<https://www.industry-of-things.de>
Comment:
Industry 4.0 is not just a question of technology!

Forbes / BrandVoice
ForbesBrandVoice® What is this?
12-Aug-2018

Industry 4.0 Depends On Engineering Talent

Roughly 63% of manufacturers believe that applying IoT to products will increase profitability over the next five years and are set to invest \$267 billion in IoT by 2020.

Industrie 4.0
IDG COMPUTERWOCHE VOICE OF DIGITAL

Industrie 4.0 Hintergrund Ratgeber Bilder Video News

Industrie 4.0 und IoT zum Anfassen bei der Smart Electronic Factory

Mittelständler senkt Fixkosten mit Industrie 4.0 um 50 Prozent

Germany's conservative economic model is being put to the test

An economy built on caution must learn to live with disruption

... they have focused on automating and digitising traditional production processes under the heading "Industry 4.0".

"IoT and predictive analytics are having a major impact on manufacturing, offering exciting new opportunities for connecting operations and transforming business processes."

M. Strand, Senior Vice President, Hitachi Solutions America.

The reliance on automation to streamline industry operations is only going to increase further as the concept of Industry 4.0 is increasingly realized.
<https://www.itproportal.com> July 18, 2018

1. What is Industry 4.0 and where does the term come from?

Definition

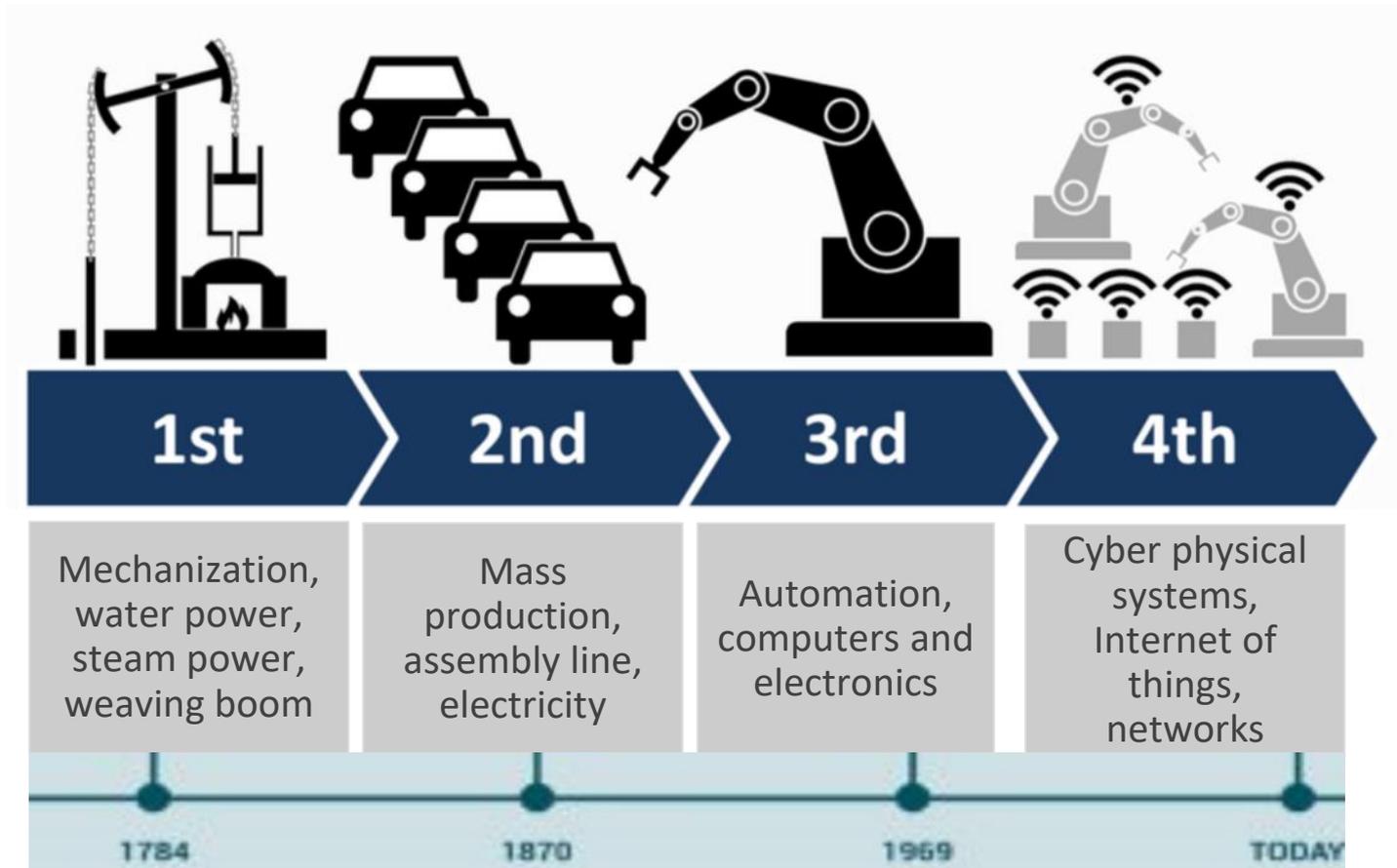
- Industry 4.0 is the name of a future project for the comprehensive **digitization of industrial production**.
- Industry 4.0 describes the **4th industrial revolution**: intelligent and digital connected systems.
- Industry 4.0 represents a new level of **organization and control of the entire value chain** over the lifecycle of products. This cycle is geared to increasingly individualized customer needs and extends from the idea, the order, through the development and manufacturing, the delivery of a product to recycling, including related services. (German “Plattform Industrie 4.0”)
- At the center is the **intelligent product**: the Internet of Things. The product carries all the information in it. By means of a chip it is able to independently communicate with the production machines. (Federation of German Industries e.V.). Basis is the availability of all relevant information in real-time.

Where does the term come from?

- Industry 4.0 was **first mentioned in public at the 2011** Hanover Fair.
- The term derives from the **Hightech Strategy** of the German Federal Government, where Industry 4.0 is a cornerstone to secure Germany as a production location. The Government was advised by the “Research Union Economy-Science”: Robert **Bosch GmbH** and **Acatech** (German academy of science and engineering) coined the (German) term INDUSTRIE 4.0.

1. Industry 4.0 is the 4th industrial revolution

In the fourth industrial revolution, we are facing a range of new technologies that combine the physical and digital worlds.

