Industry 4.0 – Overview and Policy Implications

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German Economic Team Belarus

Berlin/Minsk, March 2019

Production in earlier years

Bundesarchiv, B 145 Bild-F003555-0004
Foto: Unterberg, Rolf | Mai 1956

Bundesarchiv, Bild 183-H0813-0600-032
Foto: [illegible] | November 1949

Bildquelle: Bundesarchiv

Production today – "Lean, clean & green"

Bildquelle: Volkswagen AG

Fraunhofer IAO

Industry 4.0 is everywhere in the news

sme

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Three Ways Industry 4.0 Is Forcing Manufacturers to Rethink Lead Times

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

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

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

INDUSTRIE 4.0

Industrie 4.0
A change with potential for growth

78 billion Euro until 2025!

The Economist

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 increasing realized.
https://www.itproportal.com July 18, 2018

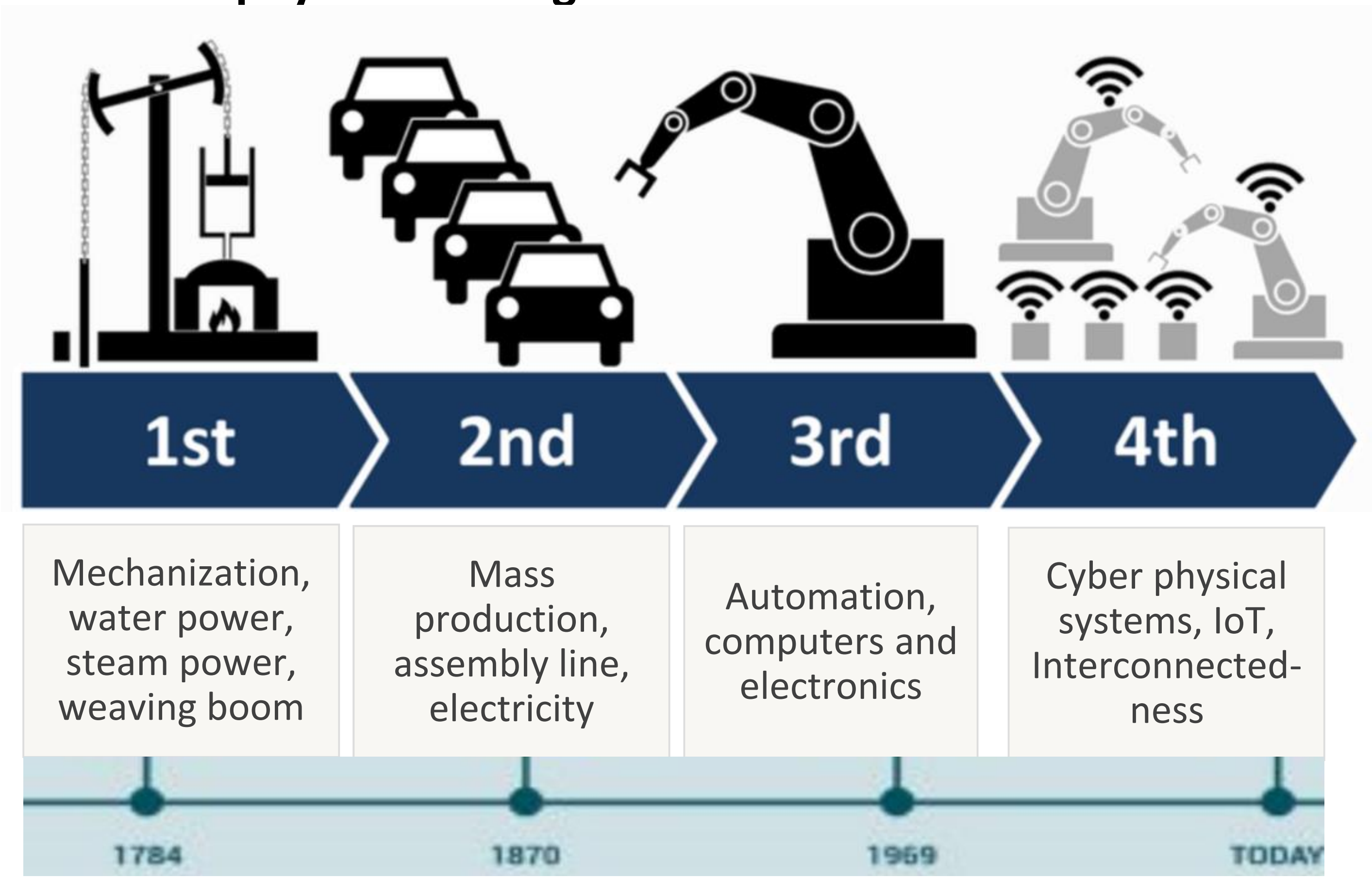
Structure

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. 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 and where does it come from?

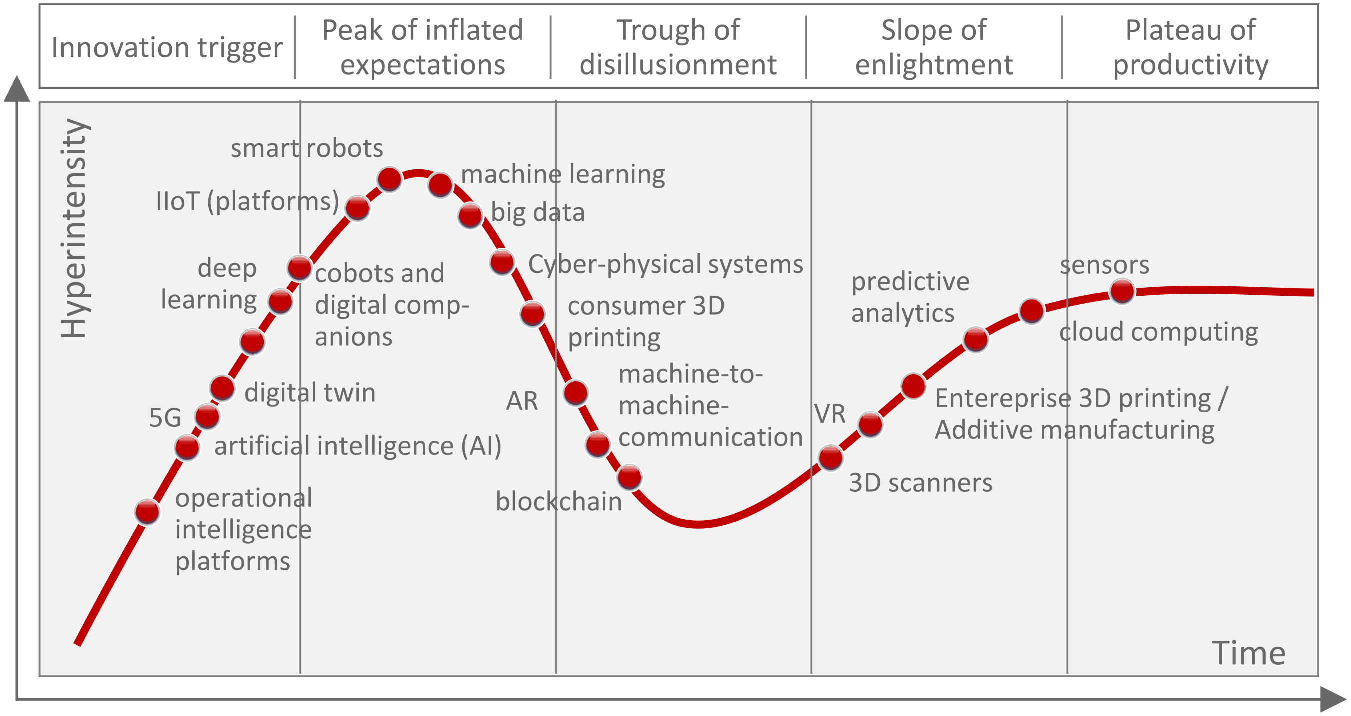
Definition	▪ Industry 4.0 is the name of a future project for the comprehensive digitization of industrial production. ▪ Industry 4.0 describes the 4th industrial revolution: intelligent and digital connected systems. ▪ Industry 4.0 represents a new level of organization and control of the entire value chain over the lifecycle of products. This cycle extends from the idea, the order, through the development and manufacturing, the delivery of a product to recycling, including related services through IP-based networks (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.

