Digitising European Industries - Member States Profile: **Germany**

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Summary

General Background: Germany is the largest national economy in Europe and the third largest exporter in the world (1.2 trillion euros in goods and services). Top exports of Germany are vehicles, machineries, chemical goods, electronic products, electrical equipments and pharmaceuticals. According to a OECD forecast, Germany's economic growth is projected to remain solid, and the unemployment rate will continue to fall. Also, the digital economy is a significant sector in Germany. According to a German performance index, the country ranks 6 behind USA, South Korea, UK, Finland and Japan. In 2016, the ICT sector generated a revenue of 223 bn € and the German internet economy a revenue of another 111 bn. €. In the past 5 years, the digitization in particular of the production industries has reached a high significance and awareness in Germany under the label "Industrie 4.0". The concept of Industrie 4.0 has been developed by the "Research Union", an advisory board to the federal ministry of education and research (BMBF), and subsequently brought into practice by the three German industry associations BITKOM (digital industry), VDMA (manufacturing industry) and ZVEI (electrics and electrotechnology industry) together with scientists from the German Academy of Science and Engineering (acatech). The basis technology concept addresses embedded intelligent and digitally networked systems along with the vision that through these "cyberphysical systems" a largely self-organized production will be possible.
In 2015, the ministry for economic affairs and energy (BMWi) announced that they would, together with the ministry of education and research (BMBF) enforce the platform towards a national instrument for the development of the economy. In2015 /2016, "Industrie 4.0" has evolved from a lighthouse counseling project to a national platform that would work out the central economic and location policy perspectives for Germany as a production location. Today, there is a broad consensus in Germany that Industrie 4.0 can increase the profitability of production, the competitiveness of industry in Germany can be strengthened and the flexibility of production increased. Next to the platform Industrie 4.0 initiative, the digital transformation of the industry was promoted through a number of other measures and initiatives by the government, for example:

- the technology transfer / uptake of Industry 4.0 to SME through a number of SME 4.0 Competence centers[1] (11 centers started in 2016, more centers started their work in 2017).
- a national lighthouse project "IUNO" for IT Security in Industry 4.0.
- broad discussions of societal, legal and ethical aspects of the digital transformation of industry.

Next to the Federal level, some significant initiatives in the area of Industry 4.0 have been initiated by the German Länder, by industry corporations or by research organizations.
According to DESI 2017 [6], Germany ranks 11th among the European member states and thus belongs to the Medium performing cluster of countries. The country is a leader in spectrum assignment (score: 1) and the price of fixed broadband compared with income is second lowest in the EU (score: 2). Although rural NGA coverage has improved significantly since 2016 to above the EU average, the digital divide between urban and rural areas is still a topic. Also, 4G coverage is insufficient 86% (score: 19). In the area of digital skills, Germany is performing above the European average. However, a significant number of schools do not have broadband access and computer use in young Germans remains below the OECD average. Germany is also lagging behind concerning

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[1] http://www.mittelstand-digital.de/DE/Foerderinitiativen/Mittelstand-4-0/kompetenzzentren.html

transactional e-government solutions and in the use of Open Data (rank 20). On the other hand, Germany ranks high (rank 1) in business information sharing and in SME online sales (rank 5).

National Strategies towards "Digitizing European Industries": The government has expressed its digitization policies in a number of strategy documents, such as the "Digital Strategy 2025" (2016, Federal ministry for economic affairs and energy; BMWi), the "Digital Agenda 2014-2017" (BMWi, ministry of the interior, ministry of traffic and infrastructure) and the "New Hightech Strategy" (2016), being the leading strategy of the Federal ministry of education and research; BMBF. To modernize Germany by applying Industrie 4.0 technologies is one of the major foci of these strategies. Germany aims to develop autonomy and leadership in various high technology fields, such as IT security, big data, cloud offerings, service platforms and other. BMWi and BMBF both have launched a number of initiatives in these areas.

BMWi has announced plans to implement the recommendations developed by the five working groups of the platform Industry 4.0, particularly in the areas of standardisation, legal framework, IT security and work. Furthermore, BMWi announced to introduce a 1 bn. Euro funding program in microelectronics as part of a European IPSEI. Other innovations are especially intended in the area of data economy and in SME based research via the BMWi Central Innovation Program Mittelstand "ZIM". Concerning infrastructure development, the government has initiated the "Network Alliance for a Digital Germany" that will invest 8 bn in broadband network deployment ("Gigabit society"). Other strategies set priorities in skills development, and in eGovernment ("Digital Administration 2020", "Open Government Partnership Action Plan 2017-2019").

Digitising European Industry (DEI) - Pillar 1
Digital industrial Platform actions: The German "Plattform Industrie 4.0" aims at developing joint recommendations for all stakeholders that serve as the basis for a consistent and reliable framework. The platform initiates alliances and networks at the precompetitive stage and proactively supports activities in the market, such as demonstration centers, research projects, standardization actions and it supports the overall understanding of Industrie 4.0. The platform is led by the federal ministers of BMWi and BMBF together with representatives from industry, associations, science and the trade unions. The platform's technical work is carried out in 5 thematic working groups (reference architectures, research & innovation, security, legal framework, education and training.

The recent developments of the platform include the following:

- Public and industry involvement as a governance instrument: communication and discussion of strategies and results with a public audience (e.g. Hannover fair, National Digital summit)
- Strategic expansion of the Industrie 4.0 platform: Next to an agreement on a "Trilateral European Cooperation" (Germany, France, Italy), a number of bilateral alliances (Industrial Internet Consortium; France; Japan; Czech Republic; China, Australia) have been set up.
- Setup of a "Standardization council Industrie 4.0" that aims to initiate standards for digital production and to coordinate these nationally and internationally.
- Support of complementary regional Smart Manufacturing Platforms and test centers: The association "LNI4.0" has been founded with the mission to support German SME through associated demonstration and test centers. BMBF complements this with the "test bed" funding measure addressing SME that need to test Industrie 4.0 technology in complex test environments.

Research, Development and Innovation Actions: On the basis of a vision paper (2013 [14]) on national ICT research in Industry 4.0, BMBF since 2015 is funding research in the following priority areas:

- Production Research – ("Human and work in an intelligent and networked plant"),
- ICT Research in Industry 4.0 (Embedded 'cyberphysical' Systems, Virtualization technologies for the plant of the future),
- the excellence Cluster Its OWL ("intelligent technical systems"), and
- trans-national production research (ERAnet Manunet; Smart Maintenance).

In its current strategy, BMBF focuses on four key areas that will be funded during the next years: Industrie 4.0 application in SME, Standards and IT architectures (research on the RAMI model), IT security (national lighthouse center IUONO) and Qualification (work design, competence development). BMBF is also funding parts of the EU ECSEL program "Productive 4.0" as well as cooperative research projects in smart manufacturing with the Czech Republic and with China (02/2017). BMBF is funding research and development into Industrie 4.0 technology and applications with almost 500 mio. Euros.

BMWi is funding applied research programs in the area of autonomous systems with a close relation to Industry 4.0 ("Autonomik for Industrie 4.0", "PAiCE"). As part of the BMWi program "PAiCE", the lighthouse project "Industrial Communication for Factories" (IC4F) aims at the development of secure, robust and real-time communication solutions for the processing industry.

In a broader sense of "Digitizing European industries", the German ministries fund projects in the following areas:

a) Research in Electronics and electronic systems, IT systems, Communication systems, IT security, Human-Technology Interaction / Microsystems Technology (BMBF)(

b) Photonics research; quantum technologies (New call "Quantum Futur" in June 2017, BMBF).

c) Additive Manufacturing (BMBF call on material research / ERA-net in 03/2017)

d) Microelectronics: BMBF research call 04/2017 (400 mio. €); BMWi EU IPSEI 1bn € initiative 2016

e) Service Robotics and Autonomous Systems: BMBF calls in 3/2012 (with 10 projects), 04/2016 (interactive base functions) and 02/2017 (interactivity strategies) , other foci on medical technologies and autonomous driving

f) Future of Work: BMBF call 10/2016, cofinanced by ESF

g) IoT based Services and business models for Service platforms: BMWi calls "Smart Service Welt" (2014-2019 and 2016-2021; total funding of 107 mio EUR)

h) Machine Learning: Two BMBF calls 02/2017 and 06/2017;

i) Big Data: BMBF: 2 competence centers in Berlin and Dresden since 2014, 10 research projects since 2014; BMWi "Smart Data" 2014

k) Specific SME research programs: BMWi: "ZIM"; BMBF: "KMU innovativ 2017-2022) and other

Digitising European Industry (DEI) - Pillar 2

Standardization actions: A central activity is the German standardization roadmap 'Industry 4.0'" The roadmap not only describes the current technical status of industry 4.0 and gives an overview on all relevant standards and specifications (including the RAMI architectural model), but also gives concrete recommendations for action and outlines standardization needs in the various areas.

Regulatory Framework: In 2016, the ministry for economic affairs has taken up the topic of digital platforms, being a growing engine of digitalization. The ministry observes that platform markets are

dominated by American and to a certain extent Asian internet services and they are currently conquering one analogue industry after another or inventing completely new ones and growing into new giants. A green book and a white book have been published.

BMWi intends to use field test labs as regulatory experimentation spaces. These "laboratories" allow the testing of innovations under real conditions, by adapting the existing requirements in time and space.

BMWi announced to anchor an innovation and investment friendly regulation within the national implementation of the new telecommunications regulatory framework

In 12/2016 the Federal Ministry of Labour and Social Affairs presented a "White Paper Work 4.0". Starting 2016, there have been intensive discussions on regulation necessities relating to a digitized work environment and the effects of digital platforms on the working conditions in Germany. Furthermore, the parliament adopted the Federal Open Data Act on 18 May 2017[2]. The new Act initiates cultural change in the administrations and obliges federal authorities to publish unprocessed data in the future.

Pilot factories and testbeds: The platform Industry 4.0 hosts an interactive map which at the moment lists a total of 55 test bed centers all over Germany. Prominent examples are the SmartFactoryOWL (Lemgo), the demonstration plant (WZL) Aachen or the SmartFactory Kaiserslautern as well as the Robotics and Mechatronics Center (Oberpfaffenhofen). Current initiatives are the "Track and Trace" testbed (Industrial Internet Consortium; SAP) or the Learning factory (University of Braunschweig). BMBF has initiated a program for Industry 4.0 test environments for SME.

Digitising European Industry (DEI) - Pillar 3

Digital Innovation Hubs actions: The digital hub initiative developed by BMWi seeks to support the establishment of digital hubs in Germany to foster cooperation between companies and business start-ups within a confined area. At the Digital innovation hubs, start-ups, scientific institutions, SMEs, industry and government shall evolve to centres of the digital transformation. BMWi is working on establishing a common label and a hub agency for the large German hubs that act as flagships (networking of hubs throughout Germany, knowhow transfer). BMWi also will strategically promote these digital hubs abroad with the help of Germany Trade and Invest. Since the launch of the Digital Hub Initiative at the IT Summit 2016, selected hubs in 12 locations (see map) with different focus areas have started their work.

Digitising European Industry (DEI) - Pillar 4

Skills development: BMWi is funding a number of measures according to its program "Future of the German Mittelstand" [4] that predominantly target SME: An alliance to strengthen vocational training, a activity for SME consultation; continuous work with the social partners on regulations for modernizing vocational training and an activity on social skills for workers. BMBF is reorganising vocational training in the "Berufsbildung 4.0" (vocational training 4.0) measure.

SME 4.0 competence centres: In June 2015, the Federal Ministry for Economic Affairs and Energy (BMWi) launched the funding initiative "SME 4.0 – Digital production and work processes" ("Mittelstand digital"). One element of this initiative are so-called SME 4.0-Competence Centers (Mittelstand 4.0-Kompetenzzentren). Their goal is to pool the relevant knowledge on the digitization and networking of business processes in their demonstration and learning factories and to pass them

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[2] https://www.europeandataportal.eu/de/news/new-open-data-act-germany

on to companies SMEs in their regions ("speaking the language of SMEs"). Ten centers plus one center for crafts have been established in 2016. In 2017 another 13 centers are starting their work. Additionally, four agencies were established to inform and advise small and medium-sized and craft-based enterprises about the digitization process and the implementation of Industrie 4.0.

Specific national measures

Innovation promotion: As of today, tax incentives for R&D are not implemented in Germany. However, at Hannover fair 2017, minister Wanka (BMBF) has announced that Germany wants to raise the gross domestic expenditures on R&D (GERD) from 3,0% to 3,5%. Therefore, after the election, the government plans to invent tax research funding for businesses up to 1000 employees. BMWi funds activities with innovation vouchers for SME ("go digital") in addition to traditional programs (go innovative, KMU innovative) of BMBF and BMWi. The BMWi program "InnoKom" aims at compensating the lack of industrial research in structural weak regions. With the program "WE!" ("WIR!"), BMWi engages in regions with particular challenges in structural change. In April 2017, BMBF minister Brigitte Zypries, presented an innovation agenda, "Innovation policy cornerstones - Bringing more ideas into the market". It is based on two pillars: firstly, a technology-driven subsidy, which supports entrepreneurs in making decisions on technologies to invest in. Secondly, the promotion of specific, particularly worthwile future technologies.

The BMWi program WIPANO supports SME in securing and using intellectual property for economic exploitation.

Since 2007 BMBF launches leading-edge cluster competitions as part of their "High-Tech Strategy" to pool regional potential along value chains. The selected clusters are sponsored for a maximum of five years with up to 40 million euros per cluster. Examples are the Software Cluster (Karlsruhe), "Silicon Saxony" (Dresden) or the Logistics Cluster (Dortmund). Currently, BMBF promotes the internationalization of leading edge clusters and future projects.

Germany is making use of ESIF funds with a total budget of 595 mio. Euro, especially in two of the east German Länder: Saxony (157 mio €) and Sachsen-Anhalt (152 mio. €).

Facilitate access to finance: In total, BMWi provides around two billion euros to strengthen the venture capital market in disruptive innovation leaps [4]. Several measures for suitable financing offers are provided, e.g. "INVEST venture capital grant", "ERP-EIF Growth Facility", "coparion" fund

I. General Background

Overall economic situation of the country

Germany is the largest national economy in Europe, the fourth-largest by nominal GDP in the world, and fifth by GDP[3]. In 2017, the country accounted for 28% of the euro area economy (IMF[4]). In 2016, Germany recorded the highest trade surplus in the world ($310 bn.). Germany is the third largest exporter in the world with 1.21 trillion euros in goods and services exported in 2016. The top country of destination for German exports were the United States (109 bn €), France (101.4 bn €) and the United Kingdom (86 bn. €)[5]. The service sector contributes around 70% of the total GDP, industry 29.1%, and agriculture 0.9%. Top exports of Germany are vehicles, machineries, chemical goods, electronic products, electrical equipments and pharmaceuticals.

99 percent of all German companies belong to mostly family-owned medium-sized companies (the German "Mittelstand"). Measured by revenue, the top large companies in Germany are Volkswagen, Allianz, Daimler, BMW, Siemens, BASF, Munich Re, E.ON, Bayer, and RWE.

Strong integration in global value chains (including by outsourcing labour-intensive tasks, and strengthened sales in distant dynamic markets, notably Asia), depreciation of the euro and wage restraint have made Germany's manufacturers very competitive. The number of workers with relatively low wages has risen. While the unemployment rate has been falling constantly during the past years, the average duration of unemployment spells is long. High household saving, low business investment, and budget consolidation have all contributed to a large current account surplus.

According to a OECD forecast[6], economic growth is projected to remain solid, and the unemployment rate will fall further. OECD suggests reforms to remove barriers to entry in services and a boost of public infrastructure, which would strengthen investment and reduce the large current account surplus.

The digital economy is a significant sector in Germany. According to an own performance index, the country ranks 6 behind USA, South Korea, UK, Finland and Japan. In 2016, the ICT sector generated a revenue of 223 bn Euro and the German internet economy a revenue of another 111 bn €. [1] Germany's greatest strength by far is market access, i. e. the ability to market products and services nationally and internationally. The links between the ICT sector and other areas of the economy are stronger in Germany than in any of the other countries, followed by Finland, South Korea and the USA. Germany's ICT experts also attest to high innovation levels. However, innovation is considered higher in Finland, UK, France and USA [1]. Among Germany's greatest weaknesses are the shortage of skilled workers, the network infrastructure, and a relatively strict regulatory framework. Also, broad parts of the population are lacking interest in technology. The start-up scene is fragmented.