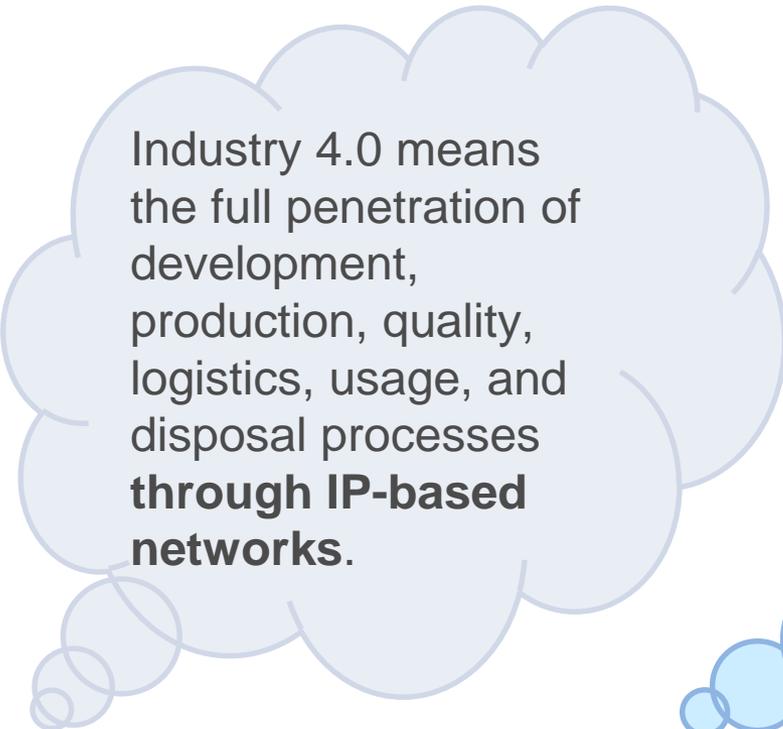


Source: Own display

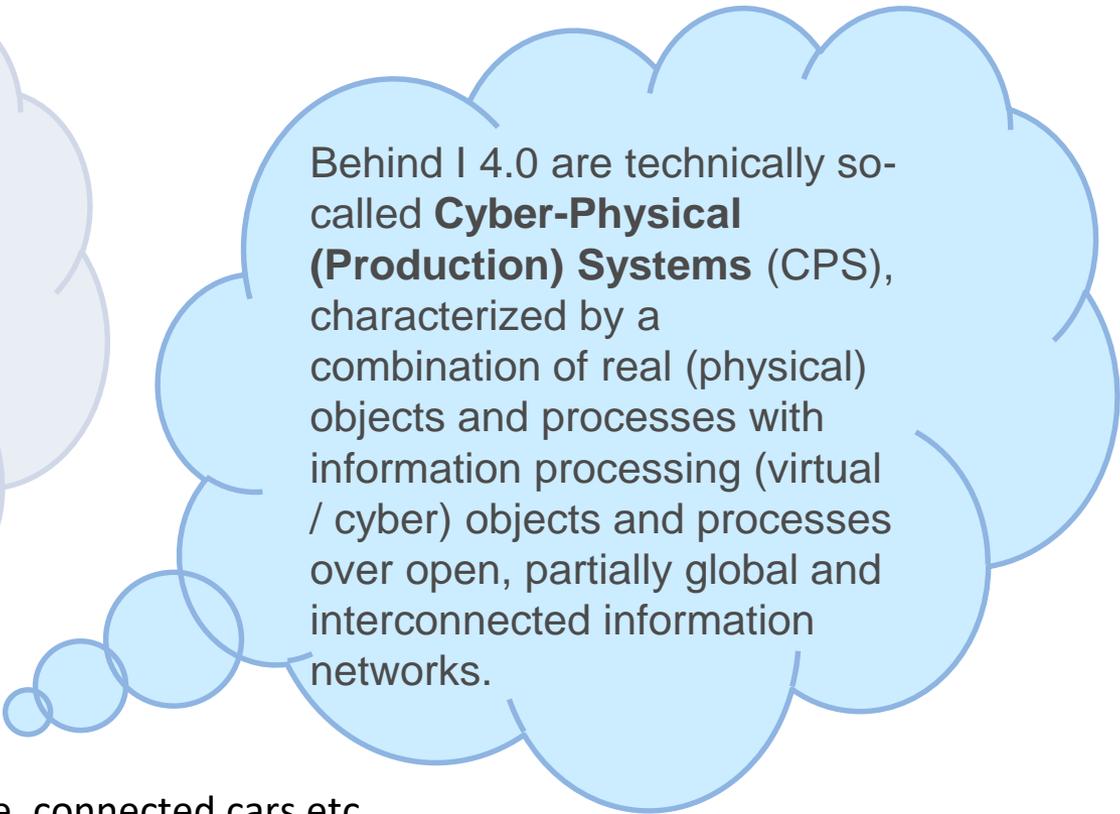
1. Industry 4.0: What exactly is it?

Industry 4.0 is digitization and connected machinery:

Cyber-physical systems are the basis of the Internet of things (IoT). This is expected to expand to all industries. The term Industry 4.0 refers to manufacturing industries only, i.e. production processes and production-related services. ¹⁾



Industry 4.0 means the full penetration of development, production, quality, logistics, usage, and disposal processes **through IP-based networks.**



Behind I 4.0 are technically so-called **Cyber-Physical (Production) Systems (CPS)**, characterized by a combination of real (physical) objects and processes with information processing (virtual / cyber) objects and processes over open, partially global and interconnected information networks.

¹⁾ ... and not to wearables, smart home, connected cars etc.

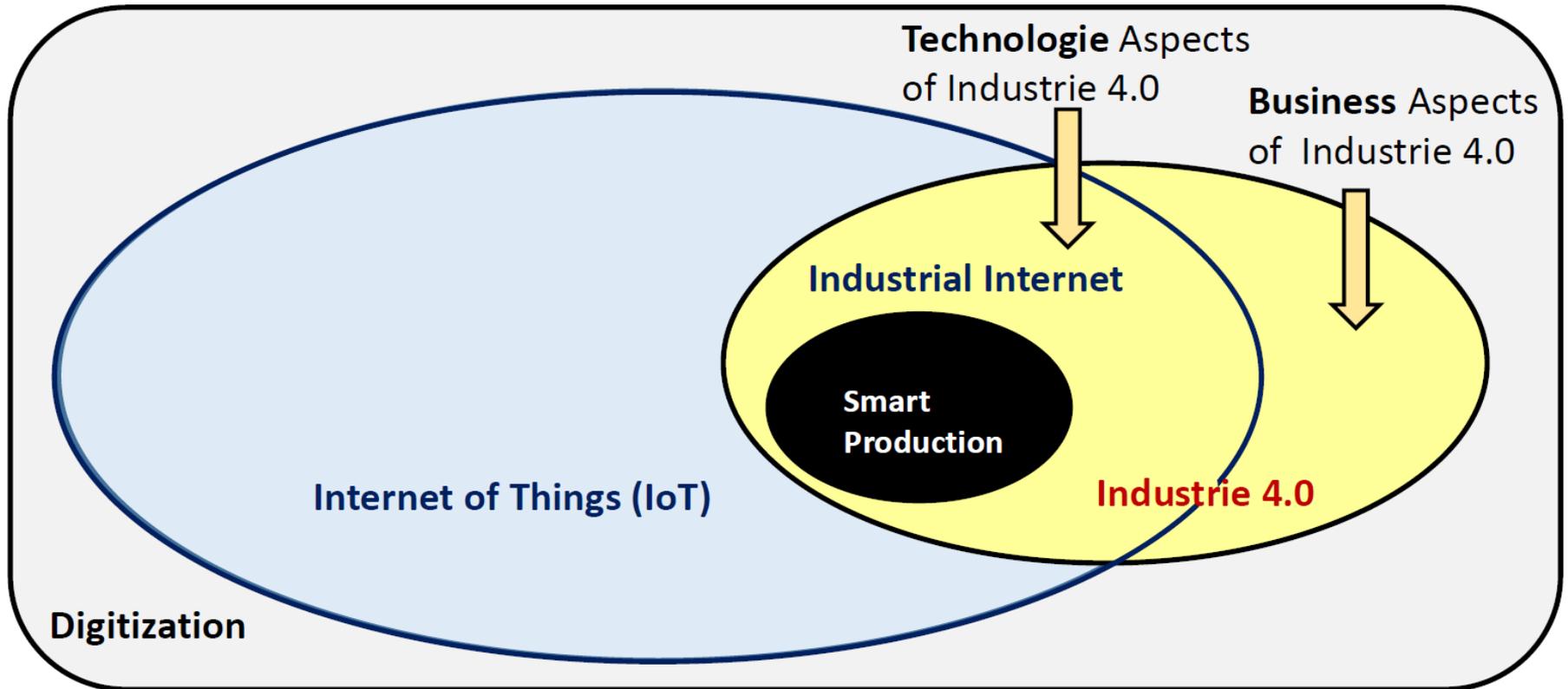
1. Industry 4.0: Organizational design principles

In Industry 4.0, connecting all systems enables a largely self-organized production. Not just individual production steps are optimized, but an entire value chain.