2. Which aspects belong to “Industry 4.0”?

Relevant technologies in Industry 4.0 and digitization

Technology studies & expert interviews

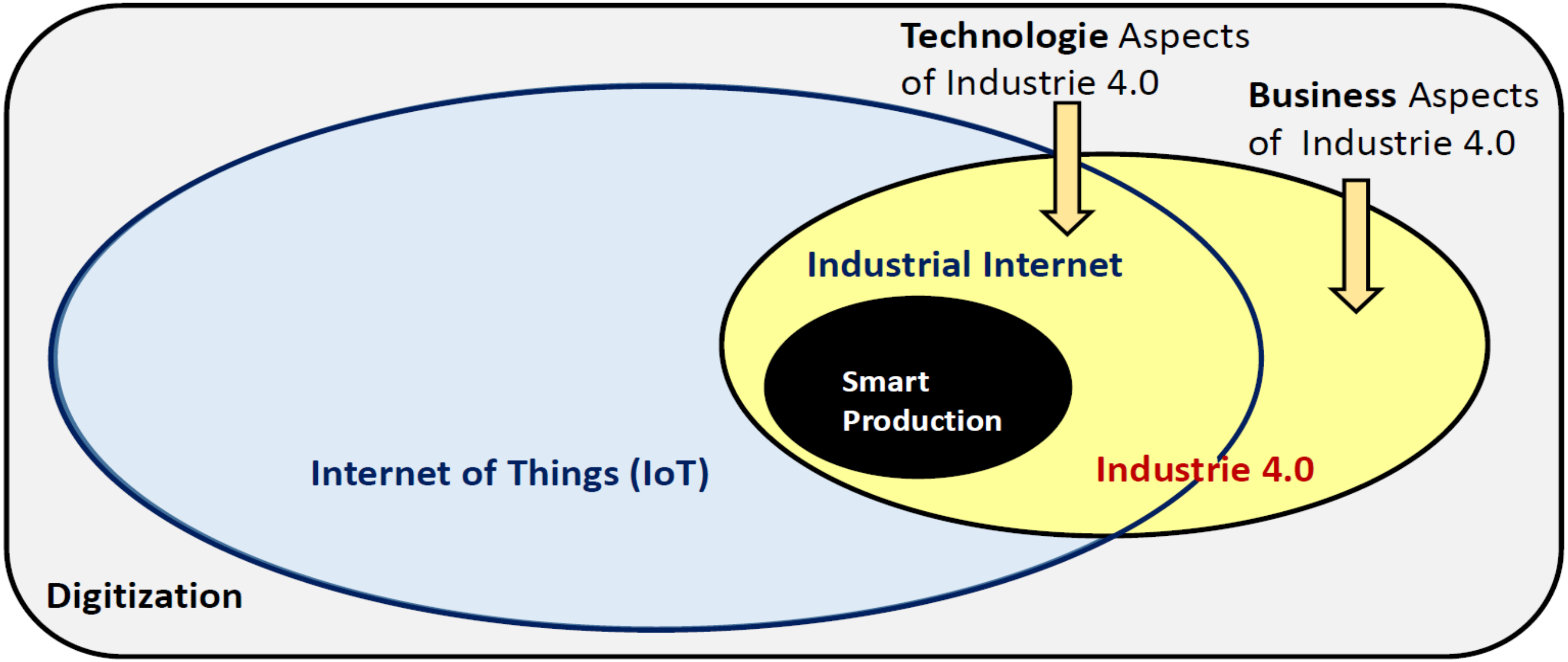
Selection and structuring of relevant technologies in automation



Source: Gartner 2018 hype cycle, own research, expert interviews

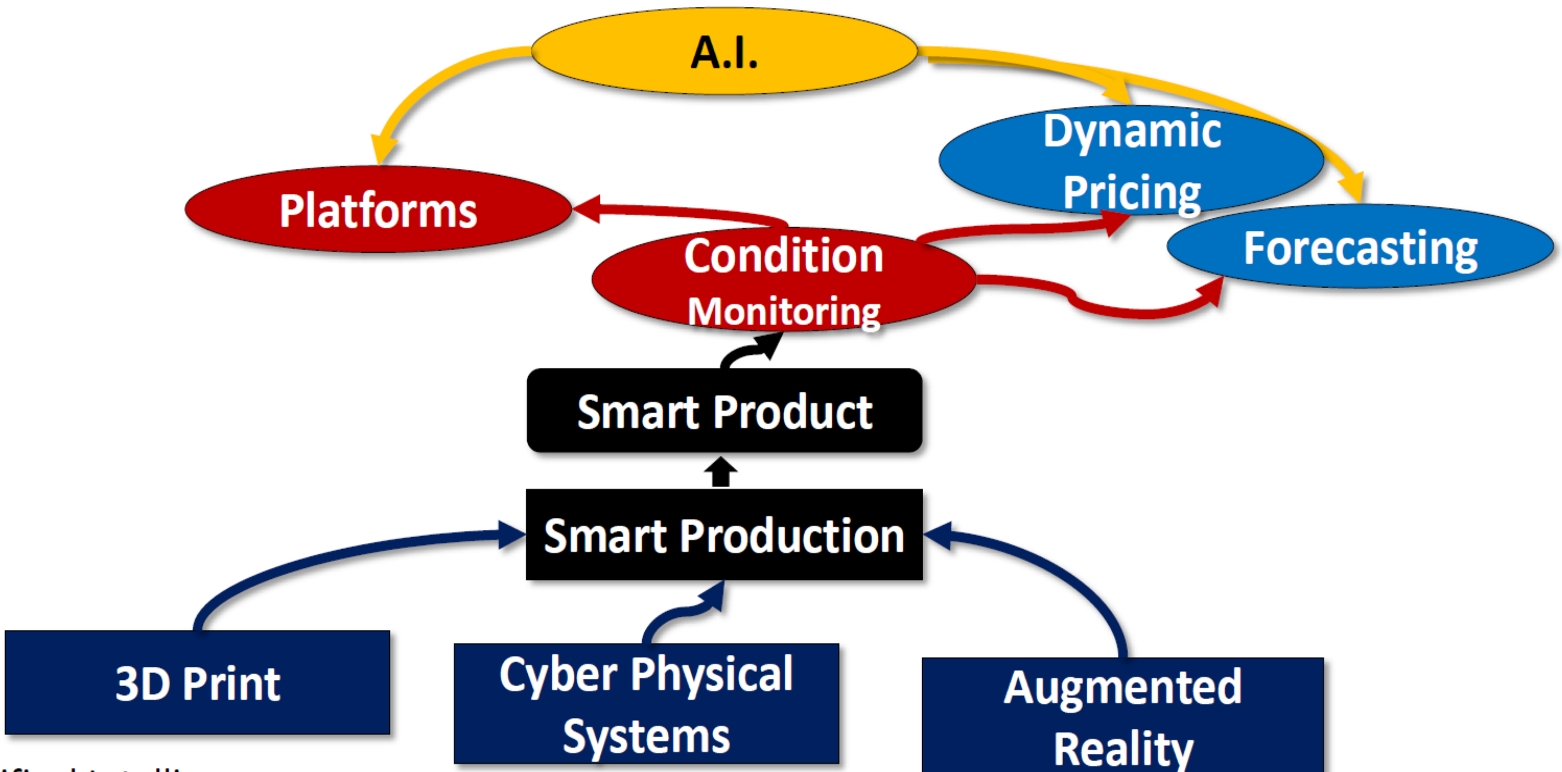
2.1 Connection between Digitization, IoT and Industry 4.0

Industry 4.0 is digitization and connected machinery:
The term Industry 4.0 refers to manufacturing industries only, i.e. production processes and production-related services.