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[3] https://en.wikipedia.org/wiki/Economy_of_Germany
[4] http://www.imf.org/en/News/Articles/2017/07/05/na070717-germany-spend-more-at-home
[5] https://www.destatis.de/EN/FactsFigures/NationalEconomyEnvironment/ForeignTrade/ForeignTrade.html
[6] http://www.oecd.org/economy/germany-economic-forecast-summary.htm

Overall strategy / situation concerning the digitization of manufacturing / production

In Germany, the term "industry 4.0" is an essential expression of the national strategy for the digitization of the economy and in particular of production.

In 2013, the three German industry associations BITKOM (digital industry), VDMA (manufacturing industry) and ZVEI (electrics and electrotechnology industry) established a joint initiative "Plattform Industrie 4.0" ("Platform Industry 4.0"). The platform was initially invented as an instrument to continue and coordinate their activities work within the "Forschungsunion Wirtschaft Wissenschaft"[7], a research council by BMBF to the German government (2006-2013). They regarded the platform as an instrument to secure and expand Germany's future as a production location.

The work of the Plattform Industrie 4.0 was strongly influenced by the works of ZVEI and 40 industry organizations within projects of the "National Roadmap Embedded Systems", which was already presented in 2009 at the national IT summit[8]. It was also influenced by the German Academy of Science and Engineering (acatech) and their strategic research agenda "Cyberphysical Systems"[9]. This project, funded by the Federal ministry of Education and Research (partners: BMW, Siemens AG, Festo, SAP, fortiss, Intel Germany, Bitkom, VDMA, ZVEI),

•   described the social and economic importance of cyber-physical systems,
•   analyzed the state of science and engineering in an international comparison,
•   and prioritized research objectives, initiatives and key projects necessary for exploiting the potential of CPS.

The technical basis behind the idea of "Industrie 4.0" are embedded intelligent and digitally networked systems. It is the vision that with their help, a largely self-organized production will be possible: people, machines, plants, logistics and products communicate and cooperate directly; machines learn to act and can be used in an increasingly autonomous manner.[10] Through networking, it will be possible to optimize not only one production step, but whole value networks. These networks will cover all phases of the product's life cycle - from the idea of a product through development, manufacturing, use and maintenance to recycling.

Overall, the profitability of production can be increased, the competitiveness of industry in Germany can be strengthened and the flexibility of production increased. For Germany as a location for innovation and business, this offers enormous potential: around 15 million jobs directly and indirectly depend on the manufacturing industry. It is expected that the digitization of industry and the economy will not only change the processes of value creation processes. Moreover, new business models and new perspectives for employees will arise. It is assumed that the intelligent, digital production methods of Industry 4.0 will offer great opportunities especially for SME. It was estimated that Industry 4.0 could lead to an additional 250 bn Euro surplus in value creation within 10 years.

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[7] http://www.forschungsunion.de/
[8] http://www.it-times.de/news/zvei-prasentiert-nationale-roadmap-embedded-systems-19045/
[9] http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Projekte/ Laufe nde_Projekte/Integrierte_Forschungsagenda_Cyber-Physical_Systems/ACA-11-XXX_Flyer_CPS_v3.pdf
[10] http://www.plattform-i40.de/I40/Navigation/DE/Industrie40/WasIndustrie40/was-ist-industrie40.html;jsessionid=D7ED4118DED525F176F382A8F939369D

Therefore, from 2015-2017, "Industrie 4.0" has evolved from a lighthouse counseling project to a national platform that would work out the central economic and location policy perspectives for Germany as a production location. At Hanover Trade Fair 2015, the ministry for economic affairs and energy (BMWi) together with the ministry of education and research (BMBF) announced that the platform should evolve to a political instrument that ensures a common approach of economy, science, politics and the unions. In April 2015, the platform published a report on future objectives and an implementation strategy [2]. In order to ensure the scientific quality of the work of the platform, a "Scientific Advisory Board Industry 4.0" was convened under the leadership of acatech. In 2016 and 2017, the platform has been expanded in three areas: Partners from the Plattform set up the standardization council Industry 4.0 and founded association LNI4.0 with associated test centers (see below, chapter platform measures). The platform also took a leading role in the international exchange on Industrie 4.0. Numerous international co-operations were expanded or newly established. New companies – also non-German companies – joined the platform.

Next to the Plattform Industrie 4.0 initiative, the digital transformation of the industry was promoted through a number of other measures and initiatives by the government.

- Major initiatives are concerned about the technology transfer of Industry 4.0 to SME, e.g. by developing maps of application examples and good practices[11] or test labs; the ministry for economic affairs and energy stimulates the uptake of Industrie 4.0 in SME through a number of Competence centers[12] (11 centers started in 2016, more centers started their work in 2017; see below). Another BMWi initiative for SME technology transfer focused on usable mobile business apps ("Funding initiative Usability", 2015)[13]
- The project IUNO[14] is a national lighthouse project for IT Security in Industry 4.0. The project, identifies threats and risks for the intelligent factory, develops protective measures, and implements them in four application scenarios. The aim is to develop general methods and solutions to meet the challenges of IT security in the industrial application field. The tested and transferable IT security solutions are then combined into a toolbox and can be used as a "blueprint" for secure industry 4.0 applications. In particular, SME that often avoid the digital transformation due to indisputable economic risks, could exploit the project results.
- Next to the technical and business aspects in relation to Industry 4.0[15], the recent discussions and developments have been extended to societal, legal and ethical aspects. The ministry of work has published a white paper with announcements and ideas concerning working conditions such as a "Occupational Safety and Health Strategy 4.0" or regulations on employee data protection[16]. In May 2017, the Federal Ministry of Education and Research has announced the foundation of the future German "Internet Institute for the Networked Society", that has the

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[11] http://www.plattform-i40.de/I40/Navigation/Karte/SiteGlobals/Forms/Formulare/karte-anwendungsbeispiele-formular.html
[12] http://www.mittelstand-digital.de/DE/Foerderinitiativen/Mittelstand-4-0/kompetenzzentren.html
[13] http://www.mittelstand-digital.de/MD/Redaktion/DE/PDF/faktenblatt-usability-pdf,property=pdf,bereich=md,sprache=de,rwb=true.pdf
[14] https://www.iuno-projekt.de/
[15] https://www.bmbf.de/de/das-deutsche-internet-institut-entsteht-in-berlin-4227.html
[16] http://www.bmas.de/SharedDocs/Downloads/EN/PDF-Publikationen/a883-whitepaper.pdf?__blob=publicationFile&v=3

mission to profoundly analyze transformation processes in digital change and the changes in society. The institute will also outline future options for action.

Next to the Federal level, some significant initiatives in the area of Industry 4.0 have also been initiated by the Deutsche Länder, by Industry or by research organizations. Some Examples are

- Bayern Innovativ GmbH[17] is Bavarias' organisation for innovation, technology and knowledge transfer. It supports players from industry and science in all stages of the value chain by providing customised services to boost innovation dynamics. Bayern Innovativ operates at the interfaces of various industries and technologies. The goal is to build an ecosystem of dynamic networks to accelerate the innovation process. In addition to the organisation's own clusters Energy Technology, Automotive and New Materials, activities focus on "crossclustering" with other Bavarian clusters and networking with key players in the Bavarian innovation landscape.
- The Cluster BICCnet[18] has the mission to secure the growth of information and communication technology (ICT) in Bavaria. It is initiated by the Bavarian State Ministry of Economic Affairs and since 2016 integrated into the CenterDigitization.Bavaria (ZD.B).
- Allianz Industrie 4.0[19] is a network initiated and supported by the Ministry of Economic Affairs of Baden-Württemberg. Together with their partner organizations, the initiative bundles the competences of production and information and communication technology and accompagnies industrial SMEs in the direction of industry 4.0 and offers various regional funding mechanisms[20]. The coordinating office is located at the VDMA-Landesverband Baden-Württemberg.
- Baden-Württemberg has furthermore worked out a "Roadmap Economy 4.0" with investments of 16 mio. Euro, e.g. in four "Digital hubs"[21].
- The state government of Northrhine-Westfalia is funding various projects such as a vocational education and training infrastructure "Lernfabrik 4.0 mit Lernfilialen" ("Learning Factory") which is part of the technology network and excellence cluster "its OWL"[22].
- In Saxony, the state government has worked out a digitization strategy "Digital Saxony"[23]. The government wants Saxony, which is already strong in chip production ("Silicon Saxony") to develop into one of the most technologically, economically and culturally leading regions in Europe. The strategy focuses on the implementation of the Internet of Things, Industry 4.0, Mobility 4.0 and Mobile Networks of the Future (5G).

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[17] http://www.bayern-innovativ.de/company/glance/?Edition=en
[18] http://bicc-net.de/
[19] http://www.i40-bw.de/en/
[20] http://www.i40-bw.de/de/foerderprogramme/
[21] http://www.ideenwerkbw.de/initiative-wirtschaft-4-0/
[22] http://www.its-owl.de/home/
[23] https://www.silicon-saxony.de/next-2016/digitales-sachsen/

Fact Sheet German National Strategy 'Industry 4.0'	
Ministries in Charge	Ministry of Education and Research (Research, Standardisation, Qualification policies) – BMBF[24]; Dr. Georg Schütte, State Secretary georg.schuette@bmbf.bund.de Ministry for Economic Affairs and Energy (Industry policy, Innovation programs, SMEs, Standardisation) - BMWi[25] Matthias Machnig, State Secretary, matthias.machnig@bmwi.bund.de
Contact Person	BMBF[26]: Prof. Wolf-Dieter Lukas; wolf-dieter.lukas@bmbf.bund.de BMWi[27]: Dr. Wolfgang Scheremet, Director General Industrial Policy; Wolfgang.Scheremet@bmwi.bund.de
Other relevant ministries	Ministry of Transport and Digital Infrastructure (Broadband infrastructure); Ministry of Labour and Social Affairs ("Work 4.0"); Ministry of the Intereor (Cybersecurity)
Main Strategy Documents	Ministry for Education and Research: Industrie 4.0 – Innovationen für die Produktion von morgen (2015) "Vision Paper / Zukunftsbild Industrie 4.0" (2015) "ICT 2020 - Research for Innovation" (2014) "New High-Tech Strategy" (2014): The digital economy and society (Industrie 4.0, Smart Data, Smart Services, Cloud Computing, digital networking, digital science, digital education, digital life environments "High-Tech Strategy 2020" (2010), "High-Tech Strategy (2006) Ministry for economic affairs and Energy: Digital Strategy 2025 (2016) [3] "Future of the German Mittelstand" (2016) [4] Industry 4.0 and the Digital Economy (in German] [5] Plattform Industrie 4.0: Industrie 4.0 gestalten: Wegweisend. Vernetzt. Praxisnah., Fortschrittsbericht (2017)[28] Digitalisierung der Industrie - Die Plattform Industrie 4.0, Fortschrittsbericht (2016)[29] ZVEI - Industrie 4.0: Das Referenzarchitekturmodell Industrie 4.0 (RAMI 4.0)[30]

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[24] https://www.bmbf.de/de/zukunftsprojekt-industrie-4-0-848.html
[25] https://www.bmwi.de/Redaktion/EN/Dossier/industrie-40.html
[26] https://www.bmbf.de/pub/orgplan.pdf
[27] https://www.bmwi.de/Redaktion/DE/Downloads/M-O/organisationsplanbmwi.pdf?__blob=publicationFile&v=92
[28] http://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/i40-gestalten.html
[29] http://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/digitalisierung-der-industrie-plattform-i40.html
[30] http://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/zvei-faktenblatt-rami.html

Related Strategy documents	"Research for greater internet security" (BMBF, 2015): Data protection, Cybercrime, Privacy preservation, Security of critical infrastructures White book "Digital platforms" (BMWi, 2017): Regulatory frameworks for the platform economy Digital Agenda 2014–2017 (BMWi, Ministries for Transport & Digital Infrastructure and Interior; 2014): Digital Infrastructures, digital work, e-Administrations (Open Data Action plan / "Digital Administration 2020"), Inclusiveness in the digital world, Cybersecurity, digital skills) "Strategy for Automated and Connected Driving" (Ministry for Transport and Digital Infrastructure, 2015) "Green Paper / White Paper Work 4.0" (Ministry for Labour and Social Affairs, 2016)

- The German Research Foundation ("Deutsche Forschungsgemeinschaft" DFG) has oriented their newer programs at Industry 4.0 related topics. One example is the program "Soft Material Robotic Systems"[31], performed by Leibniz Universität Hannover. This initiative aims at setting new impulses in robotics with a focus on characteristics such as indulgence and adaptability. Another basic research program is working on "Modeling and designing of business and communication processes in the factory"[32] (Technical University of Dresden and University of Hannover). A third DFG basic research program is stressing the change of production work due to industry 4.0 (University of Dortmund)[33].

- The Fraunhofer Society has also initiated strategic lighthouse projects, such as "E3 production". This strategic research aims at how to better plan, implement and monitor the flow of materials, energy and information in emissions-neutral E³ factories (ergonomic, energy- and resource-efficient production) through integrative solutions and utilizing synergies in future production processes. Furthermore, seven Fraunhofer Institutes have joined forces to set up a Fraunhofer Group for Production[34] and conduct collaborative, production-oriented research and development. It is their aim to pool the expertise and experience of the individual institutes to develop holistic and tailored solutions for customers that meet the challenges of the future. This encompasses several business areas such as Product development; Manufacturing technologies; Manufacturing systems; Production processes; Production organization and Logistics.

Digitization level of the country

According to the Digital Economy and Society Index (DESI) 2017 [6], Germany ranks 11th among the European member states and thus belongs to the Medium performing cluster of countries.

The country is a leader in spectrum assignment (score: 1). Germany is fully covered by broadband services, including fixed, mobile and satellite networks. Although rural NGA coverage has improved significantly since 2016, from 36% to 49%, and is now well above the EU average (40%), the digital divide between urban and rural areas is still obvious. 4G coverage is 86% (score: 19). Germans are reluctant to subscribe to fast broadband, only 31% of the population have subscriptions to

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[31] http://industrie.de/technik/dfg-startet-schwerpunktprogramm-zu-soft-robotics
[32] http://gepris.dfg.de/gepris/projekt/222826614
[33] http://www.neue-industriearbeit.de/index.php?id=13
[34] https://www.produktion.fraunhofer.de/en.html

broadband > 30 Mb/s (score: 21). This is despite the price of fixed broadband compared with income is second lowest in the EU (score: 2).

In the Human Capital dimension, Germany is performing above average and making further progress in their digital skills, according to the DESI report. However, a significant number of schools do not have broadband access and computer use in young Germans remains below the OECD average. 3.7% of the workforce are ICT specialists (rank 10), yet demand exceeds supply, as in most European countries. Therefore, addressing the shortage of ICT specialists remains crucial to support digital transformation in Germany.

The German population is using internet services less than the European average and, in comparison, even fell back from rank 15 to rank 18. This especially true for the use of Social Networks (rank 25) and Video Calls (31%, rank 27). Also, online banking (rank 16), online news (72%; rank 19) and online games consumption (78% rank 17), is practiced below the European average. However, the use of online shopping (82%, rank 3) and "Video-on-Demand" (23%, rank 11) is above the European average.

Concerning the integration of Digital Technology in business processes, the picture is inconsistent. While Germany ranks number 1 in business information sharing (56%) and also scores high in the number of SME selling online (26%, rank 5), various other variables only reached a medium ranking (use of Social media, use of RFID, eInvoices). With only 9% use of Cloud offerings, German enterprises obviously are more reluctant than businesses in other member states (rank 21). Also, eCommerce turnover is significantly lower than the average (rank 20). For some indicators, however, DESI 2017 refers to data from 2014 and may not fully be up to date. Referring to a survey performed by TNS Infratest[35], DESI concludes that "big and micro companies are adapting well to the digital era, but medium sized companies, 10-249 employees, are slow adopters and frequently lack a digitisation strategy. Also, some sectors are lagging considerably behind in terms of digitisation, including in particular the health sector and certain manufacturing industries".

The greatest challenge for Germany, however, according to DESI, is to improve the online interaction between public authorities and citizens (Only 19% eGovernment users, rank 23). Germany is one of the EU countries with the lowest online interaction between public authorities and citizens. Germany also reached a low ranking in the use of Open Data (51%, rank 20).