4 organizational design principles:

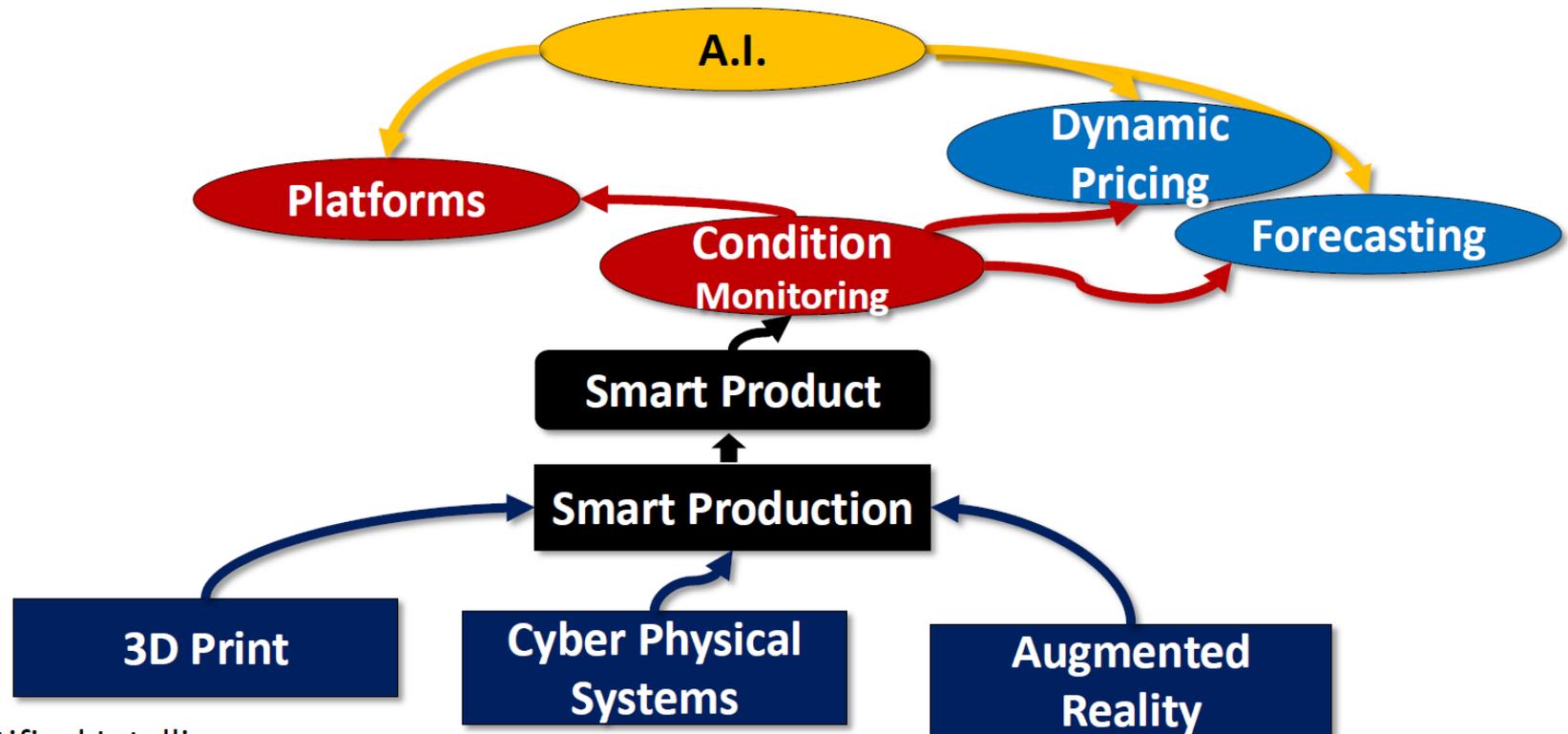
- 1. Intelligent and digital interconnected systems:** machines, tools, sensors, products, human beings communicate via the internet or the Industrial Internet of things (IIoT).
- 2. Information transparency:** data generated by **sensors** (temperature, vibration, rotation speed, sound patterns, etc.) expands information systems of digital factory models, to create a virtual image of the real world.
- 3. Technical assistance** systems support people with the help of aggregated, visualized and understandable information. This enables sound decisions to be made and problems to be resolved faster. In addition, people are physically supported in strenuous, unpleasant or dangerous work.
- 4. Decentralized decisions:** cyber-physical systems are able to make independent decisions and perform tasks as autonomously as possible. Only in exceptional cases, for example in case of disruptions or conflicting goals, do they transfer the tasks to a higher authority.

2.1 Connection between Digitization, IoT and Industrie 4.0



Source: Klaus Schlichting: „Digitalisierung konkret“ - Konzepte, Konsequenzen, Handlungen, presentation 23.11.2017.

2.1 Concepts of Digitization / Industry 4.0



A.I. = Artificial Intelligence

Source: Klaus Schlichting: „Digitalisierung konkret“ - Konzepte, Konsequenzen, Handlungen, presentation 23.11.2017.

2.1 Smart production produce smart products

Smart products = hardware + embedded systems

- Have a product memory
- Communicate via internet
- Use sensors and actuators
- Adapt situationally and autonomously and optimize continuously

Smart production = Network of machines, objects and people

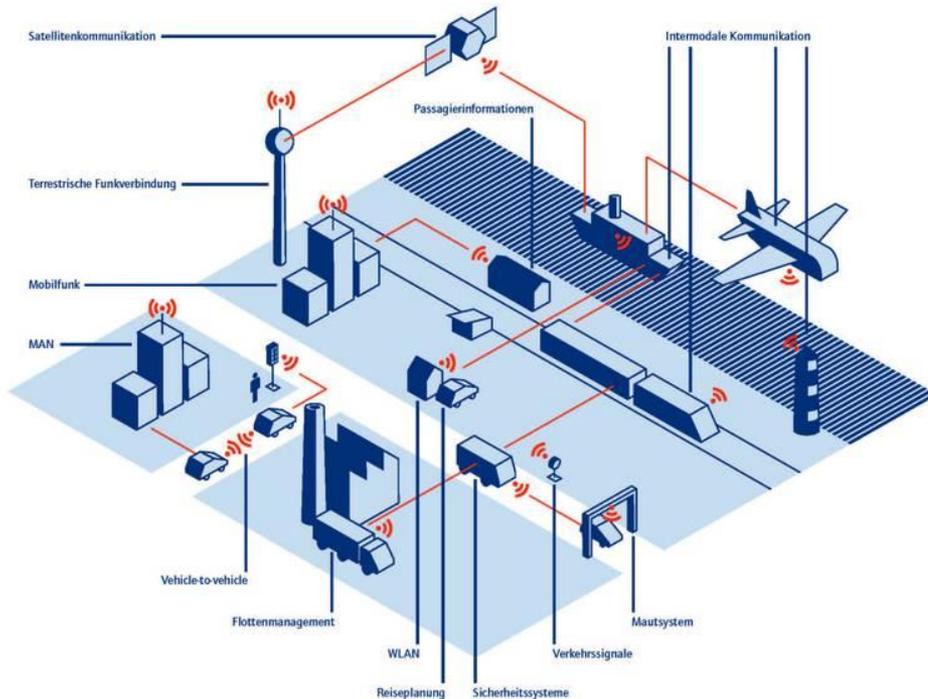
Functioning:

- Self-organizing of manufacturing equipment and logistics systems
- Cyber-physical systems are the technical basis
- „Social Machines“ include peoples via specialized interfaces
- Communication between smart product und manufacturing equipment
- Digital transportation links the elements within the production

Goal: Achieving the optimum of quality, costs and lead time

2.1 Cyber-physical systems (CPS)

... are an interacting network of physical and intelligent components:



Source: ACATECH

- Are complex systems
- Communicate in real time
- Are intelligent by itself
- Work autonomously
- Are modular designed
- Are decentralized and self-organized
- Manipulate its physical environment
- Use data from the cloud
- Have a man-machine-Interface

2.1 Cyber-physical systems (CPS)

CPS enable a decentralization of value creation In the context of manufacturing:

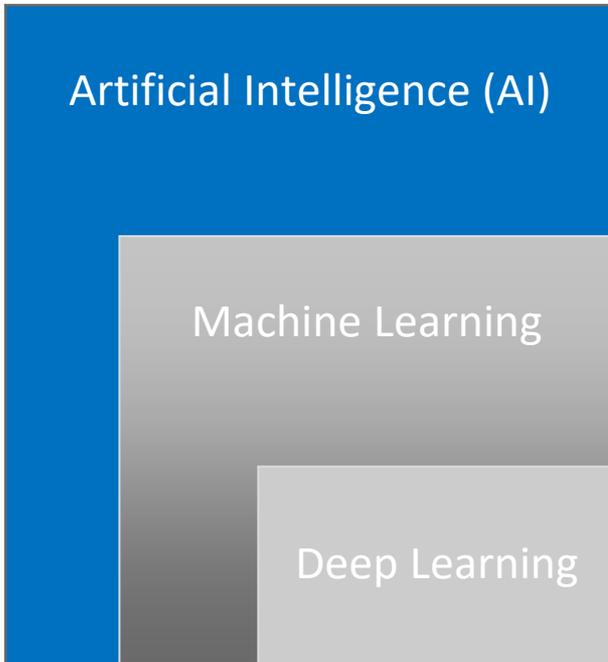
- Mobile information and decision support
- Asset tracking
- Parts self-organized through production
- Condition monitoring
- Remote maintenance



Source: Fraunhofer IAO, presentation „Urban production - ultra efficiency plant“ 2016.

2.1 Artificial Intelligence (AI) in production and logistics

Definitions:



A computer makes decisions similar to a human being, in an ambiguous environment. It solves problems.

A machine is trained for certain tasks. It does not simply learn examples. Instead it recognizes patterns, so that later unknown data can be classified.

An artificial neural network with multiple layers solves tasks that are hardly described with mathematical rules. (self-learning system)

The objective are digital companions that act as an intelligence amplifier, which must be broadly available

2.1 AI has many applications in production and logistics

Areas of industrial applications for AI:

- Assembly robots that automatically assemble technical components to systems without being programmed for that task
- Self-optimizing production lines in factories
- Screws communicating with assembly robots
- Software recognizes material defects in products via image recognition
- Computers control complex logistic chains and book cargo space
- Machine learning can be used to profile the devices for patterns of sensor readings that lead up to a failure. When these patterns are identified, they are integrated as new rules into the proactive workflows.
- Wind turbines that request maintenance on the basis of operating data and AI, that deliver more accurate prediction than the development engineers

2.1 Machine Learning and its role for Asset Maintenance

Sensors + IoT + (big) data + AI = Enablers for predictive maintenance

- So far: traditionally assets like turbines have been taken offline based on an annual maintenance plan, much like the regular checkup appointments that we take a car to
- **Predictive maintenance** is an attempt to be pointed and precise in the identification of risks and failures on precious assets, and to enhance the ability to be responsive to the unique pressures on each machine. Consequently, each machine receives the maintenance that it needs and when it needs it (*maintenance efficiency*), in order to keep it running and operating in peak condition for the longest time possible (production efficiency).
- Often used in Manufacturing, Aerospace, Power Generation, Elevator, and ATM monitoring and maintenance

- **Example:** **A train operator receives a direct instruction, in which locomotive a specific spare part has to be replaced**

“Only a human being has the competence to translate this instruction into the real world. In the future professional mechanics will still have to do the job of high precision work like welding accurate to a tenth of a millimeter.”

(Roland Busch, CTO, Siemens AG, 20.07.2018.)

2.2 Examples of Industry 4.0: 3D printing (1)

- **Less weight**
- **Low waste**
- **Flexible or stable**

Advantages:

- **Print on demand (spare parts)**
- **Print at point of use**
- **rapid prototyping (printing molds, jigs and fixtures)**

Essential are not printing costs, but the disruptive potential in value creation!

2017:
Volkswagen and Kinazo
Design presented a 3D
printed EUR 20.000 E-Bike:
Kinazo ENDURO e1



2.2 Smart factory demonstrator (2)



The demonstrator by Bosch Rexroth and „Deutsches Forschungszentrum für Künstliche Intelligence“ (DFKI) consists of several modules to produce cardholders. It allows unlimited exchange of data between the modules of different producers.

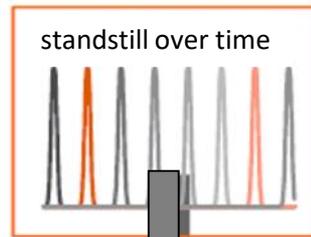
2.2 OSRAM GmbH (Lighting Solutions) (3)

1 The development of new standardized tools and secure technologies

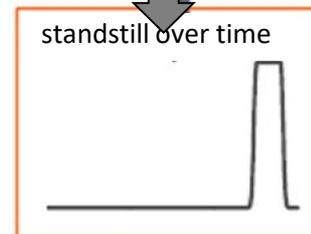


Mobile decentralized communication and planning tools combined with diagnostics for predicting errors

2 Increase of maturity of processes with the paradigm shift of from functional orientation to preventive error intervention



Errors (and thus error reactions) are part of the operating concept



Hohe Maschinen- und Prozessreife (geplante Stillstände)

3 The work organization and design, training and education of our employees



Example: training and simulation module for job-related training, offline programming and testing of software as well as offline error analysis.

2.2 Siemens Messgerätewerk Berlin (4) (Plant for measuring devices)

Siemens “MindSphere”: Cloud based operating system for IoT:

55 parameter per machine/measuring point. Parameters for pressure, energy consumption, photo of the circuit boards.



Plant cloud:

- 100 machines are connected
- 2.5 mio. documents per day with 14 GB of data
- 300 GB data available for analysis
- Reports available in the cloud

VISION 2020

Boards on demand

Quality in real-time

Production progress in real-time

Energy performance

Machine efficiency

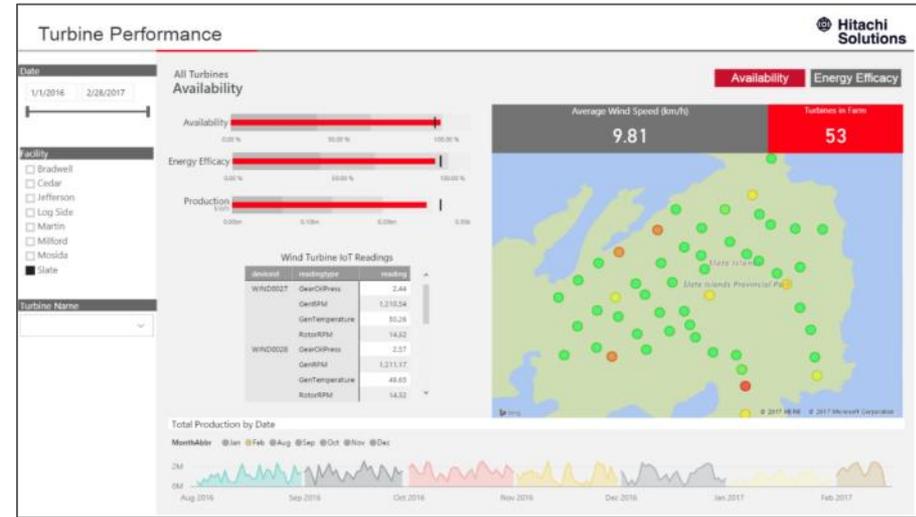
Optimized production planning and control