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

2.1 Concepts of Digitization / Industry 4.0



A.I. = Artifical 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:

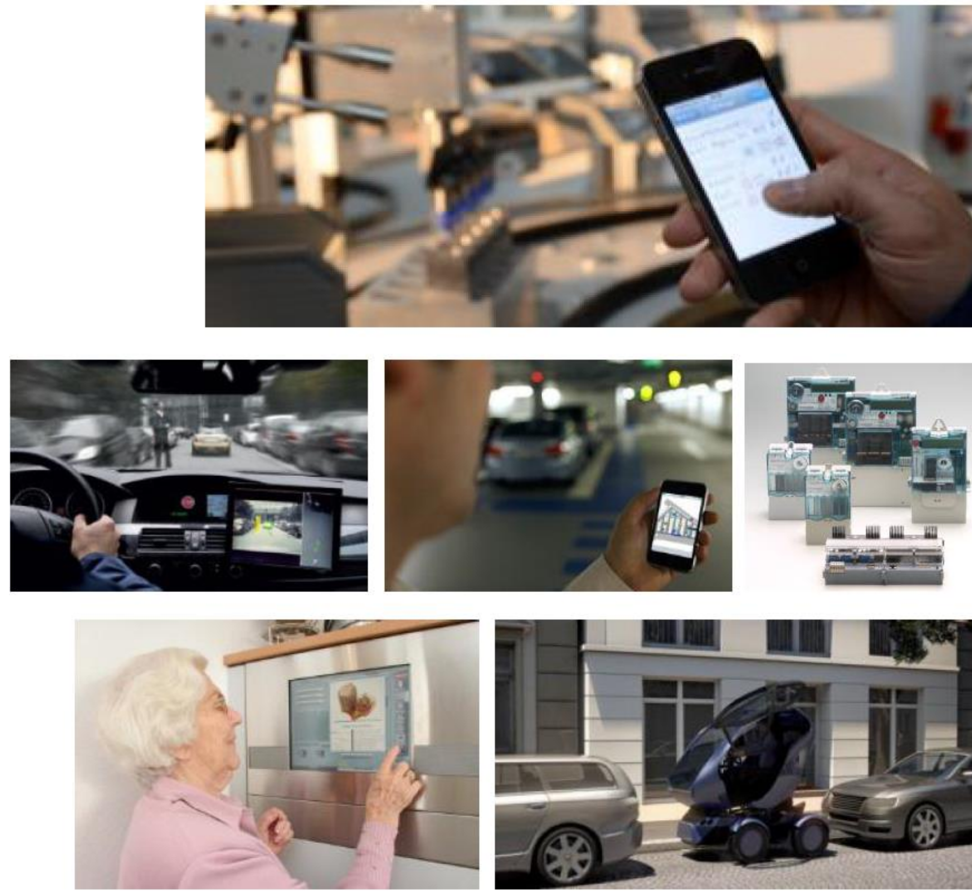
- Self-organizing of manufacturing equipment and logistics systems
- Cyber-physical systems are the technical basis
- „Social Machines“ include peoples via specialized interfaces
- Communication between smart product und manufacturing equipment
- Digital transportation links the elements within the production

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

2.1 Cyber-physical systems (CPS)

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:

Artificial Intelligence (AI)	A computer makes decisions similar to a human being, in an ambiguous envrionment. It solves problems.
Machine Learning	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.
Deep Learning	An artificial neural network with multiple layers solves tasks that are hardly described with mathematical rules and improves its own performance (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
- Predictive maintenance (manufacturing, aerospace, power generation, elevator, ATM): precise identification of risks and failures on precious assets. Consequently, each machine receives the maintenance when it needs it (*maintenance efficiency*).
- 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

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

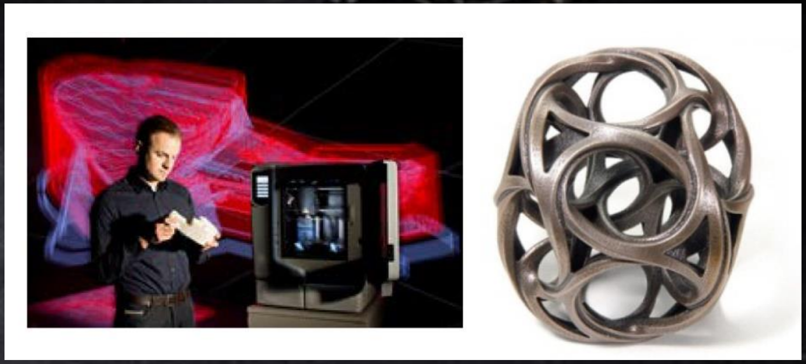
- Less weight
- Low waste
- Flexible or stable

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

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!



2.2 Smart factory demonstrator (2)

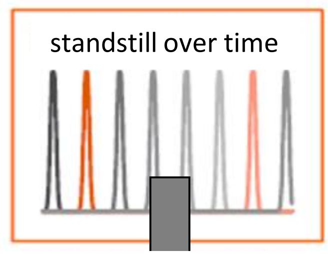
The demonstrator by Bosch Rexroth and „Deutsches Forschungszentrum für Künstliche Intelligence“ (DFKI) consists of several modules to produce cardholders. It allows unlimited exchange of data between the modules of different producers.

2.2 OSRAM GmbH (Lighting Solutions) (3)

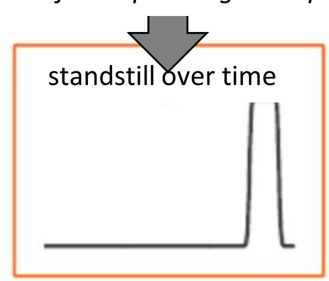
1 The development of new standardized tools and secure technologies

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



High machine and process maturity (planned standstills)

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.

Source: Berlin Partner for Business and Technoloy GmbH, 2018

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:

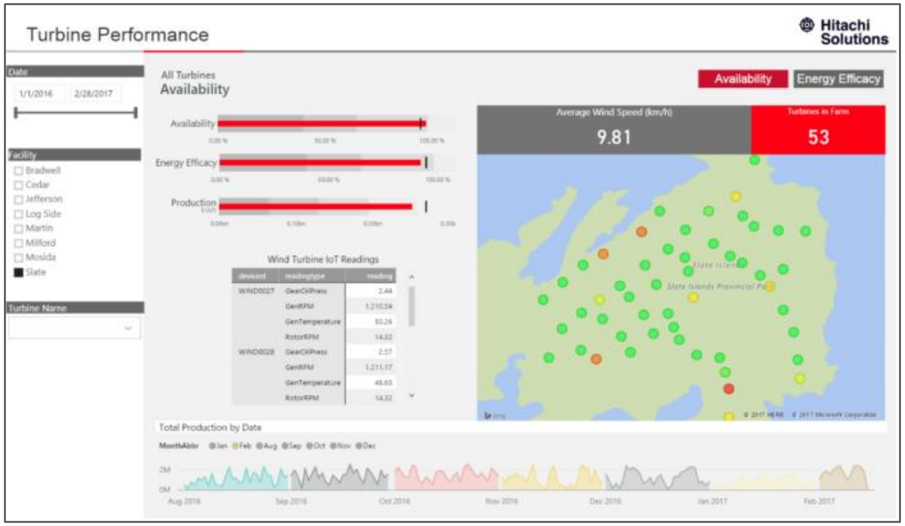
- 100 machines are connected
- 2.5 mio. documents per day with 14 GB of data
- 300 GB data available for analysis
- Reports available in the cloud