National strategies towards digitization (economy, society)

According to the ministry for economic affairs and energy, digitalising the industry will open up a potential of an additional cumulative added value of 425 billion euros in Germany alone [7].

Projections put productivity gains at up to 30%, annual efficiency gains at 3.3% and cost reductions at 2.6% annually. Improved cooperation between companies and start-ups in Germany could open up growth potential totalling 100 billion euros up to 2020.

In March 2016, the Federal Ministry for Economic Affairs and Energy presented the "Digital Strategy

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[35] https://www.tns-infratest.com/wissensforum/studien/monitoring-report_digitale_wirtschaft.asp

2025". Furthermore, the German Digitization policy is expressed in the "Digital Agenda 2014-2017" (ministry for economic affairs, ministry of the interior, ministry of traffic and infrastructure) as well as in the new "Hightech Strategy" which is the leading strategy of the ministry of education and research.

In its "Digital strategy 2025" [3], the Federal Ministry of Economic Affairs and Energy has pointed out and substantiated the following strategic priorities[36]:

- The establishment of a powerful and competitive digital infrastructure by setting up gigabit networks in rural areas.
- Encouraging a new Start-up era through a number of specific measures to ease access to Venture Capital (see below: Coparion-Fonds, High-Tech Start-Up Fund and other), a new Digital Innovation Start-up Competition ("Gründerwettbewerb Digitale Innovationen"), by promoting the internationalisation of German start-ups (information, advisory and support services, international accelerators) and a Start-up Portal ("Gründerportal 4.0").
- Creating a regulatory framework for more investment and innovation. Here, the European digital regulatory framework is mentioned as a priority topic, as well as developing a digital legal code that adheres to the principles of open and fair competition, data security and informational autonomy. Furthermore, regulatory "experimental spaces" for new technologies and business models are needed. The ministry also wants to work on a modern competition policy that takes the global market situation into account and is not limited to the European Single Market.
- Encouraging "smart networks" in key commercial infrastructure areas of our economy (: education, energy, health, traffic and administration). As one of the measures, BMWi aims at improving the basis for smart networks on a European level: according to the strategy, standards must be determined in order to create a uniform pan-European market environment.
- Concerning Data Security and Informational Autonomy, the ministry aims at taking measures that will help to convince SME that digitalisation of their business is future-proof. Germany relies on the new European General Data Protection Regulation, that will create a uniform, high level of data protection and helps to eliminate fragmented national data protection rules, legal ambiguities and possibilities for circumvention.
- Various measures are taken to enable new business models for SMEs, the skilled craft sector and the services sector. Involved in this initiative are numerous centres of excellence in the area of digital production (Mittelstand 4.0 Digital Innovation hubs, see below), four Mittelstand 4.0 agencies (expertise and service provision in digital communication, cloud computing, process management and e-commerce); the Go-Digital project (innovation vouchers, see below) and the go-Inno programme (50% funding of consultancy services fees; see below). Furthermore, the Digital Investment programme for SMEs (Digitales Investitionsprogramm Mittelstand) will be expanded and reach a volume of €1 billion available until 2018.[37] A multitude of smaller measures are also part of this strategic priority.
- Utilising Industry 4.0 to modernise Germany as a production location is a direct priority of the Digital Strategy 2025. Especially, it is announced to introduce a funding programme for microelectronics. With this program and investment, Germany intends to participate in a

[36] http://www.de.digital/DIGITAL/Navigation/EN/Strategy/strategy.html
[37] http://www.de.digital/DIGITAL/Redaktion/EN/Standardartikel/Strategy/strategy-06-business-models-forsme.html

European research and innovation project for microelectronics and contribute to it in the period from 2017 to 2019 with government subsidies of a total of €1 billion. The ministry also plans to implement the recommendations developed by the five working groups of the Plattform Industrie 4.0, particularly in the areas of standardisation, legal framework, IT security and work. They will develop an Action Plan for Standardisation of Industry 4.0 in which RAMI 4.0 will play a key role. Also, the ministry intends to strengthen cooperation on an international level, e.g. with the Industrial Internet Consortium and with China.

- In the area of Research, Development & Innovation Creating, the ministry aims at excellence in digital technology research, development and innovation. Next to Industry 4.0, innovations are especially intended in the area of data economy and in SME based research via the BMWi Central Innovation Program Mittelstand "ZIM". Some strategic application areas for research are mentioned here, such as manufacturing methods, service robotics and house connectivity / smart home. By promoting R&D projects in the innovative stage, the ministry

- wants to ensure that forward-looking topics in ICT are addressed early on and that scientific results are transferred to market-oriented leading technologies with substantial application potential. The ministry runs strategic research programs such as Smart Data, Paice or Smart Service Welt (see below).

- Concerning education and skills, the Digital Strategy demands a "Digital Learning Strategy that will be supported by all stakeholders"[38]. Digital technology should be made a key component of an educational policy focused on self-determination in an open and wellthought-out process. According to the strategy, BMWi will work with trade unions and employers to create means of more flexible and individualised digital continuing education, in order to provide employees with industry-wide, practical IT-related basic knowledge and supplemental knowledge on communications and project work

- Finally, BMWi wants to build up a new federal Digital Agency, that should be based on three pillars: bringing competencies together, supporting the political digital agenda, and sustainably building up digitalisation competence. A Digital Agency should be a service point that takes on the task of informing companies and consumers, being available to government agencies as a central competent contact and also identifying and removing obstacles to political strategies.

According to the 2014 "Digital Agenda 2014-2017", the German government's aim is to provide fast broadband Internet of at least 50 Mbps nationwide to all households by 2018, through a variety of technologies. Nearshore vectoring is expected to provide connection speeds above 50 Mbps to about 1.4 million households for the first time in Germany. Moreover, companies represented in the "Network Alliance for a Digital Germany" have invested another 8 billion EUR in 2016 in broadband network deployment. The Federal Government has contributed 4 billion EUR with the broadband funding program.

In November 2016, the Network Alliance together with BMVI set out the first cornerstones of a gigabit strategy [8], which directly supports investments in a fiber infrastructure on a technologically neutral basis. It is also planned to spur demand from companies through an information campaign. Additionally, underserved industrial shall be equipped with fibre connections until the end of 2019.

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[38] http://www.de.digital/DIGITAL/Redaktion/EN/Standardartikel/Strategy/strategy-09-digital-education.html

The ministry of education and research (BMBF) presented a new strategy on ICT security "self-determined and secure in the digital world" in March 2015 [9]. The strategy encompasses 10 objectives and guidelines. One priority is to develop and use IT security to strengthen Germany as an industrial location. IT security has the function to protect the new business models of Industry 4.0 and to promote economic growth. In parallel, the IT security industry is expanding its international position with the help of innovative technologies and processes. Another priority of the strategy is IT security safeguarding the operation of critical infrastructures to ensure their availability and prevent chain reactions. Since the failure of one or more critical infrastructure would have serious effects for both the state, the economy and the population of Germany.

 The BMWi "Digital strategy 2025" [3] among other, calls for an investment fund for gigabit networks in rural areas. A fund volume of around €10 billion is expected to lead to additional investments in the period to 2025. Financing sources for this fund could include the proceeds from the next spectrum auction (the UMTS frequencies will expire in 2020) as well as funds from the Digital Dividend II which have not yet been utilised for broadband deployment. Beyond that, new financial instruments will be necessary

With their new "Hightech strategy", the government (lead: ministry of education and research) established six thematic priorities in research and innovation. While the first one is stressing digital economy and society directly, also the other priorities are closely related to the digital transformation of the society and businesses: a sustainable economy and energy; innovative working environments; Healthy living; Intelligent mobility; and civil security.

Germany aims to develop autonomy and leadership in various high technology fields: security, big data, cloud offerings, service platforms and other. The ministry for economic affairs and energy as well as the ministry for education and research have both launched a number of initiatives in these areas. Here, only two examples are mentioned:

- The program "Smart Service World" (BMWi 2015) addresses in 20 projects the value chains that exist within and between branches with the help of IoT based online services and common service platforms. The application scenarios of the selected projects were predominantly in the area of production and logistics as well as in solutions for mobility and "a good life". In 2017, BMWi selected 14 more projects for an extension of this program, now promoting cross-cutting flagship solutions for SMEs in the fields of employment, mobility, housing and basic services.
- At the end of 2015, BMBF launched a comprehensive research program "Bring Technology to humans", which aims at creating technologies that are built for people's needs. The related projects focus for example on the design of service robots that assist people within their home surroundings.

To raise the level of digital skills in Germany, the Conference of Education Ministers (KMK) in December 2016 adopted a strategy on "Education in the digital world," comprising curricula for all school levels, teacher trainingand more (eGovernment etc)[39]. Furthermore, the Federal Ministry for Education and Research (BMBF) presented its strategy "Education Offensive for the Digital

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[39] https://www.kmk.org/aktuelles/thema-2016-bildung-in-der-digitalen-welt.html

Knowledge-based Society"[40][41] in October 2016 and proposed a DigitalPakt#D with the Länder. The BMBF would invest EUR 5 billion over 5 years to provide 40 000 schools with digital equipment, while the Länder would provide the teachers with the necessary training. The Conference on Education Ministers (Kultusministerkonferenz – KMK) has meanwhile presented an own strategy paper and ICT employers association Bitkom has provided a commenting strategy paper on both[34]. BMBF and the Länder are currently working on a joint agreement to coordinate and integrate the respective strategies.

The "Digital Administration 2020" program, which was launched 2014 as part of the "Digital agenda 2014-2020", aims to ensure that in future public administration is generally electronically accessible for all citizens. It includes measures on electronic filing, the central DE-Mail gateway, the central e-ID service, an extended payment platform and public procurement. The existing organisations – and particularly the IT Planning Council - have the task to ensure that there are appropriate structures for the steering and coordination of federal IT.

In July 2017, the ministry of the Interior published the First National Action Plan 2017 - 2019 for Germany's participation in the Open Government Partnership (OGP)[42]. The two-year action plan creates framework conditions for further promoting open government and the implementation of appropriate reform projects in various policy areas. It includes 15 commitments by several federal ministries (e.g. fulfilling international transparency standards; promoting the provision of open data by authorities, and the support of local integration projects).

Furthermore, the parliament adopted the Federal Open Data Act on 18 May 2017[43]. The new Act initiates cultural change in the administrations and obliges federal authorities to publish unprocessed data in the future.

In December 2016, the Federal Ministry of Labour and Social Affairs presented a "White Paper Work 4.0". Starting 2016, there have been intensive discussions on subjects relating to a digitized work environment and the effects of digital platforms on the working conditions in Germany. As to the shortage of skilled IT personnel, the Federal Government pursues a cross-sectoral approach to safeguarding the future supply of ICT experts.

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[40] https://www.bmbf.de/files/Bildungsoffensive_fuer_die_digitale_Wissensgesellschaft.pdf
[41]
https://www.bundestag.de/blob/484256/80715258d6689a3686e6ea05a219b4ea/bitkom_stellungnahmedata.pdf
[42] http://www.bmi.bund.de/SharedDocs/Pressemitteilungen/EN/2017/ogp-action-plan.html
[43] https://www.europeandataportal.eu/de/news/new-open-data-act-germany

II. National Strategies towards "Digitizing European Industries"

Strategy development through the "Plattform Industrie 4.0"

The German Plattform Industrie 4.0 aims at developing joint recommendations for all stakeholders, that serve as the basis for a consistent and reliable framework[44]. The platform

•   initiates national and international alliances and networks at the precompetitive stage
•   identifies trends and developments in the manufacturing sector and combines them to produce a common overall understanding of Industrie 4.0.
•   identifies where action is required on standards and norms and will actively express recommendations for national and international committee work.

The platform does not operationally realise activities in the market, such as demonstration centres, research projects or company-led projects, however it does proactively initiate and support them.
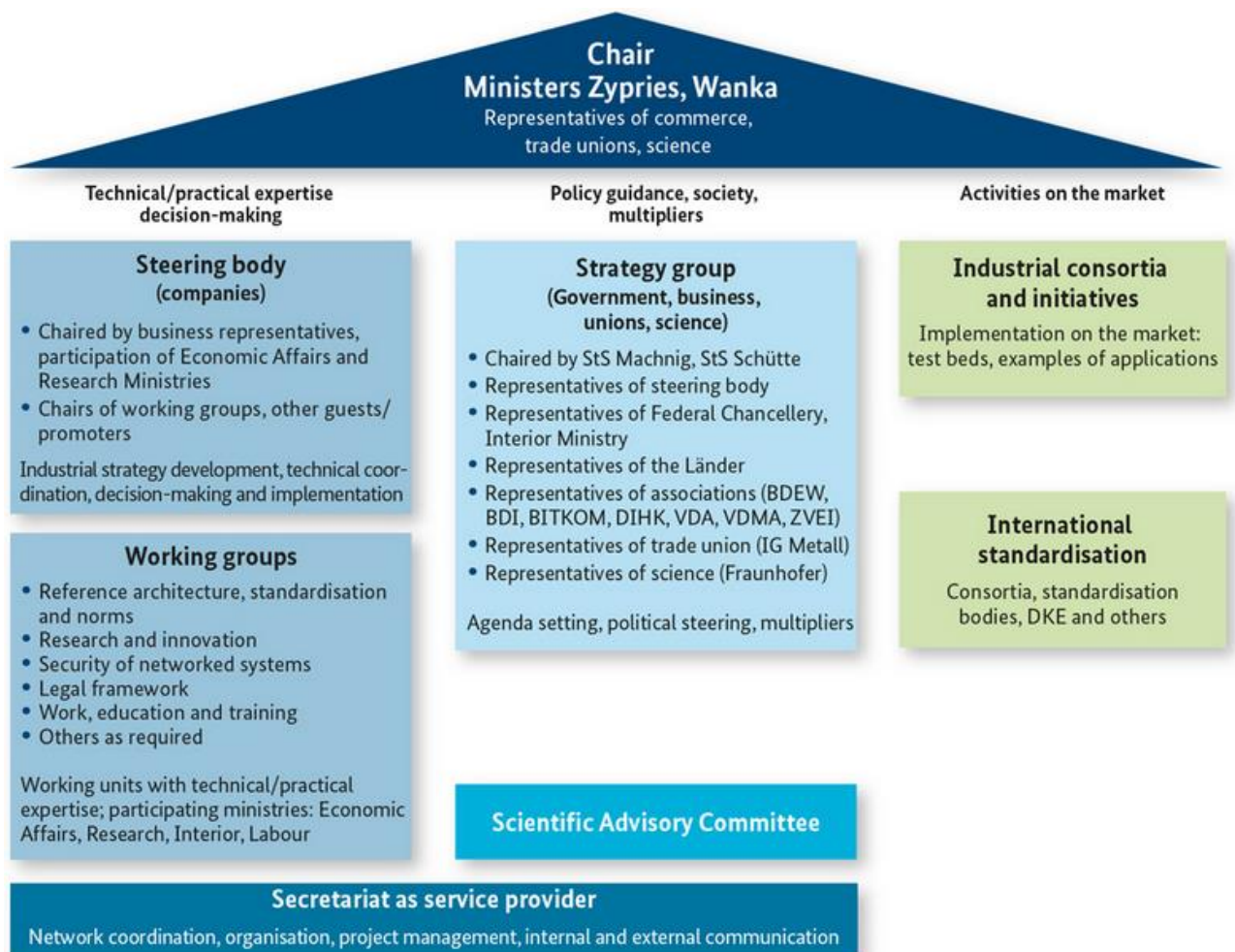

Fig. 1: Structure of the German "Plattform Industrie 4.0"

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[44] http://www.plattform-i40.de/I40/Navigation/EN/ThePlatform/PlattformIndustrie40/plattform-industrie40.html

Figure 1 shows the structure of the German Plattform Industrie 4.0. It is steered and led by the Federal Ministers for Economic Affairs and Energy (Brigitte Zypries), and of Education and Research (Prof. Johanna Wanka), together with representatives from industry, science and the trade unions. Experts from business, science, associations and the trade unions develop operational solutions together with representatives from various federal ministries in thematic working groups. The management structure as well as the companies that are represented in the platform have been published.[45]

The platform's technical work is carried out in thematic working groups. The working groups develop and document precompetitive concepts on selected topics and specific recommendations for action that, when implemented, should ensure a competitive advantage for all partners in Germany.