Integrated software landscape

2.2 A cyber-physical system: Wind Farm (5)



<http://www.entura.com.au/can-big-data-artificial-intelligence-transform-wind-sector/>

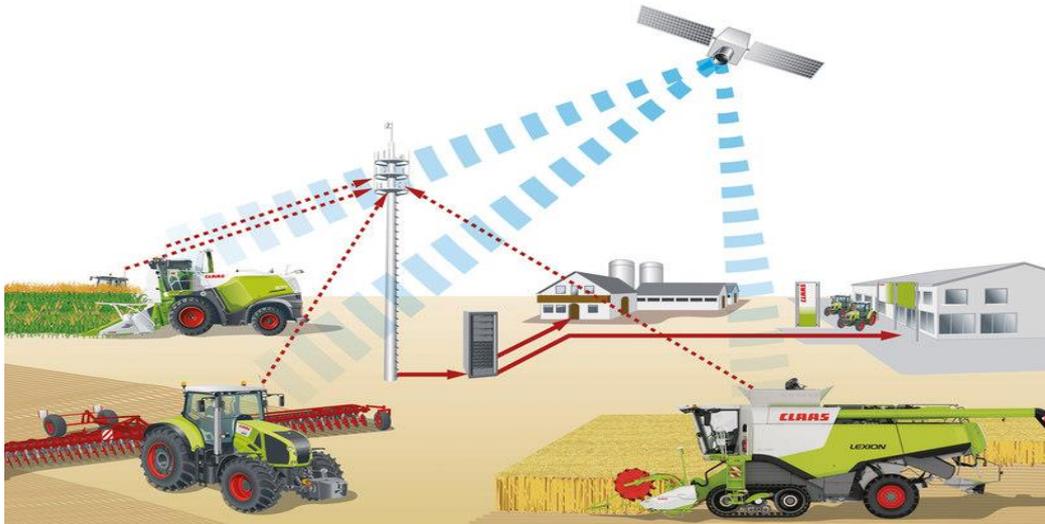


<https://us.hitachi-solutions.com/blog/6-tools-for-a-successful-predictive-maintenance-program/>

With big data technologies there is potential for improvements in the efficiency and cost of wind turbines, improved energy forecasting, and better fault prediction and detection. It is possible to move away from a costly and inefficient maintenance cycle. All data, wind, climate (humidity, ice storms, freezing winters), position of the turbine etc. can be taken into account.

2.2 A cyber-physical system: Farming 4.0 (6)

In Saxony-Anhalt agricultural equipment manufacturer Claas and Deutsche Telekom are testing a new precision farming concept for grain harvesting

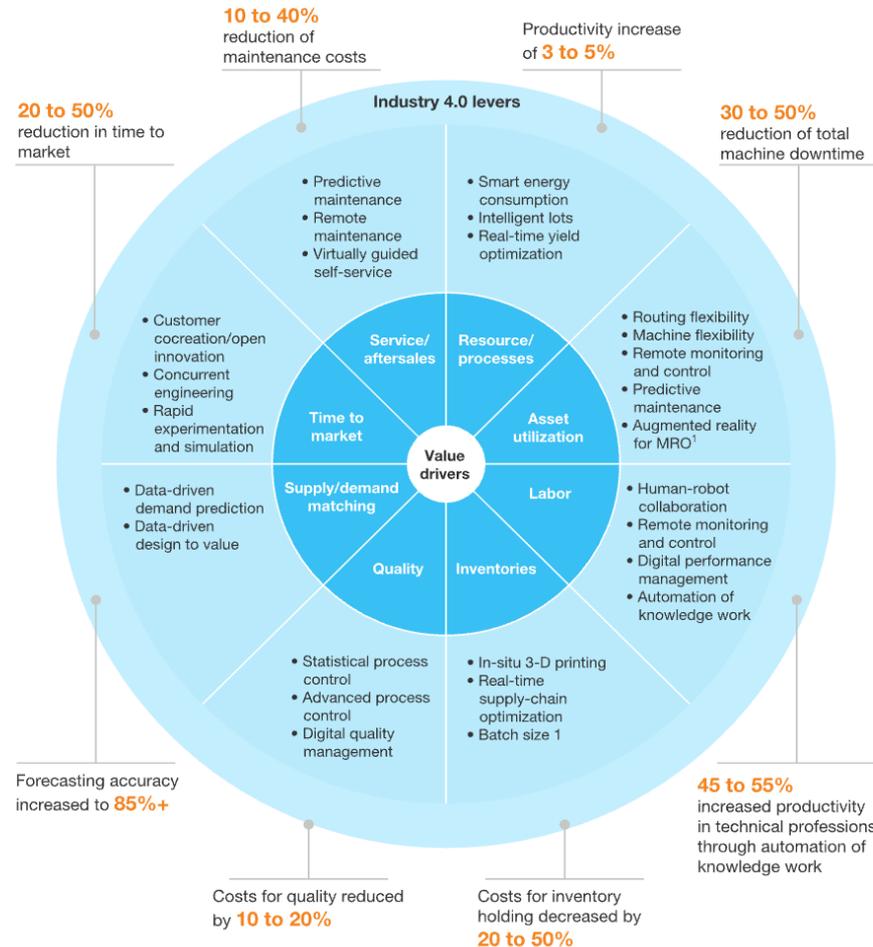


Source: Claas. Example from Agrarheute

- All units involved in the harvesting process are connected, transfer data and coordinate with each other.
- Drivers use tablets with constantly updated crop illustrations and communicate via mobile.
- The combine harvester knows when the grain tank is full and automatically calls the tractor with a transfer trailer via the LTE network. The accepted quantity of grain, incl. quality data, is reported to the company.
- The tractor knows the terrain and all machine locations and looks for the best way to the combine harvester. He pays attention to time and soil conservation.
- In the meantime, the harvester has received new weather data: it will rain in three hours. The harvester changes its strategy, suggesting the driver to work at maximum speed rather than minimum fuel consumption.

3. What can be gained from Industry 4.0?

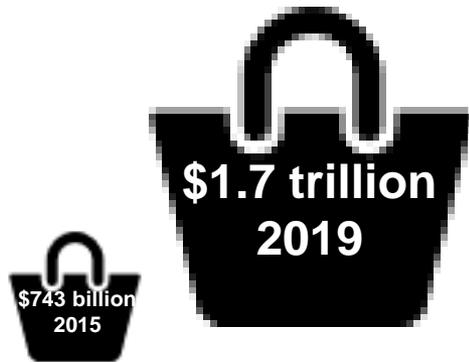
The McKinsey Digital Compass maps Industry 4.0 levers to the 8 main value drivers



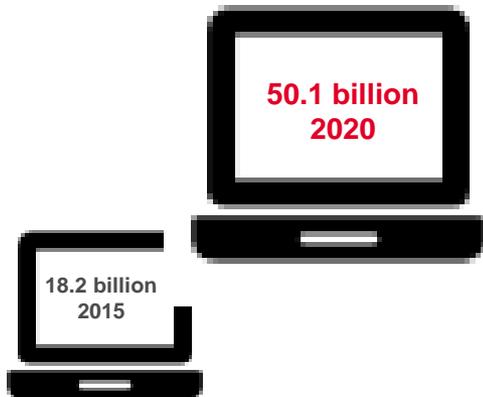
Source: "Industry 4.0: How to navigate digitization of the manufacturing sector", McKinsey, Digital, 2015

3. Industry 4.0 by numbers: it's a huge market!

Global market in Internet of Things technology



Connected devices worldwide



+ 20%

Annual growth in Industry 4.0 investments worldwide. Stock of industrial robots grows by 10% p.a.