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

Source: Berlin Partner for Business and Technology UVB Confederation of Employers and Business Associations of Berlin and Brandenburg, Siemens, 2018

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



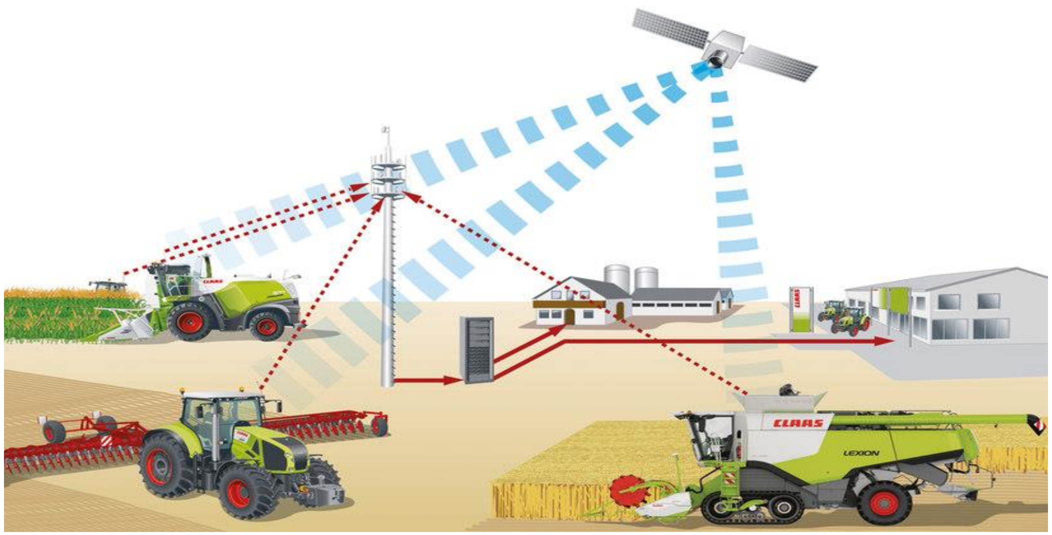
http://www.entura.com.au/can-big-data-artificial-intelligence-transform-wind-sector/

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 (digitally optimized irrigation).

2.2 Industrial and service robots (7)

Industrial Robots (unit sales +15%)

Source: International Federation of Robotics 2018. Image Yaskawa

Industries driven by automation:

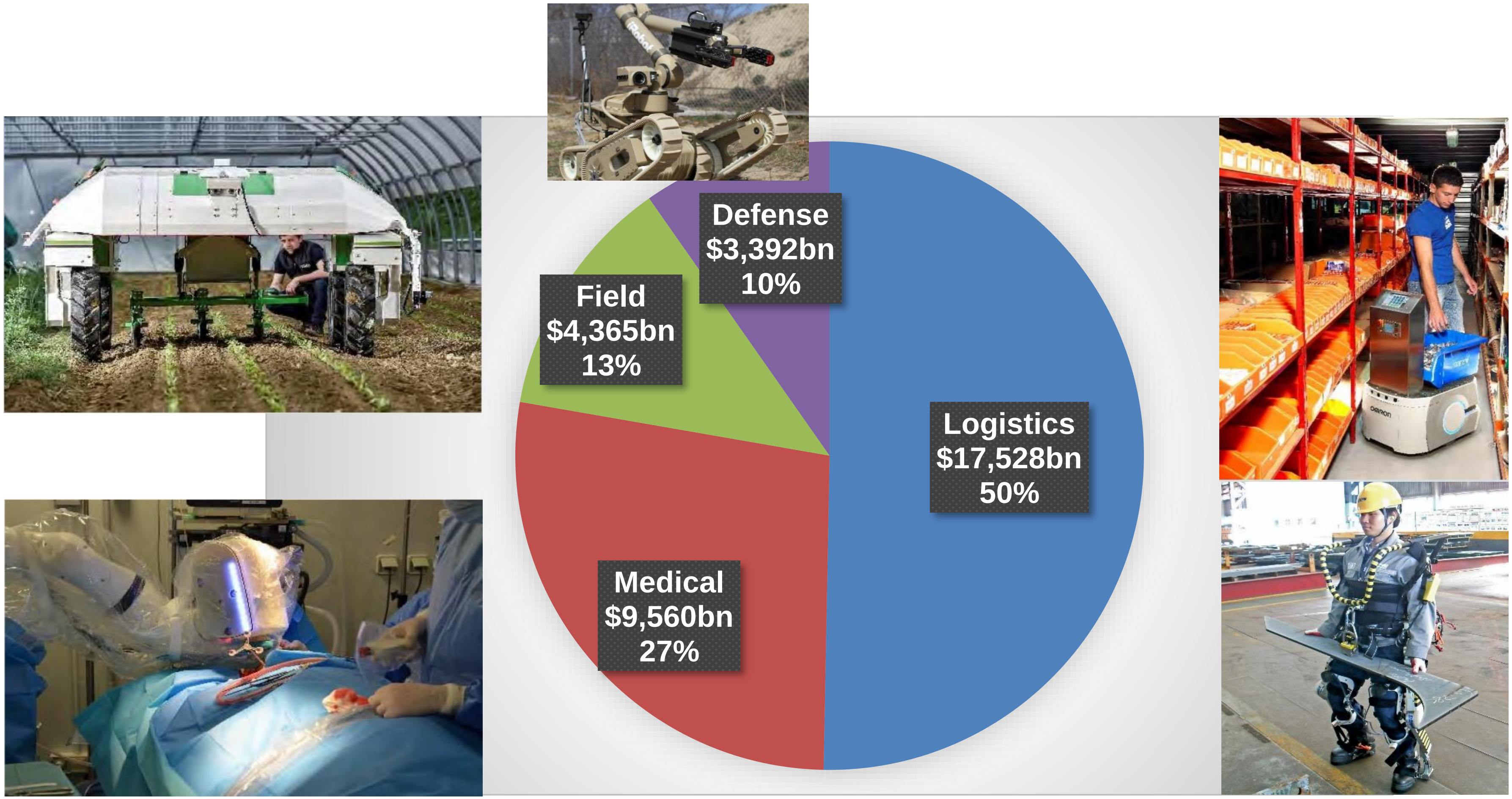
- Automotive
- Electrical/Electronics
- Metal
- Rubber/plastics
- Food/beverage
- Pharmaceutical industry

Professional Service Robots have entered our daily lives (sales +32%)