- Working group on reference architectures, standards and norms: it is a major task of the platform to incorporate existing norms and standards into RAMI 4.0 (Reference Architecture Model Industrie 4.0) [46]. RAMI 4.0 is an initial proposal for a solution-neutral reference architecture model. The working group will pay special attention to 19ptimize19a the number of standards to be employed. Another central element driven by this work group is the so-called "Industrie 4.0 core component".
- Working group on research and innovation: the group evaluates current case studies to identify research and innovation requirements from the industry perspective. It also updates the Industrie 4.0 research and innovation roadmap and identifies research necessities, together with the platform's other working groups. Findings on necessary innovation and research are presented to the national funding bodies, including recommendations for future research programs. A first research roadmap was published at Hannover Fair 2015[47]. It not only gave hints on the necessary preconditions and mutual dependencies, but also identified the concrete results to be achieved. A second core result of this work group was the definition of ten application scenarios for Industrie 4.0, published 2016 [11] and updated 2017[48].
- Working group on the security of networked systems: this group is concerned with issues of secure communication and secure identities of value chain partners. A technical overview on these topics has been published at Hanover Fair 2016. The group also addresses the detection of cyber-attacks on production processes and their implications. The working group has provided SMEs with a quick-start guide for the introduction of "Industrie 4.0 security" (published at CeBIT 2016) to enable a widespread introduction of Industrie 4.0. In addition, the working group will define knowledge and experience required of employees in relation to Industrie 4.0 security issues. Complementary to the results of this group, the German machinery association VDMA has published various guides on security requirements, traceability and related security topics.

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[45] http://www.plattform-i40.de/I40/Navigation/DE/Plattform/Plattform-Industrie-40/plattform-industrie-40.html;jsessionid=6F342D14548430C37A0CA321F541CFEC
[46] https://www.zvei.org/en/subjects/industry-4-0/the-reference-architectural-model-rami-40-and-the-industrie-40-component/
[47]

https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2014/april/Industrie_4.0__Whitepaper_zu_Forschungs-_und_Entwicklungsthemen/Industrie-40-Whitepaper-Forschung-20140403.pdf
[48] http://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/fortschreibung-anwendungsszenarien.pdf?__blob=publicationFile&v=6

- Working group on the legal framework: This group highlights where legislative action is needed. The primary issue if and how to adjust the regulatory framework, which essentially addresses human-controlled 20ptimize, needs to be adapted to cover machinecontrolled communication. A number of subgroups have been implemented, working on specific problems of Civil rights and Litigation; IT and Data protection law; Product Liability Law; IP Law and Employment Law.
- Working group on work, education and training: the group is taking care of issues concerning the transition to a networked industry and the involvement of the workforce. The working group has defined three closely interrelated fields for its endeavours: In networked information and production spaces, human-machine interfaces and cooperation must be designed to serve the interests of the people involved and the innovative capacity of enterprises. The 20ptimize20ation frameworks for coalescing value networks must be designed to facilitate working and learning within the processes. Training and qualification programs in hybrid fields must be designed to accommodate operational skills development, process oriented learning and new forms of (work integrated) learning. The group has published recommendations and best-practices on these topics.

An up-to-date overview on the technical results and the implementation strategy of the Plattform Industrie 4.0 is published in [12]. Furthermore, the working Paper "Aspects of the research roadmap in application scenarios" [11] is helpful for understanding the vision and activities of the platform.

Public and industry involvement as a governance instrument
The government communicates and discusses the strategies and results in the area of Industrie 4.0 with a wide professional audience in public events such as, for example, CeBIT, Hannover Messe and the National Digital Summit.

- At CeBIT 2017, the Plattform Industrie 4.0 presented its online map with almost 300 best practice examples[49]. The map shows locations in Germany in which Industry 4.0 is already a reality. Furthermore, the map shows the SME 4.0 Competence Centers of the Ministry of Economic Affairs and Energy as well as test beds for smart manufacturing applications and products.
- Industrie 4.0 was one of the main topics at 2017 Hanover Messe[50]. The Plattform Industrie 4.0 broadly presented its activities in 20ptimize20ation20, IT security and support for small and medium-sized enterprises at national and international level[51]. Furthermore, a great variety of topics, such as artificial intelligence for SME or synergies of intralogistics with production or cooperative robots were among the trends of the fair. 500 application examples for Industry 4.0 were presented at the fair. As international partner, Poland presented initiatives and products at the Hannover fair. Chancellor Merkel pointed out the importance of an integrated Industry, and claimed that the apocalypse of a broad job loss by Industrie 4.0 is not true. Moreover, new occupations and job opportunities are created.
- At the 2017 National Digital Summit (Ludwigshafen, June 12th/13th), the Ministry for Economic Affairs presented numerous initiatives which are successfully promoting digitization: One priority was the digital innovation hub initiative (see below) with the launch of new hub locations all over the country. A second priority was given to recommendations for SME on their road to Industrie

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[49] http://www.plattform-i40.de/I40/Redaktion/EN/News/Actual/2017/2017-03-23-cebit.html
[50] http://www.hannovermesse.de/de/news/top-themen/industrie-4.0/
[51] http://www.plattform-i40.de/I40/Redaktion/EN/PressReleases/2017/2017-04-25-hmi.html

4.0. Furthermore, the Plattform Industrie 4.0 presented its recommendations and results at the Digital Summit[52]. With a 10-point plan, the platform aims to expand and strengthen Germany's leading role in the industrial sector. In addition to existing topics, new topics will be dealt with in the future, medium-sized enterprises will be supported by a "transfer network Industrie 4.0" and the international cooperation will be deepened.

Support of complementary regional Smart Manufacturing Platforms

Another strategy of the government concerning smart manufacturing is the support of regional competence centers and clusters and their targeted internationalization[53]; in order to strengthen them in their international competition. One example is a cooperation project between the excellence cluster "itsOWL"[54] with the Finnish cluster DIMECC (project volume: 630.000 €, 50% funding by BMBF), which was published in July 2017[55].

In June 2016, the ministry of education and research has published a number of 11 regional SME networks that are funded for strategic cooperation and internationalization[56]. Production, biotechnology and electromic mobility were the predominant application scenarios.

Initiatives to support SME in mastering the digital transformation: Mittelstand Digital

The "Mittelstand digital" program consists of three initiatives that aim to support SME in mastering the challenges of digitization:

- "Simply intuitive – usability for the SME sector" helps small and medium-sized businesses to improve the quality and usability of operational software.
- "E-standards: 21ptimize21at business processes, ensure success" accelerates the development, trialling and dissemination of e-standards with the aim of strengthening the international competitive position of small and medium-sized businesses.
- Under the initiative "Mittelstand (SME) 4.0 – Digital Production and Work Processes", Mittelstand 4.0 Competence Centres (see below) raise awareness about 21ptimize21ation, provide information and training for business leaders and staff members across the country and show them solutions in practice in their demonstration factories, offering a hands-on approach for testing out the digital transformation, so to speak. The Mittelstand 4.0 Agencies pool the latest knowledge on overarching issues of digitalization like cloud-computing, communication, trade and processes and share this information via multipliers such as business chambers and associations.

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[52] https://www.plattform-i40.de/I40/Redaktion/DE/Pressemitteilungen/2017/2017-06-13-digital-gipfel.html
[53] https://www.bmbf.de/en/internationalisation-of-leading-edge-clusters-forward-looking-projects-and-comparable-1416.html
[54] www.its-owl.com
[55] http://www.its-owl.de/newsroom/news/detailseite/news/bmbf-foerdert-neues-its-owl-projekt-zur-internationalisierung/
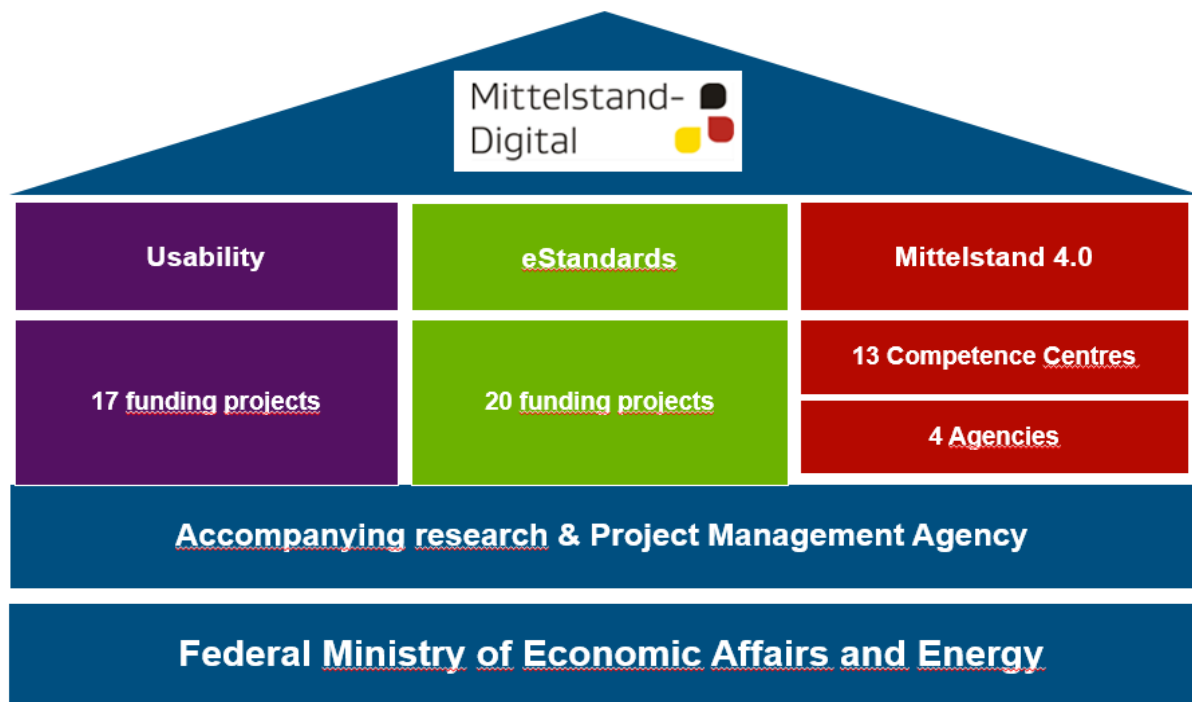[56] https://www.bmbf.de/de/regional-vernetzt-global-erfolgreich-3019.html

Fig. 2: Structure of the "Mittelstand Digital" program

Cluster Policy, technology "valleys"

The ministry of education and research had launched a leading-edge cluster competition for the first time in 2007 as part of the Federal Government's High-Tech Strategy. It was designed to pool regional potential along the entire innovation and value-added chain. Five top clusters were selected in three competitions, each of which was sponsored for a maximum of five years with up to 40 million euros per cluster. There were no thematic targets: the candidates were selected with the best strategies for future markets – in their respective sectors. Relevant examples are[57]:

- Software-Cluster, www.software-cluster.com : The software cluster in the south-west of Germany claims to be Europe's "Silicon Valley for enterprise software". In the region around the centers of software development Darmstadt, Kaiserslautern, Karlsruhe, Saarbrücken and Walldorf, more than 134,000 employees work in over 11,000 software companies. The information technology faculties and research facilities of the region regularly achieve top rankings in international rankings and ensure qualified newcomers. The cluster is coordinated by a common strategy and structure in order to maintain and further increase its competitiveness.
- Effizienzcluster LogistikRuhr, Logistics, www.effizienzcluster.de : More than 180 companies and more than 20 scientific institutions are now part of the logistics network LogistikRuhr. The

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cluster is one of the partners of the new Digital.Hub Logistics based in Dortmund[58],. The offer supports especially innovation teams from companies – so-called "start-ins" – on the way to marketing.

- Medical Valley Nürnberg, Medicine Technology, www.medical-valley-emn.de: The cluster offers a comprehensive service portfolio to support innovation processes from the initial product idea to market maturity. Following the one stop shop principle, the cluster integrates established specialists and experts along the medical technology innovation chain. Important service components are offered in the areas of subsidy acquisition and consulting, identification and procurement of clinical partners, market approval and reimbursement, strategic requirement analysis and health-economic evaluation and international market

- access. The medium-term goal of all Medical Valley EMN partners is to develop products and services that significantly increase efficiency and effectiveness in the fields of prevention, diagnosis, therapy, and rehabilitation. The long-term strategy of the Medical Valley EMN is to 23ptimize the structures of healthcare provision.

- Cluster MicroTEC Südwest, Micro Electronics, www.microtec-suedwest.de : MicroTEC Südwest has set itself the task of expanding the internationally leading position of BadenWürttemberg in the area of microsystem technology to a world leadership. The cluster has received BMBF funding for 5 years (2010-2015) and is now acting along a research agenda and financed by industry as well as EU and national projects. The cluster is part of the Allianz Industrie 4.0 network, initiated and supported by the Ministry of Economic Affairs of BadenWürttemberg.

- Cool Silicon, energy efficient technologies with micro electronics and nano technologies www.cool-silicon.org : With the aim of massively increasing energy efficiency in the area of ICT, the Cluster Cool Silicon was founded in 2009. Meanwhile,they are combining 60 companies and research facilities from the leading microelectronics region "Silicon Saxony". The area of Dresden has developed to "Silicon Saxony", when Infineon in 2011 decided to open up a production site for wafers. In the meantime, 60.000 people work for about 2300 saxonian enterprises in the ICT brench and in micro electronics with a yearly turnover of 14 bn. Euro.

Since then, continuous measures of a targeted cluster policy have been launched by the ministry, such as a competition for the "internationalization of leading edge clusters, future projects and comparable networks (august 2015)[59]". This program supports the development of internationalization concepts and their implementation in projects with the help of global partners, each with up to EUR 4 million for up to 5 years. The independent selection committee has recommended 10 projects in the third round of tenders, which will start to work in early 2018. The program is accompanied by a support action project "InterSpiN" since December 2015 (continually develop the knowledge on the international cooperation of clusters, analysis of the promotion effects, support participants in the exchange of experiences) on the successful development and implementation of their internationalization strategies. Since March 2017, another support action has been devoted to the topic "The Virtual Cluster Academy", in which a concept for the education and training of science, innovation and cluster managers is developed on the basis of a sharing

[58]

https://www.bvl.de/misc/filePush.php?mimeType=application/pdf&fullPath=/files/441/442/1640/1746/1768/Digital_Hub_Logistics,_DLK_2016,_Michael_ten_Hompel.pdf
[59] https://www.bmbf.de/de/die-3-internationale-clusterkonferenz-2015-in-berlin-538.html

economy approach. BMBF intends to provide additional accompanying studies for further development and exchange of experience on emerging relevant issues.

With the "KMU-NetC" program (announced February 2017[60]), BMBF strengthens SME in regional networks and clusters. This measure addresses the challenge of SME to renew their processes, products and services and also their business models. To do so, it is useful to closely interlink with experienced other companies, universities or research facilities in networks or clusters. Innovation strategies or technology roadmaps can be shared, thus facilitating and accelerating SME innovations. "KMU-NetC" aims to enable less innovative SMEs to develop new ideas and to exploit the latest research results. KMU-NetC alliances encompass at least two SMEs and are coordinated by a network or cluster organization along an existing innovation strategy / technology roadmap.

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[60] https://www.bmbf.de/de/kmu-netc-3244.html

III. Digitising European Industry (DEI) Pillar 1 - Digital Industrial Platforms actions & Research, Development and Innovation actions

Digital Industrial Platforms actions

Launched in 2013 as a "future project" by three German industry associations (see above), the Plattform Industrie 4.0 was expanded in April 2015 to additional players from companies, associations, trade unions, science and politics were added. In April 2016 within the framework of the Hannover Messe, the Platform Industrie 4.0 published its first progress report after one year in the expanded constellation. A scientific advisory board advises the Plattform Industrie 4.0, in all scientific and programmatic research questions in close exchange with the accompanying research. Members of the Advisory Board are professors from the fields of production and automation, computer science as well as jurisprudence and working sociology. The spokesman of the advisory board is a member of the steering committee of the platform. The advisory board is coordinated by acatech - the German academy of engineering sciences.

General and Strategic objectives of Industry 4.0

The Plattform Industrie 4.0 has published an implementation strategy in January 2016 [11] and progress reports in April 2016 [12] and April 2017[61]. Furthermore, Working Group 2 in 2014 and 2015 had published a "White Paper R&D Topics" [13]. These documents form the basis for the common objectives, key targets and activities of the Plattform Industrie 4.0.