\$300 billion

Investments by manufacturing companies in digitalization projects by 2020



4 out of 5

Executives say Industry 4.0 is the most important tech development of the decade



Smart factories are expected to create a **sevenfold increase** in overall productivity by 2022.

Source: Capgemini Smart factories: How can manufacturers realize the potential of digital industrial revolution.



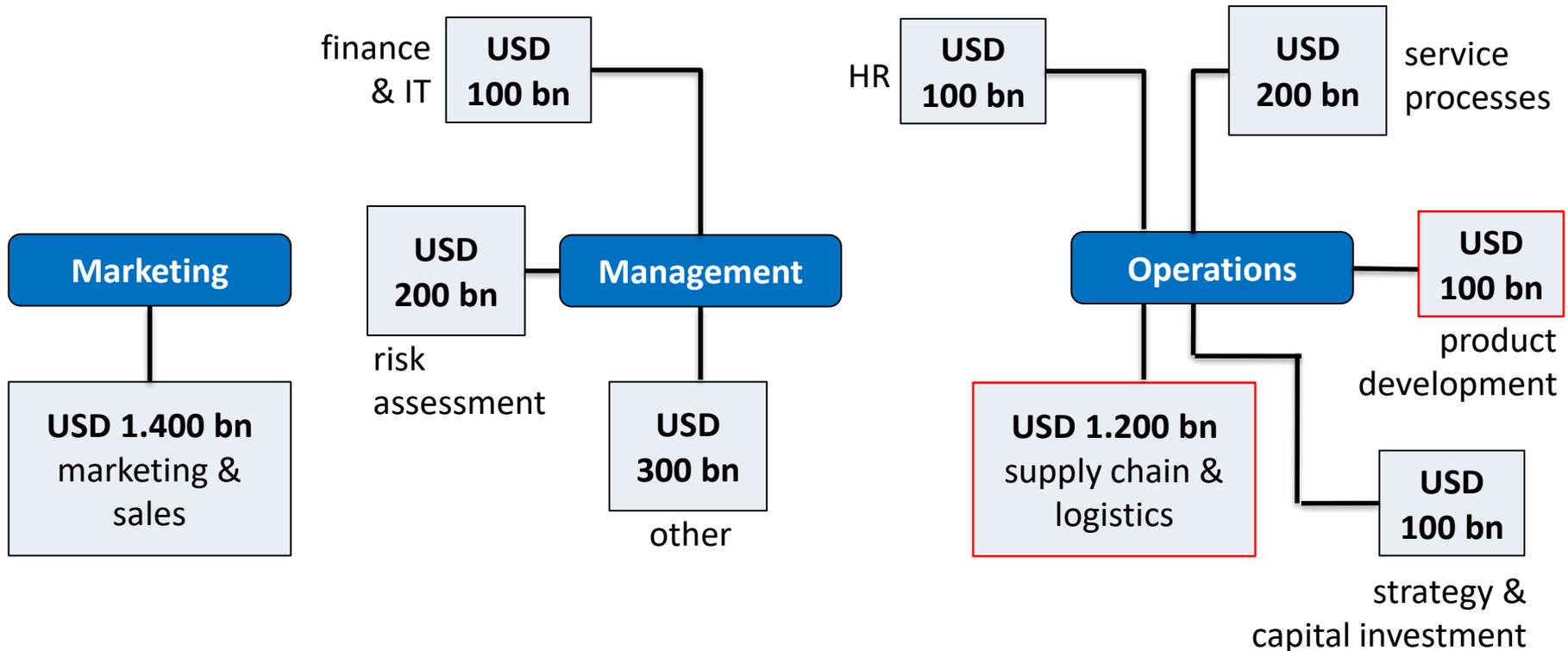
80%

Companies already using some Industry 4.0 technology



3. Great potential of AI for industrial manufacturing

Possible economic value added through the use of AI, worldwide p.a.



Source: McKinsey, in Wirtschaftswoche Magazine, 27.07.2018

Germany is estimated to have a potential of up to EUR 430 bn additional GDP through AI (11% increase). (PwC)

4. Lessons for economic policy

Industry 4.0 is the 4th industrial revolution. But why should economic policy care about it?

- Transformation of the traditional manufacturing plant to a smart factory boosts productivity, quality and competitiveness
- Shorter production times, less waste, energy consumption and deficient products
- New and better customized products and services and disruptive business models become possible (disruptive potential in value creation)
- Costs to produce customized items on par with the cost of mass production
- Industry 4.0 opens up new chances for FDI attraction and economic development
- Industry 4.0 and AI can become a job motor, but new qualifications are needed.
- Urban production becomes attractive again
- Reshoring of production from low cost countries to traditional industrial countries
- A growing market. Example: No. of industrial robots grows by 10% p.a. globally.
- But the number of robots per 10000 employees lags behind in Eastern Europe.
Romania 15, Poland 32, average world 74, USA 176, Germany 301, South Korea 531

4. International comparison of policy approaches

Approaches to Industry 4.0 by country – a comparison

Country	Programme name	Driver	Current focus
Germany 	Industry 4.0	Product Excellence	Engineering Excellence: Alignment of all components
China 	Made in China 2025	Resource-Efficiency	Speed: build competence clusters and key technologies
USA 	Industrial Internet	Vision	Disruption: digital radical software innovation
Japan 	Industrial Value Chain Initiative	Demographic Change	Scale: Enlarge pilot applications
EU-Central/North 			Similar to Germany
EU-South 			Re-Industrialization
Ukraine 	?	?	?

Source: Klaus Schlichting Assessment 2017 and BE Berlin Economics.

→ Countries put emphasis on different issues

4. General policy approaches to Industry 4.0

Policy sector	Examples of industrial policy
Incentives for I 4.0 related investments	<ul style="list-style-type: none"> ▪ Subsidized loans ▪ Grants
Technology policy / technology transfer	<ul style="list-style-type: none"> ▪ Joint research projects ▪ Transfer Center or Network Industry 4.0 to support SMEs especially ▪ Innovation voucher ▪ Promotion of industrial start-ups
Information and networking opportunities	<ul style="list-style-type: none"> ▪ Enabling big multinationals, SME's and craftspeople to apply AI and I 4.0. ▪ Showcases an demonstrators ▪ Website analogues to German "Plattform Industrie 4.0"
Education and teaching	<ul style="list-style-type: none"> ▪ Promoting media competence in school ▪ Strengthening vocational training ▪ Using test beds and competence centers for training and qualification
Consulting services	<ul style="list-style-type: none"> ▪ Self-assessments, Check-lists ▪ Subsidized coaching and counseling service for orientation
Economic development	<ul style="list-style-type: none"> ▪ Fostering national and international cooperation ▪ FDI attraction & business promotion with a clear focus an manufacturing industries and most promising sectors: fDi markets newsletter (04/12/ 2018) names agriculture, logistics, banking, health care, real-estates investments for Ukraine. ▪ Revitalization of the SME sector ▪ Promotion of cluster and networks. Example: Technology network "It's OWL" (OstWestfalenLippe) with 200 members. (http://www.its-owl.de)