- Logistics, Medical, Field, Defense, Exoskeletons

2.2 Professional service robots (8)

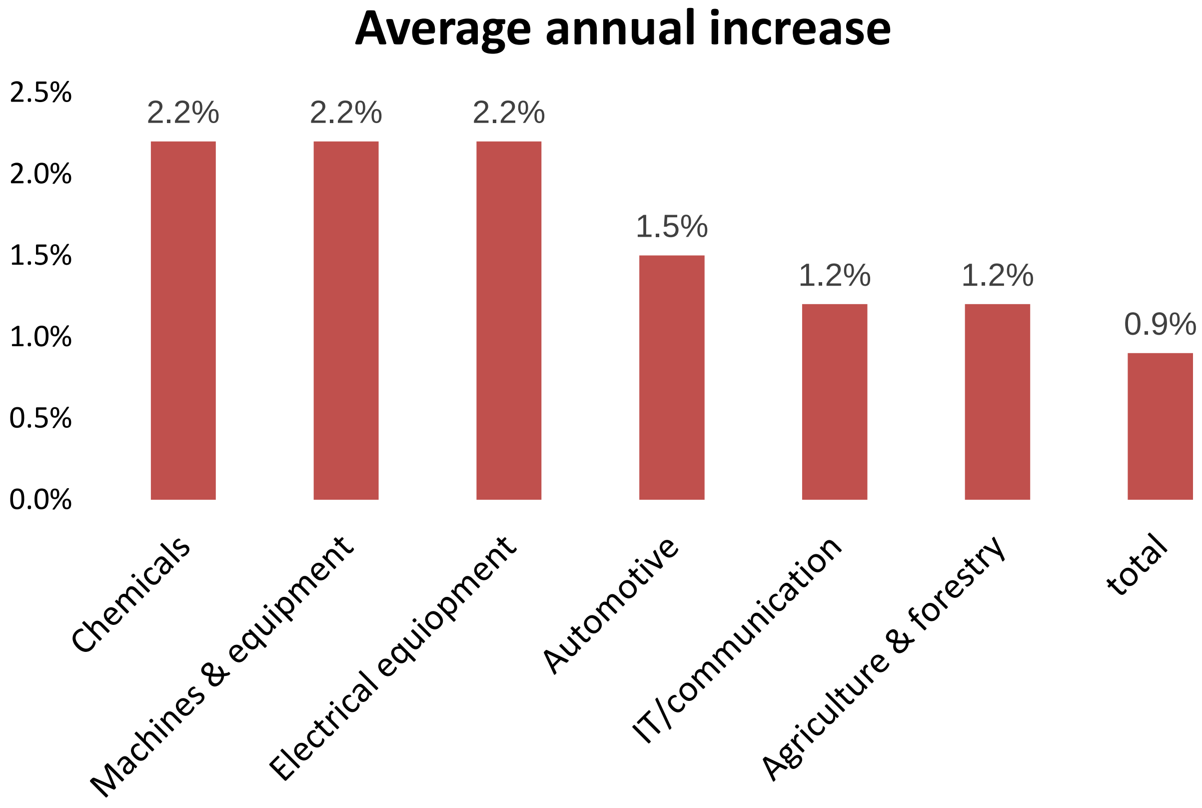
Main Applications. Value growth forecast 2019-2021 in billion USD



Source: International Federation of Robotics. Press Conference, Oct 18, 2018

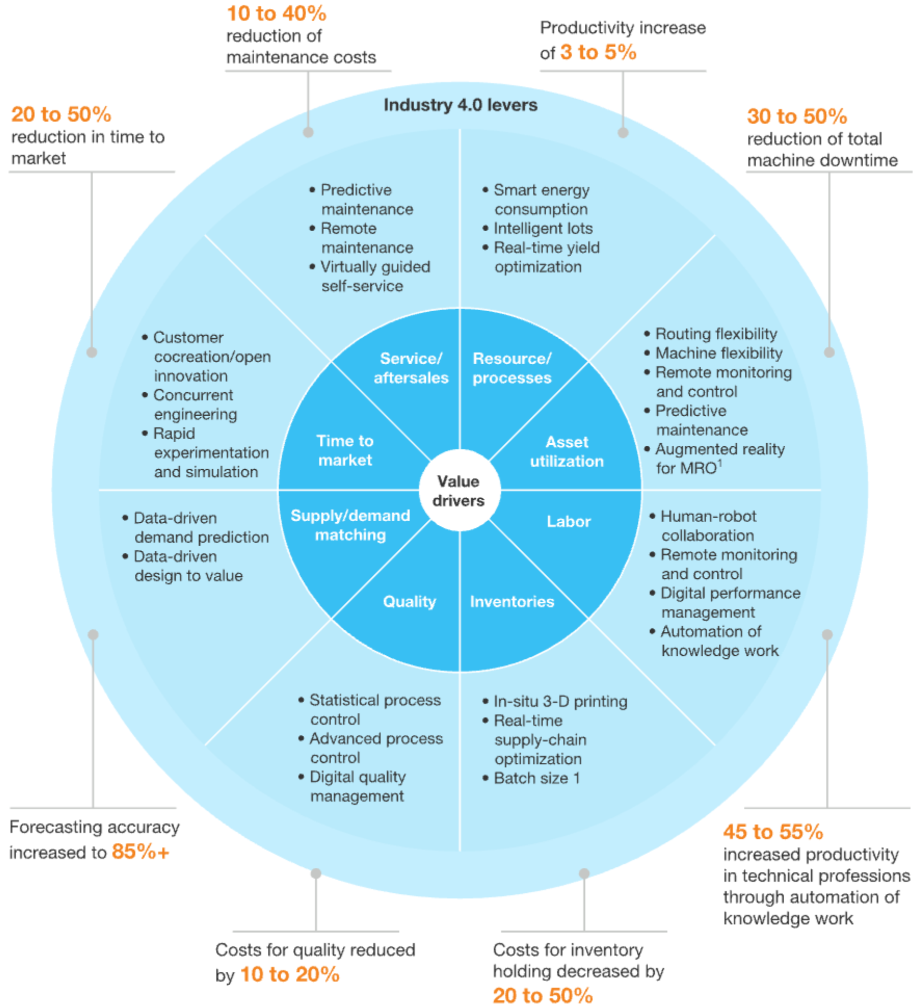
3. What can be gained from Industry 4.0?

Growth in gross value added by conversion to Industry 4.0 also includes agriculture



Source: "Sector Analysis – Agriculture 4.0", DZ Bank AG on the basis of Fraunhofer , 12.12.2017

3. 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

$743 billion
2015

$1.7 trillion
2019

Connected devices worldwide

$18.2 billion
2015

$50.1 billion
2020

+ 20%
Annual growth in Industry 4.0 investments worldwide. Stock of industrial robots grows by 15% 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.

71%
Companies already using some Industry 4.0 technology in 2018

4. Lessons for economic policy: Why should economic policy care about Industry 4.0?

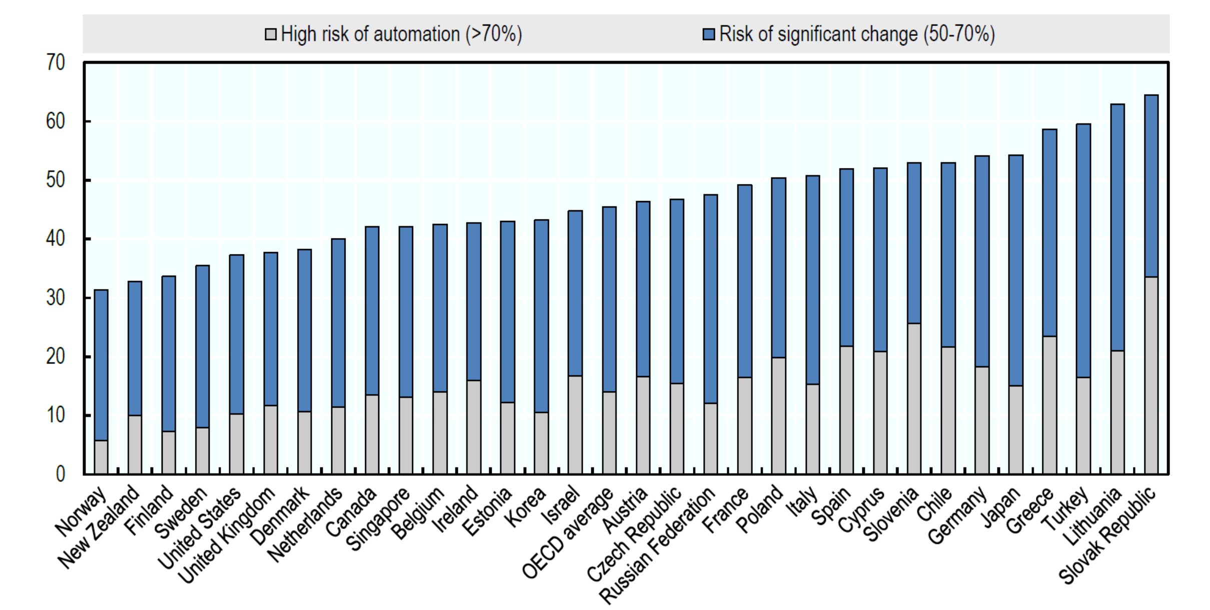
What is at risk for transition economies? What are the chances?