General objectives of the Plattform Industrie 4.0 are:
*   to provide content recommendations: Based on the knowledge obtained through research and practical experience, the platform's working groups identify where action is needed and make recommendations directed to companies, politics and academia, politics and companies for implementing Industrie 4.0 in practice and for suitable framework conditions. This makes it easier for businesses to integrate the new Industrie 4.0 approaches and technological developments into their business practices.
*   to inform and guide businesses, particularly SME. Around half of the companies within the industry sector in Germany are currently dealing with the topic of Industrie 4.0. An Online Map on the platform's website pinpoints hundreds of use cases where Industrie 4.0 it is already being practiced and it provides information on regional competence and test centers. The idea is to encourage even more businesses to get involved with Industrie 4.0. On the basis of these use cases, businesses can get direct information and contact adresses about the different topics and are encouraged to implement such use cases themselves. The online library and online map are available as a guide and knowledge database for Industrie 4.0 solutions. With the Industrie 4.0 Compass, the platform has developed an instrument that quickly and intuitively shows the way to suitable, non-commercial support offerings.
*   to promote international networking and cooperation. Plattform Industrie 4.0 receives numerous requests both from within as well as from outside Germany. It maintains close ties with initiatives from China, Japan, France, Italy, USA, Czech Republic, Australia and is

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[61] Available in German: http://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/i40-gestalten.pdf?__blob=publicationFile&v=4

systematically expanding these relationships. The platform also participates in national and international events and in multilateral network events with e.g. EU Commission Round Table or G20 conferences.

Fact Sheet German Plattform Industrie 4.0	
Political Lead organizations (Chair)	Federal Ministry for Economic Affairs and Energy, Federal Ministry for Education and Research Representatives of commerce, trade unions, science[62]
Relevant associations	• Representatives of the German Länder, Federal Chancellery, Ministry of the Interior, BMBF, BMWi • Representatives of associations: ZVEI (German Electrical and Electronic Manufacturers' Association), VDMA (Mechanical Engineering Industry Association), Bitkom (German Digital Association), BDI (Federation of German Industries) and other • Representatives of trade unions: IG Metall (German Metal Industry Trade Union) • Representatives of science: Fraunhofer Gesellschaft
Working Groups	• WG1: Reference architectures, standards and norms - development and definition of a uniform "Reference Architecture Model of Industrie 4.0" / RAMI 4.0 • WG 2: Research and Innovation- focus on identifying R&D needs as well as barriers in order to realize I40 application scenarios • WG 3: Security of Networked Systems – focus on solutions for Secure Identities and Secure Communication • WG 4: Legal Framework – focus on identifying relevant aspects of the digitized economy from a legal perspective • WG 5: Work, education and Training – focus on the future of employment, work, and professional education
Contact Persons	**Federal Ministry of Economic Affairs and Energy** **Ernst Stöckl-Pukall;** Tel.: +49 (30) 18-615-5674 Email: Ernst.Stoeckl-Pukall@bmwi.bund.de Head of Division IV A 5; Digitisation and Industrie 4.0- Hannoversche Str. 28 – 30; 10115 Berlin /Germany **Plattform Industrie 4.0, Henning Banthien, Generalsekretär** Tel.: +49 30 2759 5066-50; geschaeftsstelle@plattform-i40.de Geschäftsstelle Plattform Industrie 4.0 Bertolt-Brecht-Platz 3 10117 Berlin; Telefon: 030-2759 5066-50 ; Telefax: 030-2759 5066-59 Website

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[62] http://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation-gesamt/zusammensetzung_plattform.pdf?__blob=publicationFile&v=9

Concerning technical objectives, the platform in an earlier stage has set the objective of "Industry 4.0 by Design" [13] which means that all developments will be performed according to a reference architecture. This means that machinery and plant builders, for example, model their products in "design layers" that can be encapsulated. "Industry 4.0" by design would allow for a high flexibility and it would secure the competitiveness of German production sector. To implement this vision, it would be necessary

- to build / provide Cyber-Physical-Systems and integrate them in existing plants
- to ensure that relevant machine data and information is provided in real-time, in order to analyze the optimal value creation processes,
- to keep the complexity of technical solutions manageable (safety, privacy, security) - to standardize the architecture as well as the semantics

In 2016, additional technical objectives have been expressed after defining seven use scenarios of Industrie 4.0 (WG2 in close collaboration with the other working groups) [11]. They function as a base for identifying research needs.

- OCP – Order-Controlled Production: Autonomous and automated interconnection of production capabilities beyond factory boundaries for portfolio optimisation according to customer and market demands
- AF - Adaptable Factory ("Plug & Produce") – adaptable manufacturing configurations within a factory for quickly changing production capacities and capabilities.
- SAL – Self-organising Adaptive Logistics- Increasing flexibility and reaction time of industrial and logistics systems in increasingly volatile and adaptable production environments.
- VBS – Value-Based Services - This application scenario describes how the value-added network in the service when appropriate product and / or process information about will be provided via IT platforms. It takes up the results of the future project and BMWi program "Smart Service World".
- TAP – Transparency and Adaptability of delivered Products - Automatic collection of use based data from delivered products for optimising business processes, for new business models and for dynamic adaptation of product features.
- OSP – Operator Support in Production - Human-technology-human interaction for assisting humans as actors in the manufacturing process
- SP2 – Smart Product Development for Smart Production - Virtual products allow for new types of teamwork in engineering processes and automation of engineering activities.

A 2017 update[63] of the use scenarios presented three more scenarios:

- Complete and dynamic engineering of plants (DDA): This application scenario describes an initial engineering process for setting up plants. An integrating plant model is created, which then can be used during the whole life cycle of the realized plant in permanently iteration processes between engineering, operation and service of the plant to keep the model consistent.
- Circulation Economy (KRW): This application scenario considers a (delivered) product up to the recycling of its physical components. In accordance with the scientific advisory board of the Platform Industrie 4.0, it was decided not to further pursue this application scenario.

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[63] http://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/fortschreibung-anwendungsszenarien.html

- Additive Manufacturing (ADM): The description of this Application Scenario is planned but is not yet available.

The scenarios were systematically analyzed in relation to available and still-to-be developed technological fields. Five areas were thereby identified, which have priority for the future implementation of the scenarios:

- Semantics and models for Industrie 4.0
- Negotiation and contract award in automated value networks
- Systems engineering for variable systems
- Logistics 4.0 – self-organizing and adaptive
- Organization of work, assistance systems and the human digital shadow

Strategic expansion of the platform "Industrie 4.0"

In 2016, international cooperations and alliances have been started, e.g. with the US-based initiative "Industrial Internet Consortium", with the French initiative "Alliance Industrie Futur", with the Japanese "Robot Revolution initiative" as well as with initiatives from Italy, the Czech Republic, China, Australia and in various multilateral alliances. Acatech has performed two international surveys concerning the international cooperation in Industrie 4.0 / smart manufacturing initiatives (Inbenzhap; Industrie 4.0 global).

In 2017, the key digitising manufacturing initiatives of Germany ("Industrie 4.0"), France (Alliance Industrie du Futur) and Italy (Piano Industria 4.0) have agreed on a trilateral cooperation to support and strengthen the digitisation processes of their manufacturing sectors as well as to promote European efforts in this field. In June 2017, they have published a shared action plan with several action items and deliverables.[64] It focuses on core subjects of shared interests, which are dealt with in the following three working groups:

- Standardisation and reference architectures (lead Germany): characteristics of standards related to digital manufacturing are seen in interoperability, openness, scalability, plug & play mechanisms and security. The aim is to support a seamless and easy integration of different IoT-solutions. A strong cooperation between with working group 2 is intended.
- SMEs engagement and testbeds (lead Italy): The group aims to support the transformation process of SMEs and help them to understand opportunities and scenarios of digital manufacturing through the availability of adequate testing environments and test labs.
- Policy support (lead France): The working group will cover the shared interest in exchanging of ideas, concepts and experiences regarding accompanying measures and national policy programs. The group will also develop coordinated recommendations to the European Commission and other relevant European bodies.

Also in 2016, German industrial associations and standardization organizations were setting up the "Standardization Council Industrie 4.0" (SCI4.0) at the Hannover Messe. The aim of the council is to initiate standards of digital production and to coordinate these nationally and internationally. The initiative accelerates standardization processes and thus strengthens the international

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[64] https://www.plattform-i40.de/I40/Redaktion/EN/Downloads/Publikation/shared-actionplan-fr-de-it.html

competitiveness of Germany as an industrial location. Furthermore, there has been continuous work on the German Standardisation Roadmap, which has been published in an updated version 2016 [3].

In November 2016, the association "Labs Network Industrie 4.0" (LNI4.0) has been founded with the mission to support German SME through associated demonstration and test centers. The initiative was started by companies engaged in the Plattform Industrie 4.0 together with the business associations Bitkom, VDMA and ZVEI. Members of LNI4.0 can learn about new technologies, innovations and business models in test centers around industry 4.0, and they receive support to test their technical and economic feasibility before launching the market. The environment is offered by cooperating test centers. LNI4.0 collaborates with the Standardization Council Industry 4.0 to ensure compatibility between competing products and solutions.

Contact: Labs Network Industrie 4.0 e.V., Ernst Reuter Platz 7, 10587 Berlin, +49 (030) 36702177 Email: info@lni40.de, http://www.lni40.de; Standardization Council Industry 4.0, Stresemannallee 15, 60596 Frankfurt am Main, Tel: +49 69 6308 306, E-Mail: reinhold.pichler@vde.com, http://www.sci40.com,

Research, Development and Innovation actions

Funding programs related to Industrie 4.0
The ministry of education and research (BMBF) has published a vision paper for a national ICT research in Industry 4.0 in a report 2013 [14]. Starting from here, the ministry in 2015 presented concrete priorities and results of research calls and projects [15]:

- Production Research – ("Human and work in an intelligent and networked plant").
- ICT Research in Industry 4.0 (Embedded 'cyberphysical' Systems, Virtualization technologies for the plant of the future)
- Excellence Cluster Its OWL (intelligent technical systems)
- Transnational production research (ERAnet Manunet; Smart Maintenance)

One example was CyPRoS (finalized 2015), a BMBF funded lighthouse project that created a representative spectrum of cyberphysical systems modules for production and logistics systems. Together with the underlying reference architecture, which is also developed in the course of the project, this enables the manufacturing industry to achieve a considerable increase in productivity and flexibility. CyPRoS intends to enable Germany to become a lead user and provider of such systems. Results were published in scientific books[65]

Furthermore, BMBF has taken up proposals from the Scientific Council of the Plattform Industrie 4.0 and has since implemented the research agenda Industrie 4.0. To date, the BMBF has approved and funded funding of over € 470 million for this research[66]. Research is being pursued in fields of topics, for which up to now seven calls have been published.

In its current action strategy, the Federal Research Ministry has four key areas:

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[65] http://www.projekt-cypros.de/aktuelles-cypros.html

[66] http://www.produktionsforschung.de

- SME: Within the program "Innovation for the manufacturing, services and work of tomorrow", BMBF is funding nine applied research projects[53] that demonstrate to SMEs in particular how Industrie 4.0 technologies can be integrated in practice. The program is targeted at the development of tools for cost-effectiveness analysis (investment protection; statements on the future viability); specific best-practice approaches for SMEs and the introduction of strategies and implementation recommendations for the digital transformation.
- Standards and IT architectures: Work on the "reference architecture model industry 4.0" - RAMI 4.0 of the Industrie 4.0 platform is essential here. The work does not only deliver a basis for standardization, but will also provide further developed reference models. This program line also encompasses projects on tools e.g. for complexity management (see below – standardization)
- IT security: The national lighthouse project IUNO is in the center of this key area. In particular, the project will show how, in concrete cases, attack points for hackers can be minimized. With the first practical results for the middle class, the project will carry out more transfer activities from 2017 onward. IT security for industry 4.0 is also a major focus of the Federal Government's new IT security research program.
- Qualification: In this area, new ideas for work design, competence development and prevention concepts are to be developed. This research is part of the program "Innovations for the production, service and work of tomorrow"[67] , which is the first implementation of the new high-tech strategy. The objective is is to find applicable solutions to maintain and expand value creation and jobs in Germany, to make work economically and socially compatible and to develop the production and service processes efficiently and environmentally friendly. Companies and research institutes are invited to actively promote our society with technical and social progress. The program will be funded in three parts with a total of around EUR 1 billion until 2020.

BMBF is also funding parts of the EU ECSEL program "Productive 4.0" (04/2017-04/2020; Project Volume 106 mio. Euro; BMBF: 9,6 mio. EUR, together with the state of Saxony). Productive 4.0 is a major European research initiative in the field of industry 4.0 under the coordination of Infineon. More than 100 partners from 19 European countries are participating in the project (BMW, Bosch, Philips, Thales, NXP, SAP, Volvo, Ericsson and leading institutes such as the Karlsruhe Institute of Technology, Fraunhofer, Technical University of Dresden). The aim of Productive 4.0 is to create a user platform across value added chains and industries, which particularly promotes the digital networking of manufacturing companies, production machines and products. The partners examine methods, concepts and technologies for the service-oriented architecture as well as for components and infrastructure of the Internet of Things. Other aspects are standardization and process virtualization, i.e. the simulation of production processes to optimize real processes.

The ministry of education and research is furthermore promoting a cooperation with the Czech Republic in smart manufacturing and Industry 4.0. For example, in the presence of the highest political level[68], representatives of the Czech Institute of Informatics, Robotics and Cybernetics at the Czech Technical University (CTU) and the German Research Centre for Artificial Intelligence (DFKI)

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[67] https://www.bmbf.de/de/innovationen-fuer-die-produktion-dienstleistung-und-arbeit-von-morgen-599.html
[68] http://www.businessinfo.cz/en/articles/the-czech-republic-and-germany-enhance-cooperation-in-the-areaof-industry-40-81705.html

signed an agreement on cooperation in this field. An open laboratory-testing facility for SME should be established at CTU.

On the basis of a joint declaration of the German BMBF and the Ministry of Industry and Trade of the Czech Republic on an "innovation dialogue Industry 4.0", BMBF is funding cooperation projects between SMEs from Germany with SMEs from the Czech Republic in the industrial sector. The respective call has been published in February 2017[69].

In 2016, BMBF published a political Framework of Cooperation in the Area of Industrie 4.0 with China[70]. In February 2017, the ministry launched a call for German-Chinese cooperation in Industry 4.0 and Smart Services as part of their production research funding line[71]. The concrete research topics for the cooperations projects are:

- Smart products and services (services) for intelligent applications in intralogistics and logistics
- New transformable production systems for intelligent manufacturing (Industrie 4.0)
- Establishment of joint research, learning and demonstration factories for intelligent manufacturing (industry 4.0) and smart services

On the basis of its ICT security strategy "Self-determined and secure in the digital world 2015-2020", the ministry of education and research has launched several calls in the area of IT security and selected a multitude of projects[72] with a close relation to smart manufacturing.

- In 2015 a call "Hightech for ICT security" was launched[73]. The aim of this call was to develop effective and efficient hardware-based IT security solutions, which can be implemented in industrial production and thus maintain and strengthen the innovation and competitiveness of Germany. The promotion of cooperation between companies and research institutions in the university and non-university sector, the integration of small and medium-sized enterprises (SMEs) and the sustained strengthening of the value-added chains at the location in Germany was underlined in the call. With the call, BMBF intended to make an important contribution to technological sovereignty in order to be able to operate safely even in a networked world.
- In April 2017, a call "Privacy and informational self-determination in the digital world of work" was launched[74]. The ministry intends to promote new approaches and solutions that help to keep the protection of employment data in a digital environment at a high level and at the same time to make use of technological progress for transforming the business world.

The Ministry for Economic Affairs and Energy (BMWi) is funding applied research programs in the area of autonomous systems that have a close relation to Industry 4.0.