5. Industry 4.0 networks and institutions in Berlin

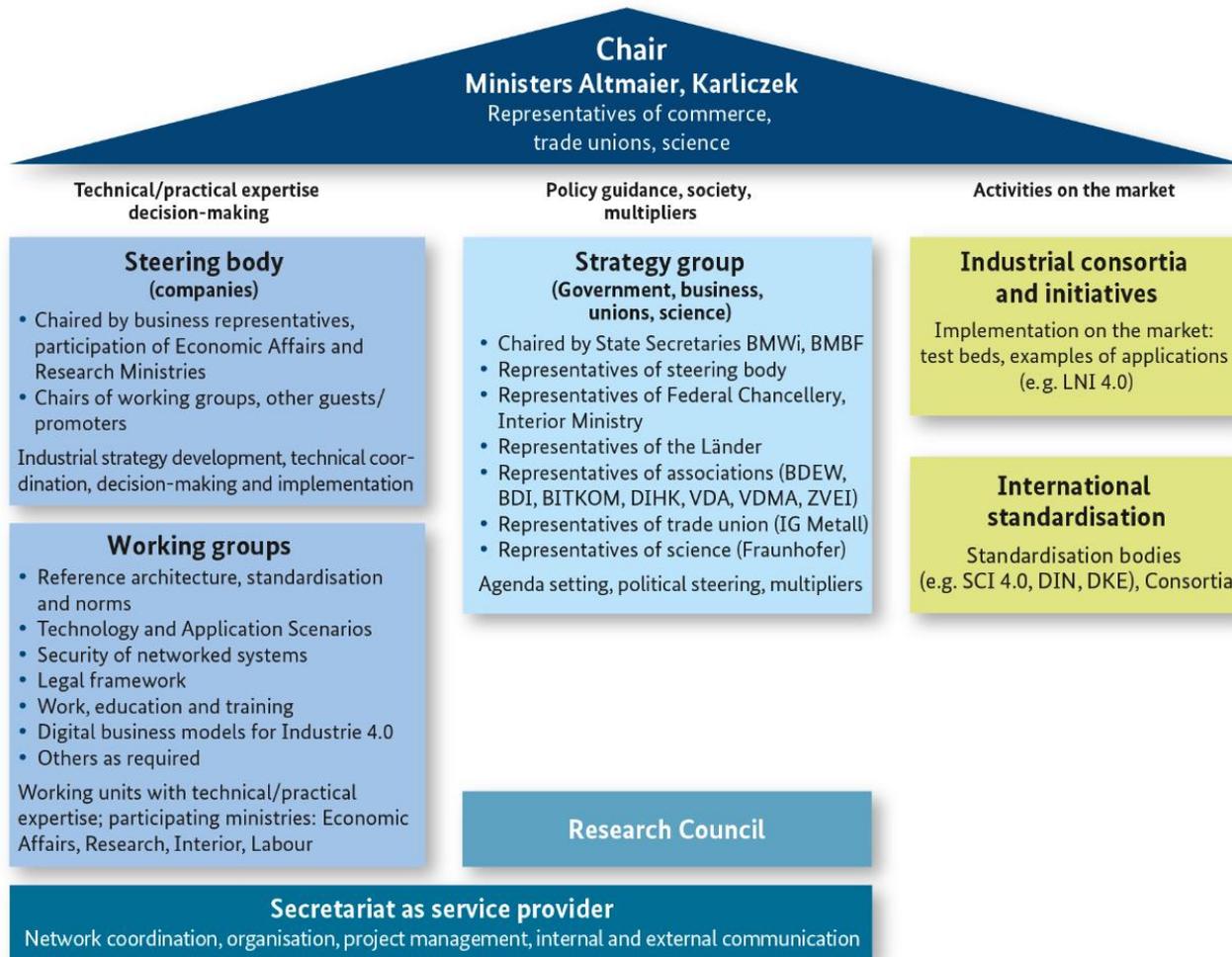
Excellent network of institutions & R&D facilities with Industry 4.0 focus



Major networks and institutions:

- **Plattform INDUSTRIE 4.0:** joint federal initiative of BITKOM (Federal Association for ICT and New Media), VDMA (German Engineering Federation) and ZVEI (Electrical and Electronic Manufacturers' Association), one of the largest Industry 4.0 networks; wants to develop Germany as a global market leader offering the most production technology; provides support for the coordinated and organized transition into the digital economy; acts as a central point of contact. 6 working groups produce recommendations for action, guidelines, solutions and policy framework
- **Berlin Center for Digital Transformation** by 4 Fraunhofer Institutes (“Leistungszentrum Digitale Vernetzung”)
- **ACATECH** – NATIONAL ACADEMY OF SCIENCE AND ENGINEERING supports policymakers and society by providing qualified technical evaluations and forward looking recommendations