- Large shares of existing jobs are at risk of automation or significant change.
- Industry 4.0 and AI can have a positive net job effect, when new skill-intensive job profiles evolve. But new qualifications and high investments are needed.
- The risk of job substitution by AI and robots depends more on the industry structure of a country than on the development level. The decisive factor are job profiles.
- The highest risk is concentrated in (manual and cognitive) routine tasks. Demand will fall for middling jobs (e.g. insurance clerks, HR specialists). Lowest risk applies to social or creative tasks (kindergarden teachers, social workers).
- Industry 4.0 boosts productivity, flexibility, quality and allows better customized products and new disruptive business models.
- Smart factories mean less waste, energy consumption and deficient products.
- Potential for additional value added estimated +0.5% - 2.0% p.a.
- Urban production becomes attractive again and a trend is emerging to locate manufacturing close to design and innovation activities.
- Reshoring of manufacturing tasks to higher-wage countries may adversely affect transition economies’ employment opportunities.

4. Large shares of jobs are at risk of automation or significant change

Frey and Osborne claimed that 47% of US occupations were at risk of being automated over time by using data on activity profiles to classify occupations in terms of their automation potential through computers and robots.[1)]

Percentage of jobs at risk by degree of risk



Notes: High risk – more than 70% probability of automation; risk of significant change – between 50 and 70% probability.

Source: OECD (2018), Survey of Adult Skills (PIAAC) 2012, 2015.

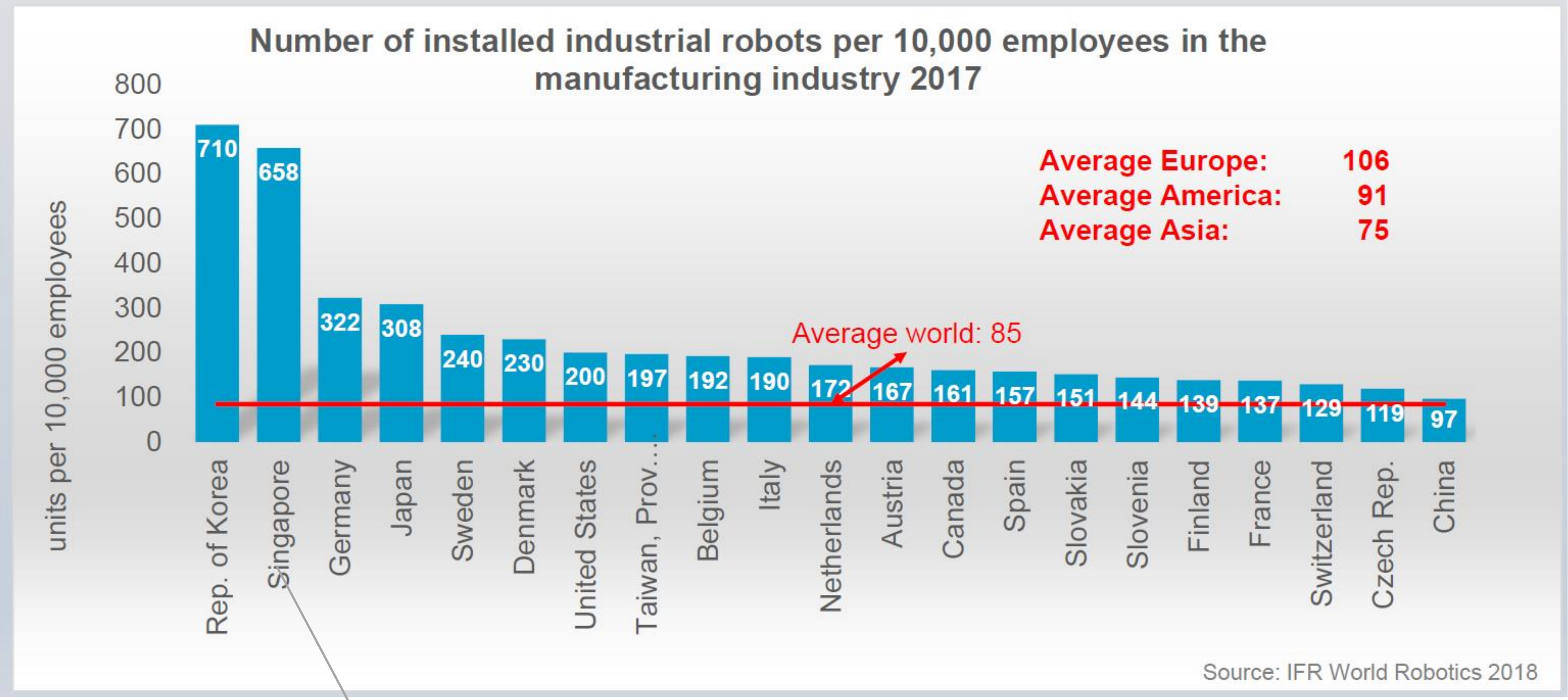
Key findings of OECD study

- 14% of jobs in OECD countries are highly automatable; another 32% face substantial change
- Automation mostly affects manufacturing industries, agriculture, mining, construction work.
- But some service sector jobs are highly automatable, too (e.g. shop assistants, building cleaners. 50% probability that robots will take over their work.

1) Frey and Osborne: The Future of Employment, in: Technological Forecasting and Social Change 114: 254–280.2017.