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[69] https://www.bmbf.de/foerderungen/bekanntmachung-1323.html

[70] http://www.plattform-i40.de/I40/Redaktion/EN/Downloads/Publikation-gesamt/german-chinese-cooperation.pdf?__blob=publicationFile&v=2

[71] https://www.produktionsforschung.de/de/deutsch-chinesische-zusammenarbeit-intelligente-fertigung-industrie-4-0-und-smart-services-642.php

[72] https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/projectfolder_view

[73] https://www.forschung-it-sicherheit-kommunikationssysteme.de/foerderung/bekanntmachungen/hightechfuer-it-sicherheit

[74] https://www.bmbf.de/foerderungen/bekanntmachung-1358.html

- The Autonomics program (2009-2014, 15 projects, 55 mio EUR)[75] was about forward-looking approaches to the development of a new generation of smart tools and systems that are capable of autonomous action – i. e. of networking with each other independently via the internet, maintaining situational awareness, adapting to changing operational conditions, and interacting with users. The program primarily focused on applications in the logistics and transport sector as well as in service robotics. The outcomes and findings of these projects formed an important basis for a successor program entitled "Autonomics for Industry 4.0"

- "Autonomics for Industry 4.0" (2013-2017, 16 projects, 44 mio. EUR)[76] used state-of-the-art ICT to reduce the amount of energy required in manufacturing processes, whilst also aiming to make these processes more environmentally friendly and efficient in terms of material wear. Another aim of the program was to foster the development of a highly flexible production infrastructure that is able to respond to customer demands for highly individualized products (batch size 1). In turn, this intends to stimulate the development of innovative premium-level products (e.g. service robots) that offer particular benefits, added value, and are thus highly attractive for users from the various industry sectors and for consumers alike. In addition to focussing on technological developments, Autonomics also dealt with important issues across multiple sectors, including law, human-machine interaction, industrial service robotics, and reference architectures for autonomous systems. Six sets of guidelines have been published based on the outcomes of the projects.

- In the current technology program "Platforms, Additive Manufacturing, Imaging, Communication, Engineering – PaiCE" (2016-2021, 14 projects, 46 mio. EUR)[77], new solutions spanning several links of the value chain are developed and tested by interconnecting different technology fields. For instance, innovative technologies and methods are developed, which open up new possibilities for universal product engineering and for correlating this with production processes. Dynamic process optimization also means the implementation of innovative logistics solutions in a highly agile manner so that these may be adapted fast to changing market requirements or unforeseeable events. 3D technologies offer new possibilities in the development and optimization of products, in process monitoring and in quality assurance. These far-reaching integration processes require appropriately designed communication networks that are specially designed for requirements in the industrial environment. These include high scalability, availability, realtime capability and high security in terms of credibility and integrity. Service robotics also plays a significant role in the automation of industrial production. The development of service robotics for wide low-cost industrial use, especially for SMEs, is a core objective of PAiCE.

As part of the BMWi program "PAiCE", the lighthouse project "Industrial Communication for Factories" – IC4F[78] (03/2017-06/2020; 18.3 mio EUR budget, 10 mio. BMWi funding) aims at the development of secure, robust and real-time communication solutions for the processing industry. By mid-2020, 15 project partners from industry and research will develop a technology kit for a

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[75] http://www.autonomik.de/en/index.php

[76] http://www.digitale-technologien.de/DT/Navigation/DE/Foerderprogramme/Autonomik_fuer_Industrie/autonomik_fuer_industrie.html

[77] http://www.digitale-technologien.de/DT/Navigation/DE/Foerderprogramme/PAiCE/paice.html

[78] https://www.ic4f.de

trustworthy industrial communications and computing infrastructure based on an open architecture that extends across domains and allows a modular extension for new applications and communication technologies. Key technologies from the areas of 5G, multi-access edge computing (MEC), cloud computing, virtualization, as well as industrial monitoring and analytics are used. The technology kit is intended to enable users to select the right ICT technologies, according to the new Industry 4.0 requirements and the specific migration approach.

R&D&I related to Digitizing European Industries:

Since the year 2007[66], the ministry of education and research funds strategic ICT research in the framework of the "ICT 2020" funding program, which in total runs for ten years. Unlike previous funding programs, ICT 2020 is thematically more open and thus more flexible towards new developments. The fundamental feature of ICT 2020 continues to be the focus on five fields of application with a high percentage of ICT, promising value creation and a large potential for jobs: automotive, automation, health and medicine, logistics and energy. A particular demand for research is seen in the following basic technologies:

- Electronics and Electronic Systems: The R&D priorities under ICT 2020 are innovative electronics systems for new applications, for example for mechanical and plant engineering and medical technology, 3D system integration, computer-based tools for the development of innovative electronic systems and competence centres for electronics research.
- IT Systems: Priorities are embedded systems; simulated reality with the topics of grid applications and infrastructure, virtual/augmented reality, simulation, information logistics and software developments for high-performance computing, the Internet of Things, ambient intelligence and business process integration, new forms of human-technology interaction, comfort and usability.
- Communication Systems: The main funding areas und ICT 2020 are: new technologies as a basis for future communication standards; new applications, in particular assistance systems; new services for business communication and the health system; cognitive wireless communication systems using rare radio frequencies and meeting the future demand for bandwidth; the Internet of the future; autonomous sensor systems for independent networked communication; future technologies such as network information theory, polymer-based communication systems and integrated photonics.
- IT security: The main areas are: basic development of verifiable and consistently safe IT systems; research on new approaches in analyzing and protecting ICT systems; ensuring security in insecure environments; protection of Internet infrastructures; security by design; new challenges in the protection of IT systems and identification of weaknesses; quantum communication for safe data exchange between IT systems; framework conditions and technologies for a new culture of trust and privacy on the Internet.
- Human-Technology Interaction, Microsystems Technology: The funding priorities under ICT 2020 are developments with a great practical relevance, such as assistance systems to maintain and restore body functions (human-technology interaction: assistance systems to support body functions), and technological research to obtain specific functions such as energy self-sufficiency of technical systems (self-sufficient mobility).

Photonics Research: Photonics has become one of the most important innovation drivers for modern society and economy. It is today a globally popular, highly dynamic world market with a sales volume

of 250 billion euros. In 2012, the Federal Ministry of Education and Research (BMBF) started the current 10-year funding program "Photonics Research Germany - Light with a Future"[79]. The framework of the program provides around 100 million euros to the photonics industry for research and development in the first four years of its lifetime. The program is based on the work of over 300 experts from business and science, who have developed the opportunities and challenges of photonics in a joint agenda process. The program continues the successful path of the first funding program "Optical Technologies - Made in Germany", but also marks the beginning of a new era: For the first time, completely new technologies will be in the focus, which enable Germany to enter the growth markets of the future, e.g. the Integrated Photonic System Technology.

In the field of quantum technologies, the BMBF has initiated a strategy process for the specialist community, which has emphasized the importance of the subject area for the economic and scientific location of Germany[80]. These findings have been synchronized with the evaluations in a European and international context[81]

In June 2017, a new call within the Photonics Research Program "Quantum Futur" has been published[82]. The "Quantum Futur" contest is intended to support excellent young scientists in the research and development of innovative applications in industry through research projects. They are given the opportunity to build up their own independent junior research group at a research institution in Germany and to take up new interdisciplinary research approaches in quantum technology.

Another BMBF funding measure, published in July 2017, focuses on the promotion and research of "miniaturized optical systems of high integration density"[83]. The program aims at supporting these developments to further expand the existing competences, to establish a leading position on the world market and to assert them. With these funding measure, the BMBF is implementing the first findings from the strategy processes.

A third call "Key Components for Quantum Technologies"[84] is aimed at enabling companies in Germany to expand the existing outstanding competences and to establish a leading position on the world market.

Additive Manufacturing: The technology field of "additive manufacturing" is part of the BMBF Hightech strategy. Additive manufacturing processes have already been able to prove their performance potential in the manufacture of end products, especially in aircraft and engine construction as well as in medical technology. At the same time, many fundamental questions remain to be answered on the way to an interdisciplinary and above all industrial use of additive processes.

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[79] http://www.faz.net/aktuell/wirtschaft/ikt-2020-milliardenfoerderung-fuer-die-informationstechnik-1408099.html

[80] http://www.photonikforschung.de/mikrophotonik-optische-technologien-auf-dem-weg-in-die-hochintegration/

[81] https://ec.europa.eu/digital-single-market/en/quantum-technologies

[82] https://www.bmbf.de/foerderungen/bekanntmachung-1371.html

[83] http://www.photonik-forschung.de/index.php

[84]

http://www.photonikforschung.de/foerderung/bekanntmachungen/aktuellebekanntmachungen/schluesselkomponenten-fuer-quantentechnologien-kopie-1/

In March 2015, BMBF has launched a call on "Additive Manufacturing - Individualized Products, Complex Mass Products, Innovative Materials (ProMat_3D)"[85]. 13 projects have been selected[86].This program focused on suitable new methods and tools for product development and production as well as on new or significantly improved materials for the additive production. The aim was to achieve a significant increase in process capability, reliability and cost-effectiveness as well as a strong leverage effect for the establishment of such manufacturing processes in companies.

In March 2017, the ministry of education and research has launched a call on "Materials for Additive Manufacturing", which is part of the M-era.Net II initiative. This is a joint initiative of 41 partners from 28 European and non-European countries. The call for tender completes the national and European funding measures for material research. It aims at the cooperation of German companies, universities and research institutes with partners of the countries / regions involved in the network.

Investments in Microelectronics are seen by the German government as a great opportunity to drive critical IT developments and for strengthening an important key industry, also with respect to economic growth and jobs. The German government has set up a strategy paper for the timeframe 2016-2020 [16]; it regards Germany in an excellent starting position: the microelectronics industry and its user sectors are benefitting from close innovation partnerships and a productive research landscape in Germany and Europe. In addition, microelectronics in Germany is primarily organised in terms of strong regional cluster that create important networks within the value-added chain of suppliers and purchaser. A prominent example is the federal state of Saxony with its prominent role in semiconductor production: a large proportion of the chips manufactured inEurope now originate from the region around Dresden.

The priorities of the strategy on microelectronics is the result of an agenda process that was started in June 2014 through a position paper of the Federal Government. Then ational priorities are also in line with a number of European initiatives (especially ECSEL) that is supported by the German government.

In April 2017, the Federal Ministry of Education and Research (BMBF) announced to launch a new investment program for microelectronics research[87]. The core focus of the program is the "Research Factory for Microelectronics Germany", where research capacities are networked for the first time nationwide, in order to gain more weight internationally as a microelectronics location. The BMBF finances the investment program with a total of around 400 million euros. Since reunification, this is the largest investment in research for microelectronics in Germany. A total of 13 participating non-university research facilities are equipped with state-of-the-art equipment and systems. The Fraunhofer Association for Microelectronics and the Ferdinand Braun Institute, the Leibniz Institute for High Frequency Technology and the Leibniz Institute for Innovative Microelectronics (Berlin-Adlershof) will receive around 350 million euros. The project has been started in April 2017[88]. In a

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[85] https://www.bmbf.de/foerderungen/bekanntmachung-1037.html

[86] https://am.vdma.org/viewer/-/article/render/17997888

[87] https://www.bmbf.de/de/forschungsfabrik-mikroelektronik-deutschland-gestartet-4053.html

[75] https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2016/20160706-gabriel-neuesinvestitionsprogramm-mikroelektronik-staerkt-innovationsstandort-deutschland.html

[88] https://www.adlershof.de/news/350-mio-EUR-fuer-zukunftstechnologien-forschungsfabrik-mikroelektronik-deutschland-gestartet/

second step, a further 50 million euros will be earmarked for such investments for microelectronics at universities from 2018 onwards, which will complement the research foci in the research factory and take into account the special capacities of the universities in the field. In regional terms, around three-quarters of the investments are concentrated in Saxony, Berlin and Bavaria as strong microelectronics research centers. Further locations are located in Brandenburg, North Rhine-Westphalia, Baden-Württemberg, Schleswig-Holstein and Thuringia. A central office will coordinate the activities and form the central interface to industrial partners.

In July 2016, the ministry for economic affairs and energy had announced that they will invest 1 bn. Euro in common EU IPSEI program[75] together with a number of countries (including France, Italy, the Netherlands, Austria, the United Kingdom). According to the project plans for the IPCEI for microelectronics, the participating European companies expect a one-time additional investment volume of about 6.5 billion euros for the years 2017 to 2020.

Service Robotics and Autonomous Systems: Since 2012, the German ministry of education and research is involved in research on Human – Technology Interaction and since has provided some 280 million euros[89]. Until the year 2020, we will continue to invest around 70 million euros annually in human-technology interaction research. At the end of 2015, the ministry has launched a comprehensive research program "Bring Technology to Humans", in which relevant objectives have been worked out. One focus is on service robots that are assisting people in their own homes. The potential for growth in this technology field is regarded as huge. It is predicted that in 2018 nearly 26 million robots will support worldwide daily housework.

The new challenge for the robot of the future is to make it an interactive partner in daily life. It not only has to be fast, strong and precise as today's industrial robot. It also should be intelligent and adaptable. BMBF has initiated the "assistance functionalities of robots" program in 2015. The focus here is on the development of interacting robots, which, in addition to physical, also have cognitive and social skills. Up to € 20 million per funding phase are invested o bring these complex systems to a new level. A first call has been launched in April 2016[90] (interactive base functions) and a second call in February 2017[91] (interactivity strategies). This research should clarify two main questions: On the one hand, the various key technologies must be matched in such a way that the robot becomes a perfect multi-tasker. That he can still navigate error-free, as well as recognize language, gestures and faces when he is dealing with many people at the same time. On the other hand, it is necessary to develop the existing technologies so that they can react not only to predictable but also to unforeseeable everyday situations.

A second focus, which BMBF has been increasingly devoted to since 2015, is medical technology. The background is here that the demographic change places enormous challenges on health care

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[89] https://www.bmbf.de/de/technik-zum-menschen-bringen-4398.html
[90] https://www.technik-zum-menschen-bringen.de/foerderung/bekanntmachungen/autonome-roboter-fuer-assistenzfunktionen-interaktive-grundfertigkeiten
[91] https://www.technik-zum-menschen-bringen.de/foerderung/bekanntmachungen/roboter-fuer-assistenzfunktionen-interaktionsstrategien

systems. A third prioritiy in this funding area is the application are of autonomous and networked driving[92].

Future of Work: In January 2016, the ministry of education and research has published a strategy brochure on the "Future of Work" [17] as part of the new high-tech strategy. The approach of the program is to support the joint development and balance of technological, economic and social factors of work through the promotion of R & D projects. The "Future of Work" program is cofinanced by the European Social Fund (ESF) of the European Commission. With the program

- Work places should be further developed, oriented on human needs
- New Potentials of digitalization and networked systems should be tapped for employees and businesses
- The transfer to SME and crafts shops should be ensured

Synergy effects of the "Future of Work" strategy with a number of other research programs are intended and expected. The strategy furthermore addresses European and international cooperation in that field.

In October 2016, BMBF has published a call "Future of Work: SMEs - innovative and social"[93]. The aim of this program is to develop new tools and models of work organization in and with SMEs. The projects are designed to demonstrate and test concrete solutions that could function as a blueprint for tomorrow's work environments.

IoT based Services and business models for Service platforms: With its program "Smart Service Welt" (2014-2019 and 2016-2021; total funding of 107 mio EUR), the ministry for economic affairs and energy addresses solutions that will use service platforms for the integration of data and their provision as secure, customer-friendly services and new business models in the provision of products and classic services. This should lead to a new quality level in corporate and transnational production with a high degree of automation (e.g. in manufacturing batch size 1). Furthermore, digital platforms and the Smart Services running on these are expected to fundamentally change the way that added value can be created. With the technology programs Smart Service World I and II the aim is to set out clearly the opportunities and benefits for the economy and society using concrete examples in different application areas.
- Smart Service World I ("Internet-based services for the economy") includes 20 collaborative projects in the areas of Production (e. g. services for system optimization, for agriculture or in the form of visualization services), Mobility (e. g. app integration in vehicles, vehicle data collection), Quality of life (e. g. water management services, patient-doctor communication services) and cross-sectoral technologies (e. g. for interoperability, security and credibility of services).
- "Smart Services World II – ("New areas of application for digital services and platforms")is designed to tap into application fields that are underrepresented in Smart Services World I. Another aim is to promote applications for small towns and rural regions. The program addresses services in the following areas of application: Employment (e. g. to secure employment or curb the shortage of skilled workers, etc.); Mobility (e. g. new logistics solutions, services for multi-

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[92] https://www.bmbf.de/de/technik-zum-menschen-bringen-4398.html
[93] https://www.bmbf.de/foerderungen/bekanntmachung-1263.html

modal public transport use, autonomous driving, etc.); living (e. g. digital services for assistance in old age, to increase building safety and comfort, etc.); Basic Services (e. g. Smart Services for use in energy supply, supply of goods and services, primary health care, etc.).