5. Plattform Industrie 4.0

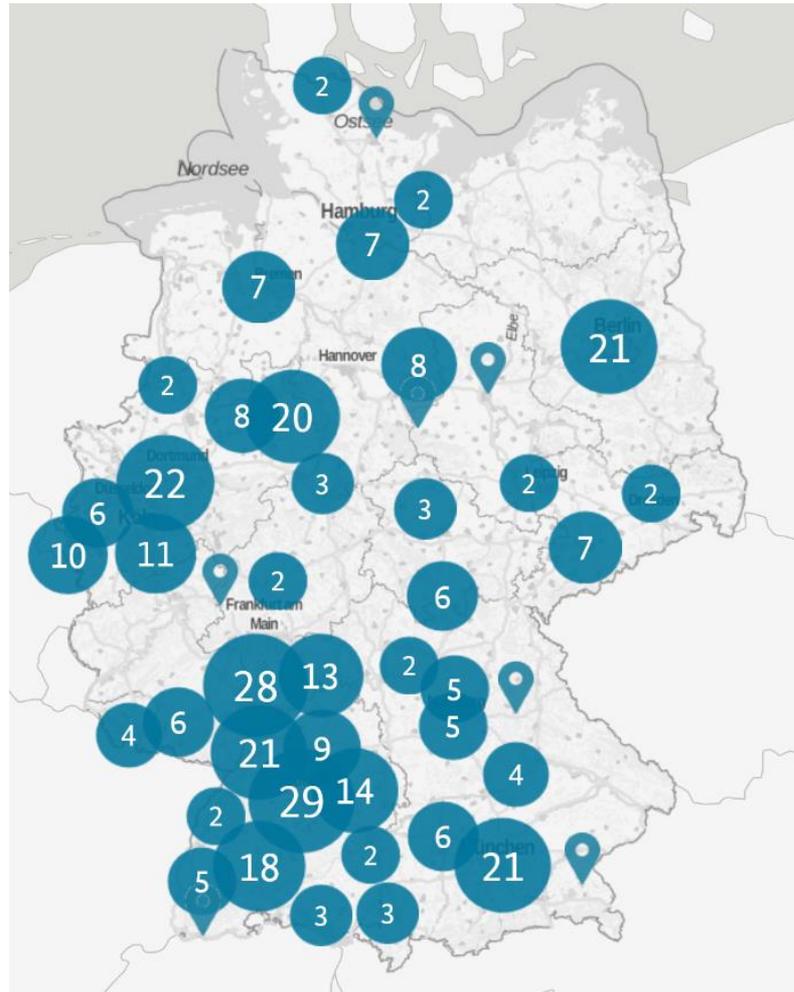


Source: BMWi



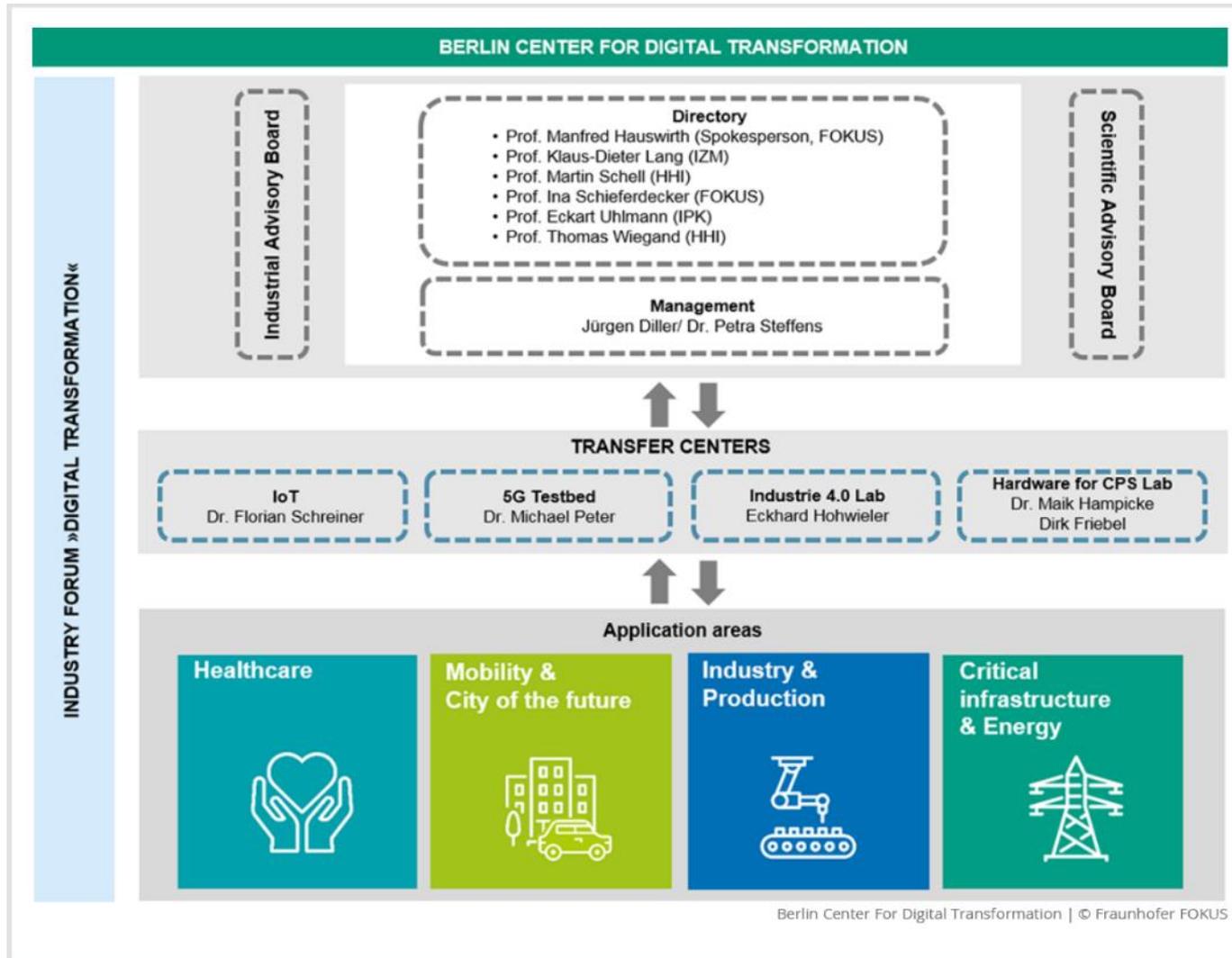
5. Industry 4.0 in Germany

The online map of “Plattform Industrie 4.0” provides more than 350 use cases



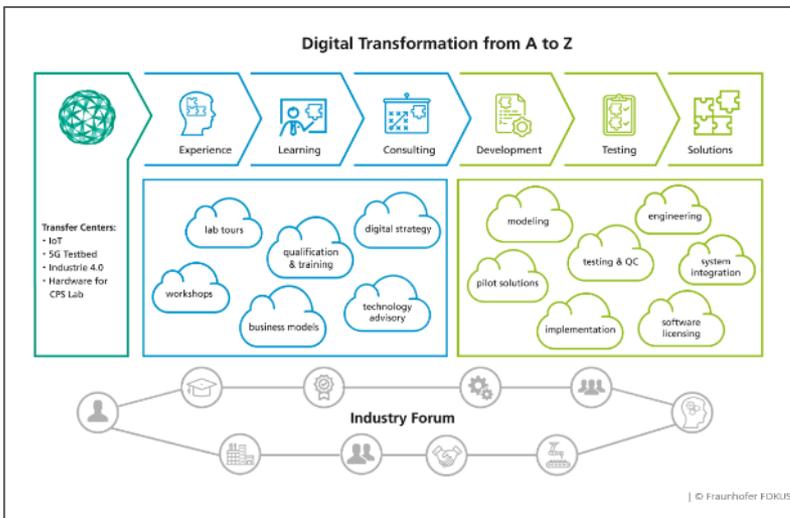
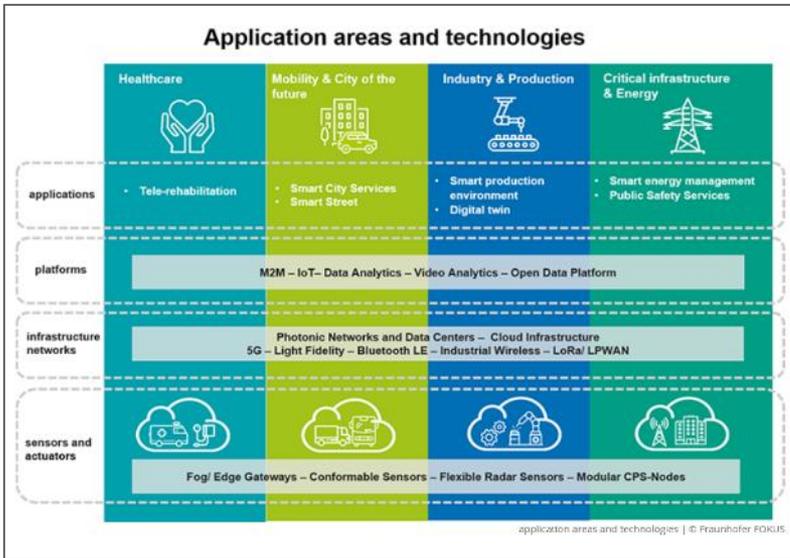
Source: Plattform Industrie 4.0

5. Berlin Center for Digital Transformation: Overview



Source: Leistungszentrum Digitale Vernetzung

5. Berlin Center for Digital Transformation: Service offerings



Transfer Center Hardware for CPS

Transfer Center IoT

Transfer Center 5G Testbed

Transfer Center Industry 4.0 Lab:

- Brings together suppliers from the ICT area as well as suppliers of automation with the production industry.
- It supports and coordinates in the identification of developmental and research themes, in the execution of joint projects to create innovative solutions.
- As a combined center and a concentrated initiative from industry, IT-industry and scientific and research institutions in Berlin, it significantly contributes to the profile-building of Berlin as hub for digital production and cooperation in value-added networks.



Dr Philip Steden

psteden@web.de

Robert Kirchner

kirchner@berlin-economics.com

German Advisory Group

c/o BE Berlin Economics GmbH

Schillerstr. 59, D-10627 Berlin

Tel: +49 30 / 20 61 34 64 0

Fax: +49 30 / 20 61 34 64 9

E-mail: info@beratergruppe-ukraine.de

www.beratergruppe-ukraine.de

Twitter: [@BerlinEconomics](https://twitter.com/BerlinEconomics)