4. Countries with large robot density experienced an increase in the share of manufacturing in total employment*

Highest robot density in Korea - lowest average in Asia

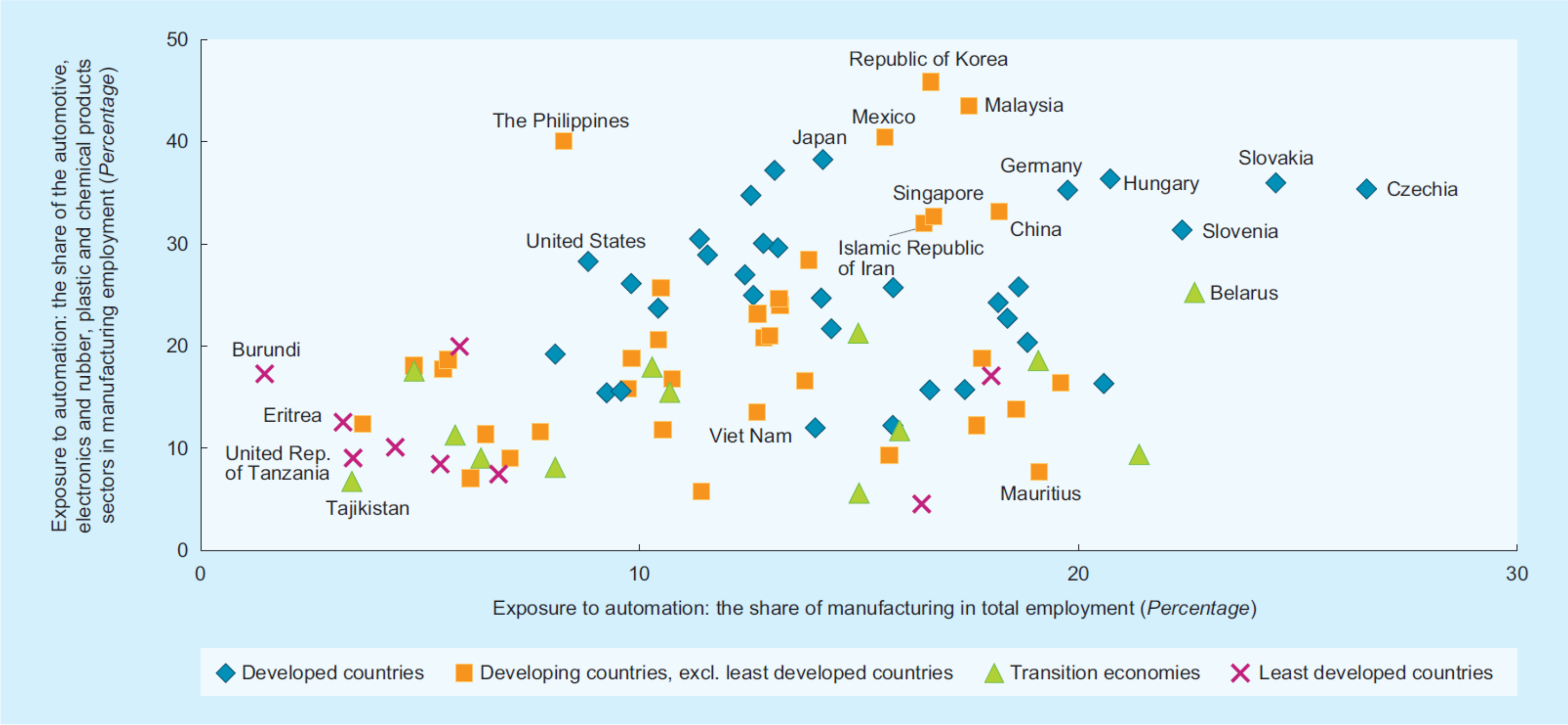


Installation of robots high automotive, electrical equipment, furniture, footwear, luggage in Germany.

** UNCTAD Trade and Development Report 2017, page 52.*

4. Developed countries to a larger extent exposed to robot-based automation in manufacturing

Proximate current vulnerability to robot-based automation in manufacturing



Source: UNCTAD secretariat calculations, based on Wood, 2017; and UNIDO, *Industrial Statistics* database.

Note: The horizontal axis reflects the share of manufacturing in total employment in 2014. The vertical axis reflects the share of the automotive sector, of the electronics sector and of the rubber, plastic and chemical products sector in manufacturing employment as an average for the period 2010–2014 over the years for which data are available. The sample includes all 91 economies for which data are available.

** UNCTAD Trade and Development Report 2017, page 50.*

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	Strategy for the Development of the Industrial Complex	Sustainable economic development	Modernization of industrial production and resource efficiency
Belarus	?	?	?

Source: Klaus Schlichting Assessment 2017 and BE Berlin Economics 2019.

→ Countries put emphasis on different issues

4. General policy approaches to Industry 4.0

Policy sector	Examples of industrial policy tools
Incentives and capital for I 4.0 related projects	▪ Subsidized loans for small and medium-sized companies ▪ Grants ▪ State guarantees
Technology policy / innovation	▪ Joint research projects ▪ Public funding for R&D in AI and robotics to maintain competitiveness ▪ Technology transfer center / Innovation agency ▪ Innovation voucher to bring together manufacturers and researchers ▪ Support for industrial start-ups (incubators) and public venture fund
Information and promotion of industry 4.0	▪ Enabling big multinationals, SME's and craftspeople to apply AI and I 4.0. ▪ Showcases and demonstrators ▪ Website analogue to German "Plattform Industrie 4.0"
Education and training	▪ Professional training in accordance with needs of industry; New occupations ▪ Training and retaining skilled IT professionals ▪ Strengthening vocational training; Promoting media competence in school ▪ Using test beds and competence centers for training and qualification
Consulting services	▪ Self-assessments, check-lists ▪ Subsidized coaching and counseling service for orientation
Economic development	▪ Fostering national and international cooperation ▪ FDI attraction with focus on manufacturing industries / technologies ▪ Export promotion
Regional policy and networks	▪ Promotion of clusters. Example: Technology network www.its-owl.de ▪ Network Industry 4.0 in Berlin ▪ Industrial parks

Source: BE Berlin Economics

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 – find answers through dialogue

Chair
Ministers Altmaier, Karliczek
Representatives of commerce, trade unions, science

Technical/practical expertise decision-making

Steering body
(companies)
- Chaired by business representatives, participation of Economic Affairs and Research Ministries
- Chairs of working groups, other guests/promoters

Industrial strategy development, technical coordination, decision-making and implementation

Working groups
- Reference architecture, standardisation and norms
- Technology and Application Scenarios
- Security of networked systems
- Legal framework
- Work, education and training
- Digital business models for Industrie 4.0
- Others as required

Working units with technical/practical expertise; participating ministries: Economic Affairs, Research, Interior, Labour

Policy guidance, society, multipliers

Strategy group
(Government, business, unions, science)
- Chaired by State Secretaries BMWi, BMBF
- Representatives of steering body
- Representatives of Federal Chancellery, Interior Ministry
- Representatives of the Länder
- Representatives of associations (BDEW, BDI, BITKOM, DIHK, VDA, VDMA, ZVEI)
- Representatives of trade union (IG Metall)
- Representatives of science (Fraunhofer)

Agenda setting, political steering, multipliers

Research Council

Activities on the market

Industrial consortia and initiatives
Implementation on the market: test beds, examples of applications (e.g. LNI 4.0)

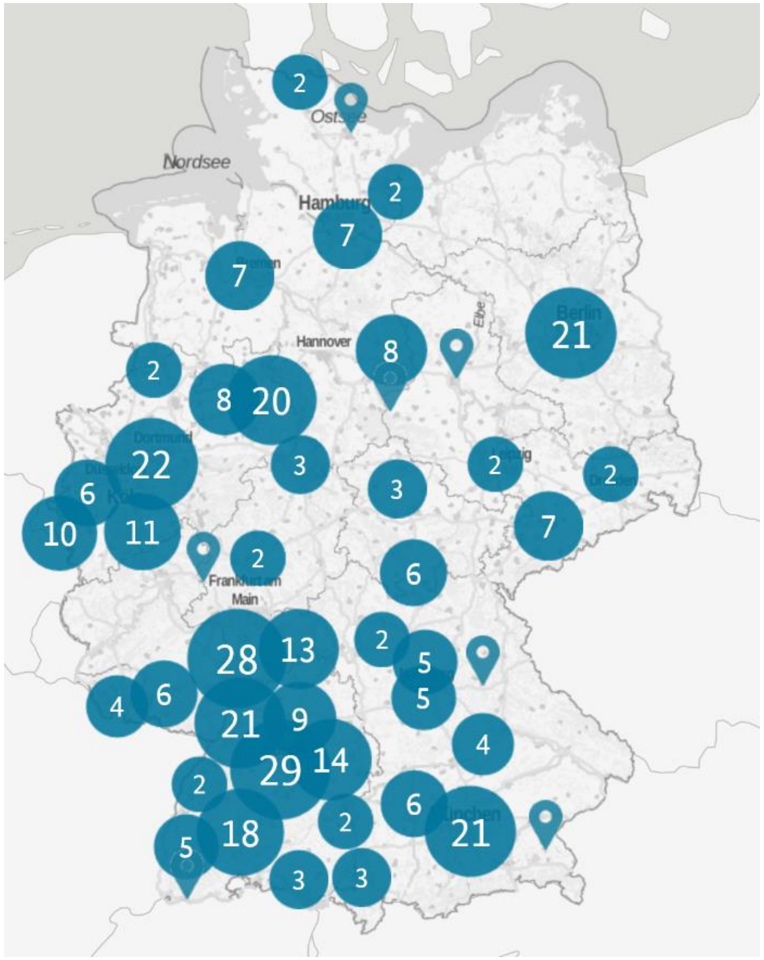
International standardisation
Standardisation bodies (e.g. SCI 4.0, DIN, DKE), Consortia