Other related research and innovation activities

Machine Learning: A number of calls have been launched by the ministry concerning MachineLearning (ML) technologies in the scope of the funding program "ICT 2020".

- In February 2017, BMBF announced a call "Qualification measures and research projects in the field of machine learning"[94] . The call intends to support and expand the education and training as well as the research in the field of ML in Germany. It aims at improving the quality of the qualifications in the area of ML primarily at master's degree courses and for business users. BMBF intends to increase the availability of specialists and young academics in the field of ML and to significantly improve their practical skills in dealing with the complex methods of the ML.
- In June 2017, BMBF has announced a call "Research projects for the automated analysis of data using machine learning". The program intends to support and expand research in the field of ML in Germany and demonstrate the practical application of ML procedures. The funding measure is intended to provide a broad and long-term benefit for the various users of the ML. Therefore, the BMBF intends to significantly increase the broad applicability of the methods and procedures of the ML and thus to enable new disruptive applications and technologies.

Big Data / Smart Data: In 2014, the ministry of education and research BMBF announced to build two competence centers for Big Data[95]:
- The Berlin Big Data Center (BBDC), located at the Technical University of Berlin and
- The Competence Center for Scalable Data Services (ScaDS) under the supervision of Professor Nagel at TU Dresden.

While the Berlin Big Data Center aims at developing scalable technologies that organize huge heterogeneous data volumes and at the same time intelligently gain information from all these data sets, the SCADS Center in Dresden and Leipzig runs a rather service-oriented approach and will develop and make accessible a portfolio of Big Data solutions for science and industry.

Moreover, BMBF has launched 10 research projects in its "Big Data" research program.[96] The selected research projects promote R&D efforts towards the cross-sectoral use of novel big-data technologies. The initiative aims at scientific advances and innovations in the interdisciplinary research area "Data Science".

- One example is the research project "Early detection and decision support for critical situations in the production environment – FEE" that aims at integrating heterogeneous data volumes recorded in production facilities in a big data analysis platform. In addition to current data from engineering and asset databases and process information management systems, extensive historical data are also being used. On top of this, real-time methods are to be developed using big-data techniques to warn operators of installations early on of unexpected operating conditions by means of suitable alarms and to support them with interactive assistance functions

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[94] https://www.bmbf.de/foerderungen/bekanntmachung-1325.html
[95] https://www.bmbf.de/de/big-data-management-und-analyse-grosser-datenmengen-851.html
[96] http://www.softwaresysteme.pt-dlr.de/de/big-data.php

in ad-hoc analysis and the development of intervention strategies.
Contact: Dr. Bejamin Klöpper, ABB AG Forschungszentrum, benjamin.kloepper@de.abb.com

- A second example is the project "Use of Big Data technologies for production fault management - BigPro". The aim of this project is to make the fault management in industrial production more efficient. A big data platform will process heterogeneous data from different sources of the production environment and set it in a common context via data pattern recognition. In addition to the system's production data, the knowledge and perception of the employees are also recorded through voice monitoring and speech recognition tools. The generated data is to be processed and analyzed in real time. In addition, scalable techniques for the visualization of the states, predictions and reaction possibilities in the case of disturbances are to be developed.
Contact: Dr. Matthias Deindl, FIR e.V. an der RWTH Aachen, Matthias.Deindl@fir.rwth-aachen.de

Funded by the Ministry for Economic Affairs and Energy, the "Smart Data – Innovations in Data" program[97] (2014-2017, 14 projects, total funding 32 mio EUR) aims to identify practicable, secure, and legally compliant solutions that allow mass data to be processed and will test these ideas using different prototypes across specific usage scenarios. There is a close connection of this program to the BMBF Big data centers. In 2016 the "Smart Data Forum" was founded to cross-link the research program nationally and internationally and to accelerate the transfer of knowledge and results. The aim of the Forum is to pool big data activities in Germany and in doing so to bring together all key stakeholders from business, science, politics and society. They also have built a demonstration and experimental space for smart data solutions in Berlin.

Furthermore, research on ICT relevant topics is performed in the various innovation programs for SME and Start-Ups of BMWi ("ZIM", "SME Digital", "go inno", "EXIST") and BMBF ("KMU innovativ 2017-2022", "Innovation Forum SME" "Industrial Cooperative Research programme for SMEs (IGF)).

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[97] https://www.bmwi.de/Redaktion/EN/Publikationen/smart-data-innovationen-aus-daten-englischeversion.html

IV.   Digitising European Industry (DEI) Pillar 2 - Standardization actions, regulation and testbeds

Standardization initiatives

The central approach in the German perspective of Industry 4.0 is the "reference architecture model industry 4.0" (RAMI 4.0). RAMI was developed by the Plattform Industrie 4.0 founding associations ZVEI, VDMA and BITKOM together with VDI/VDE-GMA and DKE. It is promoted by the Plattform Industrie 4.0 and the related associations ZVEI, VDMA and BITKOM as well as by the industry partners. An important stage for ZVEI in the standardization of industry 4.0 was reached in April 2015, when the first presentation of RAMI 4.0[98] and the industry 4.0 component[99] had been developed. Taken together, the Reference Architectural Model and the Industrie 4.0 component can serve companies as a basis for developing future products and business models. RAMI 4.0 has recently been recognized as a pre-standard by international standardisation organisations (IEC/ISO).

Emerging from the Plattform Industrie 4.0, the German industrial associations (ZVEI, Bitkom, VDMA) together with standardization organizations (DIN, DKE) have launched a "Standardization Council Industrie 4.0"[100] in April 2016. The Council acts independently from the platform and is organized at the DKE.

Contact: Standardization Council Industrie 4.0, Stresemannallee 15, 60596 Frankfurt, Telefon: +49 69 6308 306, E-Mail: reinhold.pichler@vde.com

In addition to the coordination of standards, the council represents the interests of international consortia and organizes and designs the "German standardization roadmap 'Industry 4.0'" [18]. The aim of the roadmap[92] is to present the current state of standardization relevant to Industry 4.0. The roadmap not only describes the current status and give an overview of all relevant standards and specifications, but also gives concrete recommendations for action and outlines standardization needs in the various areas of Industry 4.0. Being a "living" document, the Roadmap will be published and regularly revised by DIN and DKE to reflect the current situation as needed.

Anyone interested in Industry 4.0 is welcome to participate in this work. The Standardization roadmap, among other, provides a list of the most important standardization topics for Industry 4.0. DIN has initiated an ISO Strategic Group on Industry 4.0 in order to support the vision of Industrie 4.0 internationally under the direction of ISO. The aim is to organize the contribution of ISO and thus to develop a joint approach in particular with IEC and ITU-T. The focus of the strategic team is on the following tasks:

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[98]

https://www.zvei.org/fileadmin/user_upload/Themen/Industrie_4.0/Das_Referenzarchitekturmodell_RAMI_4.0_und_die_Industrie_4.0-Komponente/pdf/ZVEI-Industrie-40-RAMI-40-English.pdf

[99]

https://www.zvei.org/fileadmin/user_upload/Themen/Industrie_4.0/Das_Referenzarchitekturmodell_RAMI_4.0_und_die_Industrie_4.0-Komponente/pdf/ZVEI-Industrie-40-Component-English.pdf

[100]

https://sci40.com/de/

[92]

http://www.din.de/en/innovation-and-research/industry-4-0/the-road-to-the-future--77392

- Strategic and conceptual development of the subject Industrial 4.0 at ISO
- Identification of missing standards and standards
- Development of implementation strategies and recommendations for industry 4.0
- Coordination of standardization and standardization activities at international level
- Implementation of an early, cross-organizational and cross-organizational coordination
- Co-operation with other organizations at national, European and international levels, with a high emphasis on collaboration with IEC and ITU-T

Organisation	Gremienbezeichnung	Gremientitel	Arbeitsgebiet
DIN	NA 043-01-27 AA	IT-Sicherheitsverfahren	Spiegelkomitee zu ISO/IEC JTC 1/SC 27
DKE	DKE/GK 914	Funktionale Sicherheit elektrischer, elektronischer und programmierbarer elektronischer Systeme (E, E, PES) zum Schutz von Personen und Umwelt	Spiegelkomitee zu IEC/TC 65/SC 65A/WG 14
DKE	UK 931.1	IT-Sicherheit in der Automatisierungs-technik	Spiegelkomitee zu IEC/TC 65/WG 10
CEN	TC 251	Health Informatics	Medizinische Informatik
ISO/IEC	JTC 1/SC 27	IT Security Techniques	Generische IT-Sicherheit/Informationssicher-heits-Managementsysteme
IEC	TC 65/WG 10	Industrial-process measurement, control and automation	IT-Sicherheit in der Automatisierungstechnik
ETSI	TC Cyber	Technical Committee (TC) Cyber Security ETSI	Cyber Security
ISA	ISA 99	Industrial Automation and Control Systems Security	IT-Sicherheit von Produktionssteueranlagen in Zusammenarbeit mit IEC/TC 65

Fig. 3: Relevant standardization topics in industry 4.0

Moreover, the platforms in France and Germany have agreed on a common standardization framework (Shared Action plan, April 2016[101]); Standardisation is also an issue in the trilateral cooperation of France, Italy and Germany[102]. Joint Working groups have been established:

- Joint Working Group1: Standards landscape - aims to build a common standards landscape where all aspects of Smart Manufacturing will be addressed.

- Joint Working Group2: Committee Alignment – aims to coordinate, in accordance with the common standardization strategy, the various activities concerning Smart Manufacturing

- Joint Working Group3: Administration shell – has the task to define the content and mechanism of "component manager" with a description and clarify how requirements from different stakeholder can be merged into the standardisation process.

The "Standardization Council Industry 4.0" also supports practice testing in test centers in a close collaboration with the "Labs Industry Network 4.0" (www.lni40.de), which was founded in April 2017 by Plattform Industrie 4.0 players (more details, see above).

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[101] https://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publikation/plattform-i40-und-industrie-du-futur-joint-programme.html
[102] http://www.plattform-i40.de/I40/Redaktion/EN/PressReleases/2017/2017-06-20-shared-actionplan.html

In addition to standardization initiatives the German Federal ministry of education and research is promoting an industry-wide common approach also via specific tools management projects.

- In the "Software Platform Embedded Systems" project (SPES2020; public funding:14.9M 05/2014-04/2017)[103] and the successor project SPES_XT, a consortium of more than 20 partners from academia and industry drew up the foundations for a comprehensive methodological kit for the comprehensive model-based development of embedded systems. Model-based techniques can significantly reduce product development costs (on average 27% -34%) and help to avoid contradictory specifications.

- BMBF also funds the development of introductory aids for industry to use the model based approach (Project SPEDIT).

- In addition, BMBF is funding a software basis kit Industry 4.0 (Project BaSYS[104]) which intends to be an "open platform for the fourth industrial revolution" built on the RAMI 4.0 model.

Regulatory framework

Digital Platforms

In 2016, the ministry for economic affairs has taken up the topic of platforms, being a growing engine of digitalization. The ministry observes that platform markets are dominated by American and to a certain extent Asian internet services and they are currently conquering one analogue industry after another or inventing completely new ones and growing into new giants[105]. Furthermore, platforms have now entered into the business to business sector (B2B) and the world of industry in particular. While it still remains to be seen whether these platforms will be just as successful in the B2B sector as on consumer and service markets, the ministry has observed that these platforms are creating new rules for economic activity [7]:

- growth and size are more important than short-term profitability;

- the direct interface to customers and manufacturers provides the new players with considerable market power and an information lead.

Based on these findings, the ministry has performed a consulting process with business representatives, associations and interested parties from all areas of society. 70 extensive opinions were submitted via the various channels. Based on this consultation process, the published white paper focuses on four objectives:

- Transformation instead of disruption: Germany and Europe need a digital transformation process that is backed and moderated by policies instead of an uncontrolled development of digitalisation.

- Growth dynamism and participation: The growth stimuli must primarily come from industry, while the state should exercise an additional positive influence on developments (e.g. broadband development) and should ensure that the digitalisation process provides opportunities for as many people as possible.

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[103] http://spes2020.informatik.tu-muenchen.de/

[104] https://www.basys40.de/

[105] https://www.bmwi.de/Redaktion/EN/Publikationen/weissbuch-digitale-plattform-kurzfassungeng.pdf?__blob=publicationFile&v=4

- Security and clear rules for democratic discourse: Germany and Europe need a digital civil society that shares common moral attitudes and values. Citizens and businesses want to act on a basis of trust. Digital crimes and incitement to hatred must be prosecutable. The state must develop authorised and qualified institutions to monitor the digital spaces, register infringements and above all sanction them.
- European sovereignty: Germany will profit most if Europe can pull together to use the opportunities presented by digitalisation. It is time to depart from the patchwork of provisions and to develop a cohesive set of rules and regulations.

The white paper then indicates measures and regulations
- for ensuring fair competition (e.g. creation of a "level playing field" in the telecommunication markets)
- to politically accompany the creation of a modern data economy (e.g. establishment of a clear legal framework for the use of data)
- for a nationwide expansion of gigabit-capable digital infrastructure (e.g. establishment of municipal centres for infrastructure-relevant digitalisation issues)
- to secure a democratic digital culture (e.g. the elimination of legal vacuums in the internet)
- to develop digital state competence and strengthen the institutional structures (e.g. setup of a digital agency).

Innovation Policy
In April 2017, Federal Minister for Economic Affairs, Brigitte Zypries, presented an innovation agenda, "Innovation policy cornerstones - Bringing more ideas into the market"[106] . The innovation agenda, which has to be specified during the next legislation, is based on two pillars: firstly, a technology-driven subsidy, which supports entrepreneurs in making decisions on technologies to invest in. Secondly, the promotion of specific, particularly worthwile future technologies.

BMWi 's announced to embed its innovation policy in a large scale new social and broad-based Initiative that has the goal to initiate a cultural change towards a more future-oriented society. With the initiative, BMWi wants to accomplish.
- More open-mindedness towards technology and innovation in the population;
- A culture of cooperation between creators of ideas, translators and users;
- Wide digitalization in education and all public and private institutions;
- Highly trained specialists;
- A new entrepreneurial culture, which leads to significantly more highly qualified people to become entrepreneurs.
- An innovation - friendly legal framework that is compatible with the speed of technical development and innovation

Furthermore, BMWi announced
- to invent Tax research funding for businesses up to 1000 employees.
- to raise budgets for innovation funding programs such as the SME innovation funding program ZIM, (700 Mio Euro / year), as well as industrial cooperative research (program IGF, 200 mio.

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[106] https://www.bmwi.de/Redaktion/DE/Downloads/I/innovationspolitische-eckpunkte-lang.html

Euro / year), and Innokom (structural weak regions; 90 mio. Euro / year) and to start a program on non-technical innovations

- to raise budgets for foundation funding programs, such as EXIST (founding culture in academic institutions; 90 mio Euro / year) and to also foster foundations in non-technical areas, to raise the high-tech founding fund up to 300 Mio. Euro; and to implement the "German Accelerator" that has been successful in the United States also in locations in Asia and in Israel.
- several measures (e.g. the counseling service go-digital) to start an SME digitization initiative, as well as a specific SME investment funding program for digital technologies and digital knowhow.
- to strengthen the cooperation between science and economy and to foster the strategic platforms such as Industrie 4.0 or electric mobility.
- To actively accompagny "Industrie 4.0" to ensure Germany's leading role in this issue
- to set up a quality infrastructure (standardization, accreditation and conformity assessment, technical product safety and market surveillance) to foster the core brand "made in Germany".
- to consider the invention of a Strategic Innovation Center Germany (SID) that features elements of the DARPA (U.S. Defense Advanced Research Projects Agency) as a think tank for innovation programs, however without an own high budget.
- to focus innovation policy on future-oriented technologies such as Microelectronics, artificial intelligence, biotechnology; quantum technology and a number of fields in the area of digitization, such as "Autonomics for Industry 4.0", "Smart Services", "Smart Home", "Augmented Reality", "Service Robotics" or "Blockchain".

Field test labs („Reallabore")

BMWi intends to use field test labs as regulatory experimentation spaces. These "laboratories" allow the testing of innovations under real conditions, by adapting the existing requirements in time and space. Thus, new regulations are to be found which, on the one hand, have a more effect on innovation, but on the other hand are also socially acceptable and take into account the interests of consumers. By 2018, the conceptual work and the regulatory prerequisites on the systematic use of field test labs shall be completed and the operational implementation prepared.