Secretariat as service provider
Network coordination, organisation, project management, internal and external communication

Source: BMWi

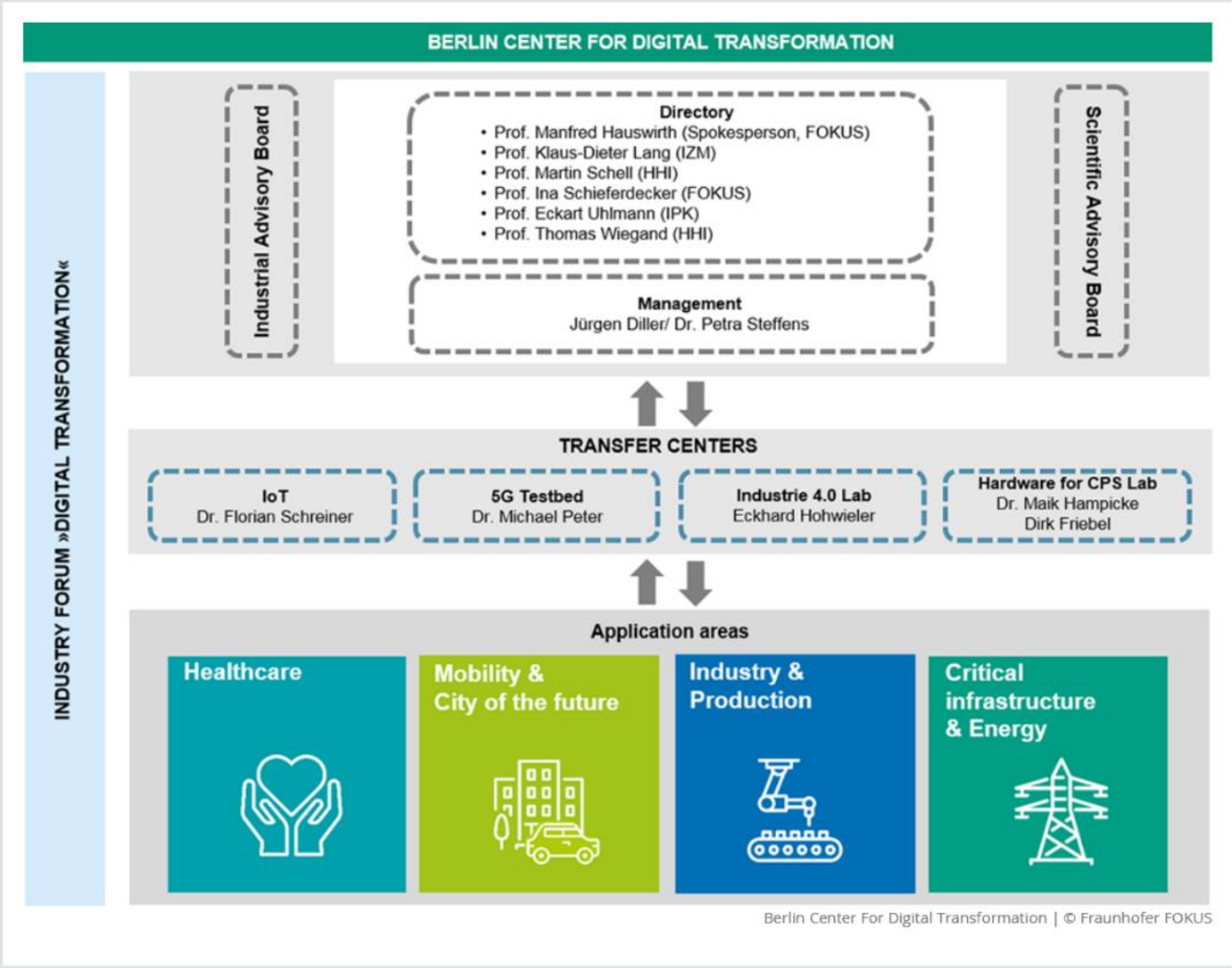
5. Industry 4.0 in Germany

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



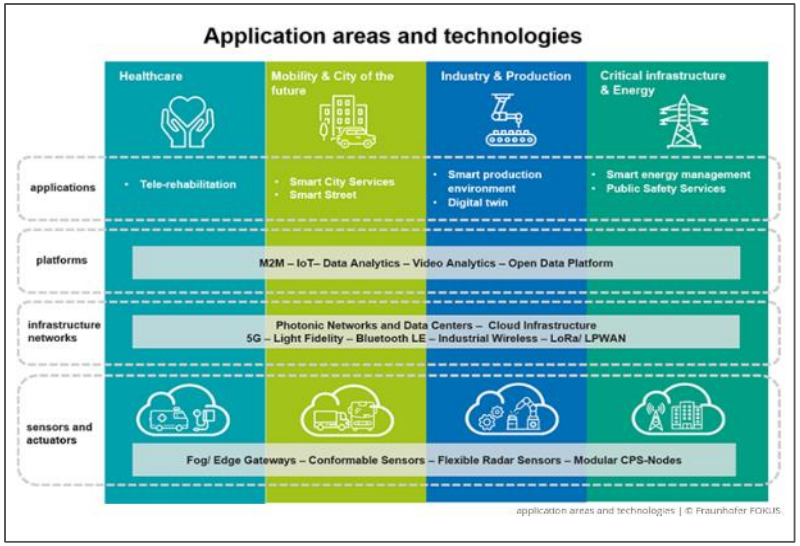
Source: Platform Industrie 4.0

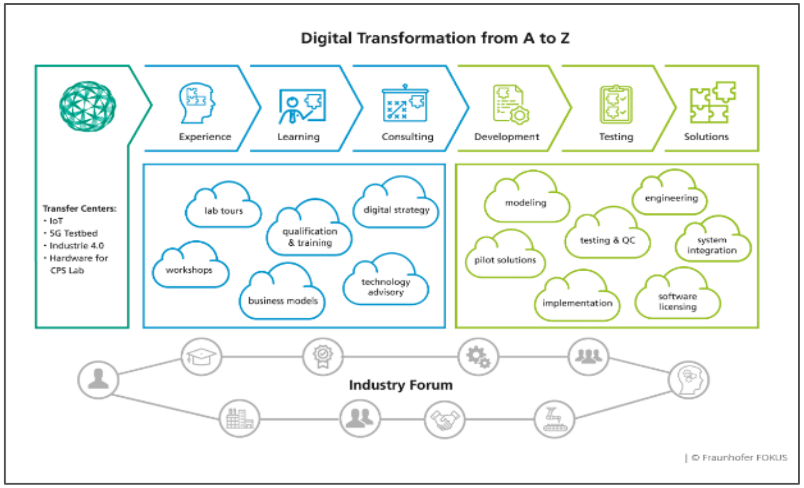
5. Industry 4.0 in Germany



Source: Leistungszentrum Digitale Vernetzung

5. Berlin Center for Digital Transformation: service offerings





Source: Leistungszentrum Digitale Vernetzung

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.

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

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 training
  - Consulting services
  - Economic development

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