Telecommunication regulatory framework

BMWi announced to anchor an innovation and investment friendly regulation within the national implementation of the new telecommunications regulatory framework[107]. Examples are to free pioneers from specific regulations or more flexibility in remuneration.

Pilot Factories and Testbeds

The Plattform Industrie 4.0 hosts an interactive map[108]which currently lists a total of 55 test bed centers all over Germany. A second map of test bed centers is presented by the national contact point of the BMBF program I4KMU[109]. Here only a few examples can be named.

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[107] https://www.bmwi.de/Redaktion/DE/Downloads/I/innovationspolitische-eckpunkte-lang.html
[108] http://www.plattform-i40.de/I40/Navigation/Karte/SiteGlobals/Forms/Formulare/karte-testbeds-formular.html
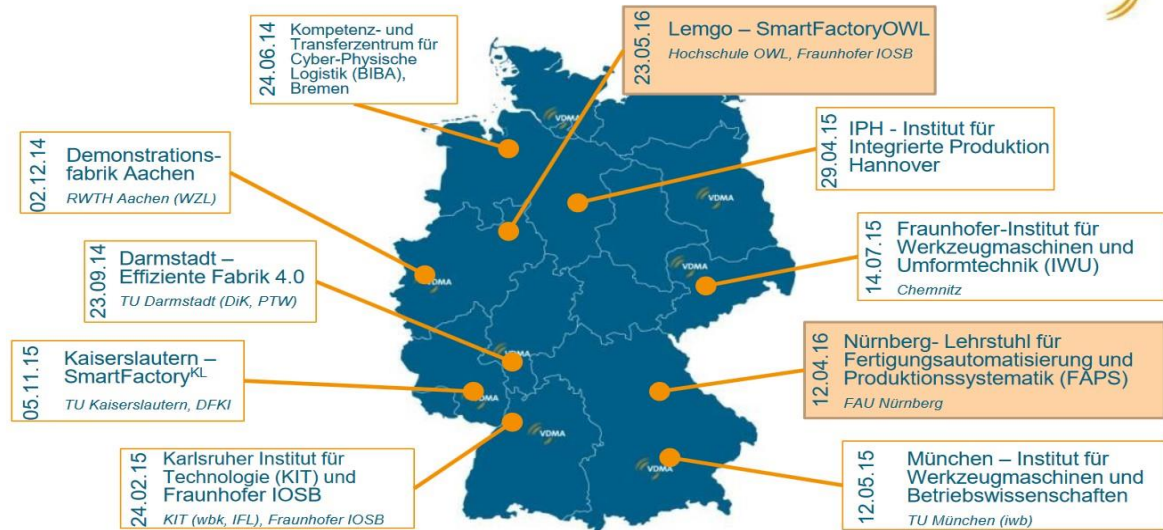[109] http://www.i4kmu.de/I4KMU/DesktopDefault.aspx?tabindex=2&tabid=4

Fig. 4: Selected pilot factories and Industry 4.0 testbeds in Germany

Research program Industry 4.0 Test Environments for SME (I4KMU):

In April 2016, the ministry of education and research (BMBF) has announced to fund research and development projects in the area s of Industry 4.0, Internet of things and cyberphysical systems[110]. The aim is to support SMEs through the promotion of pilot projects by means of industry 4.0 test environments at German research institutes, adaptation to digitized processes and the research and development of new digital products. The funding addresses individual projects to try out new digital products, to test new digital products, to adapt to digitized processes and to develop networked business models. The funding of the BMBF is up to 50 percent of the expenses (maximum funding EUR 100.000), and the duration of the project is limited to twelve months. Funds from the grant should be used to achieve the project objectives for a research and development contract with the operator of an industry 4.0 test environment. BMBF has selected 4 Projects (4/2017 – 03/2018):

- ACTOS - Intuitive operation of assistance systems and automated evaluation of work steps by the use of low-level sensors (Bremen)
- BaseCON_Test - Test support for IP compatible solutions for Ambient Assisted Living and Home automation applications; baseCON product development (St. Georgen)
- ExpertSHARE - Collaborative real-time expert service in tool construction based on control, simulation and machine data (Aachen)
- FAST 4.0 - Factory Analysis and Control 4.0 (Hanover)

Contact: Miriam Poetter Münchener Straße 20, 82234 Weßling, Tel.: +49 8153 28-2297

Smart-Factory OWL, Lemgo:

In 2016, one of the world's most modern factories was opened in Lemgo. The Smart-Factory OWL is an initiative of the Fraunhofer institute IOSB-INA and the OWL University and located in the neighborhood of the university campus. The various modules of intelligent production are completely networked and are controlled over the Internet. This also includes CNC milling machines and 3D printers. SmartFactoryOWL provides a cutting-edge lab environment for ICT-based automation technologies and addresses important research topics for the digitization of the shop

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[110] https://www.bmbf.de/foerderungen/bekanntmachung-1181.html

floor level, such as adaptability, resource efficiency and cognitive human-machine interaction. The Smart factory is part of the leading-edge technology cluster "Intelligent Technical Systems OstWestfalenLippe it's OWL". It is likewise a research and testing lab for the scientists and engineers of the involved research institutes and companies as well as a learning environment for students of engineering. In particular, it is possible for SME to test and optimize their production systems with integrated Industry 4.0 technologies and to train their staff.

"Track and Trace" testbed (Industrial Internet Consortium)[111]:

This collaborative effort between Bosch and international companies (Cisco, SAP, Mahindra), all members of the Industrial Internet Consortium, had been announced in February 2015. This testbed is driving forward tool connectivity and the detection of tools in a fabric hall. The first outcome of their collaboration on the "Track and Trace" project is the ability to determine the position of a cordless nutrunner on the shop floor with extreme precision, among other applications. The testbed partners are each lending their different areas of expertise to the project: Bosch is supplying the Nexo cordless nutrunner, while Bosch Software Innovations is contributing the software necessary to gather and evaluate data in the form of their Bosch IoT Suite.

Learning factory ("Lernfabrik") at University of Braunschweig:

The learning factory consists of three pillars: the research factory, the experimental factory and the training workshop. In each pillar, the focus is more on research or teaching. Common to all pillars, however, is their thematic orientation. Across the two areas of the Professorship Sustainable Production and Life Cycle Engineering, the focus areas are addressed in the learning factory: Energy and resource efficiency in production; Industry 4.0; Urban factories. The Lernfabrik is a member of the Initiative of European Learning Factories.
Contact: Langer Kamp 19b, Braunschweig, 38106; Prof. Dr.-Ing. Christoph Herrmann

Robotics and Mechatronics Center Oberpfaffenhofen:

The Robotics and Mechatronics Center (RMC) is one of the largest and most important research centers worldwide for applied automation and robotics. It is a cluster of 3 DLR institutes which received a new infrastructure co-financed by the Bavarian State and the Federal Ministry of Economics and Energy[112] as well as a subsidy (500.000 Euro) for the further expansion of the RMC competences.

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[111] http://www.iiconsortium.org/track-and-trace.htm
[112] http://www.dlr.de/dlr/desktopdefault.aspx/tabid-10081/151_read-17462/%20%20/gallery/22685#/gallery/22685

V. Digitising European Industry (DEI) Pillar 3 - Digital Innovation Hubs actions

The digital hub initiative[113], developed by the Federal Ministry for Economic affairs and Energy, seeks to support the establishment of digital hubs in Germany. The underlying idea of establishing hubs is that cooperation between companies and business start-ups within a confined area will boost innovation, especially in the digital age. At the Digital hubs, startups, scientific institutions, SMEs, industry and government co-operate and evolve to centres of the digital transformation. BMWi is working on establishing a common label and a hub agency for the large German hubs that act as flagships in order to ensure the best possible networking of hubs throughout Germany and thus improve the transfer of know-how between each of them. BMWi also will strategically promote these digital hubs abroad with the help of Germany Trade and Invest to make them better known internationally and to put them in contact with founders and investors from abroad.

The networking idea has objectives on different levels: within the hubs it is about the networking of start-ups, science, middle class and large companies. The networking of the hubs among each other speeds up the innovation processes of individual sectors and thus drives the digital transformation. Established businesses and start-ups both should profit from such an exchange: the established economy of the fresh ideas of the start-ups and the young founders of the experiences and contacts of the old ones. In addition, the international exchanges with global market leaders and potential investors are also planned in the hubs from abroad. For this purpose, it is necessary to create hubs with international radiation power which are attractive to international founders, scientists, entrepreneurs and, of course, investors.Together with the Hub Agency and the GTAI, BMWi is developing a creative international advertising campaign which aims to ensure that international start-ups are located in industrialized Germany.

Since the launch of the Digital Hub Initiative at the IT Summit 2016, selected hubs in 12 locations (see map) have started their work. They are focused on various priorities (artificial intelligence, chemicals, healthcare), all with a close connection to the digital transformation of the economy. Through the innovation hubs, start-ups will be provided with EUR 2bn. of new public funding available over the next few years.

An advisory board[114] has been installed to consult the government concerning the digital hub initiative.

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[113] http://www.de.digital/DIGITAL/Redaktion/EN/Dossier/digital-hub-initiative.html

[114] https://www.de.digital/DIGITAL/Redaktion/EN/Standardartikel/members-of-the-digital-hub-initiatives-advisory-board.html
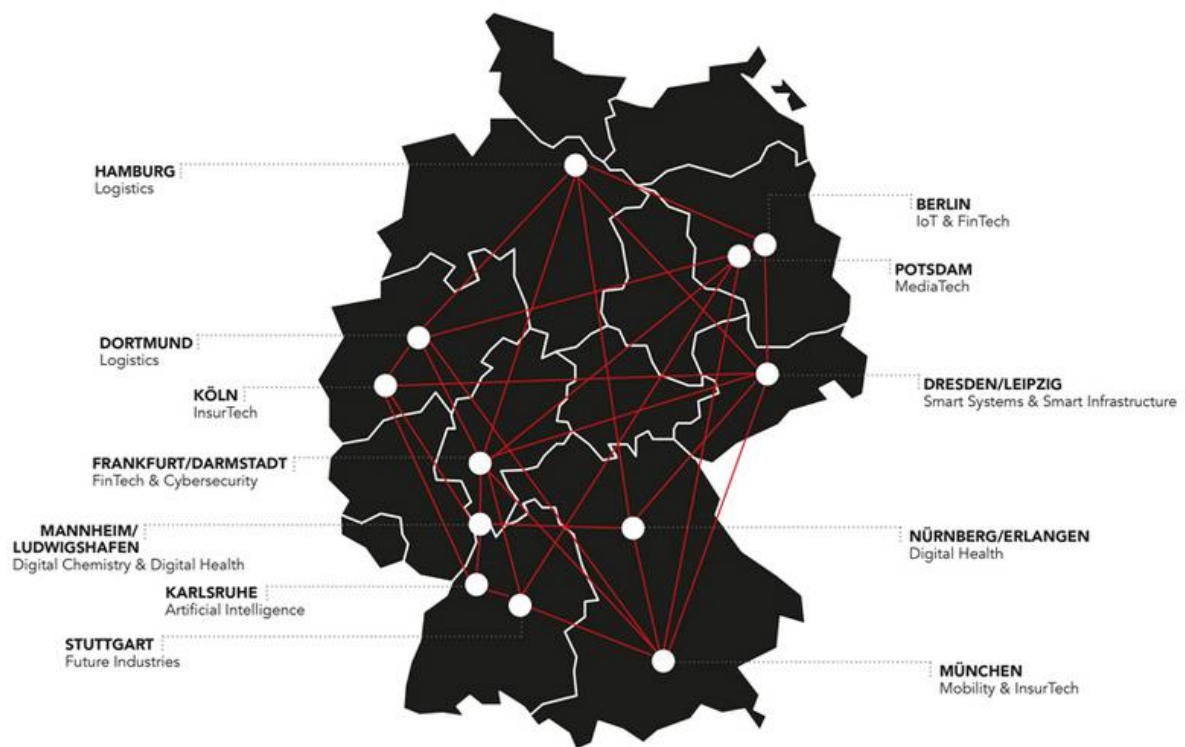
Fig. 3: Map of the German Digital Innovation Hubs

VI. Digitising European Industry (DEI) Pillar 4 - Skills development

In 2016, BMBF launched a set of measures to quickly respond to the challenges related to the integration of migrants. These measures also help implement key elements of the joint integration strategy of the Federal Government and the Länder. Under this strategy, BMBF focuses on language learning and the identification of competences and potentials as well as access to vocational education and training and higher education. Furthermore, funding is provided for research projects to enhance our knowledge of migration and integration.

In its program "Berufsbildung 4.0" (Vocational Training 4.0) the Federal ministry of Education and Research (BMBF) launched an initiative called Berufsbildung 4.0, which, in cooperation with the Federal Institute for Vocational Education and Training (BIBB), aims to develop new measures for a future - oriented, attractive and competitive vocational training in Germany and to connect them with other BMBF initiatives on digitization. The initiative also supports the Digital Agenda of the Federal Government.

- One of the key elements of "Vocational Training 4.0" is a new research initiative "Qualification for Skills and Competences for the Digitized Work of Tomorrow", which is jointly supported by BMBF and BIBB, In dialogue with companies. Jobs that are affected by digitization are examined in selected professions with regard to work processes, activities and qualification requirements. The aim is to recognize at an early stage how qualifications of skilled workers need to change and to establish an early detection system. The initiative also examines the importance of digital skills of trainees and trainers for a successful management of vocational training.

- Another component of "Vocational Training 4.0" is a special BMBF program for the promotion of digitization in intercompany vocational training centers (ÜBS) and competence centers. Over-the-job vocational training centers supplement the company's training in many sectors through practical courses. They are competent partners especially for SME which cannot provide all the necessary training contents themselves. The program supports selected equipment of the training centers in the field of digitization, such as the purchase of 3D printers or CNC machines, that automatically manufacture workpieces thanks to modern control technology.

The Federal Ministry of Education and Research (BMBF) announced for 2017, that they will provide over 14 million euros p.a. in funding for digital learning opportunities and new didactic strategies in basic and advanced vocational training under the "Digital Media in Vocational Training" programme[115]. A "Educational Campaign for the Digital Knowledge Society" is currently designed to provide digital education in Germany with a comprehensive framework for action.

In its program "Future of the German Mittelstand" [4], the Ministry for Economic Affairs and Energy describes the following measures in skills development, that predominantly target SME:

- At the end of 2014, The Federal Government, the Federal Employment Agency, commerce, the trade unions and the Länder founded a 2015-2018 Alliance for Initial and Further Training. The shared aim of this Alliance is to strengthen vocational training and to promote the equal value of vocational and academic education. The Alliance started with an intensive campaigning for "dual" vocational training and the reporting of more training opportunities in companies to the

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[115] https://www.bmbf.de/en/education-and-research-priority-areas-of-federal-government-policy-1410.html

Federal Employment Agency. Also, the partners responded quickly to the arrival of refugees with a declaration[116], they identified key ways to integrate refugees into work environments and paved the way for specific measures.

- The programme "Support for SME with finding the right people for training places and with integrating foreign skilled workers" has been expanded to include further advisory elements: In total about 310 consultants part-funded by the Ministry are helping SMEs to recruit young talents and assist them in integrating foreign trainees and foreign skilled workers.

- BMWi continues to work with the social partners in adapting the training regulations to the rapid advances in technology and particularly to the demands deriving from digitisation. Where necessary, new training courses will be introduced or restructured. In the perspective of the ministry, media literacy, broadband technology and high-speed networks, which are important in the context of digitisation, play a key role. A study on the four dual IT occupations (= IT-Ausbildungsberufe) has been launched to find out what skills are needed in the IT sector for the industry to remain competitive.[117] The federal institute for vocational training (BiBB) concludes that a modernisation of the four dual occupations is needed. They could demonstrate the specifically high need for application developers and IT systems integrators, while the need for IT specialist with a more economic background is declining.

- The rising level of digitisation in companies (e. g. use of new technologies, increasing project work and thus increase in the need for team skills, situation-appropriate communications and more independent work) is also resulting in a growing significance of social skills in the world of work. In 2016, BMWi launched a program for teaching social skills as part of vocational training. This would boost the quality of training and subsequent employment opportunities and it will prevent contracts being terminated prematurely.

- Measures for talent recruitment from foreign countries are the website www.make-it-ingermany.com and a telephone hotline for potential migrants, run in an inter-ministrial cooperation. A new "Study and Work" initiative seeks out innovative ideas of regional networks of higher education institutions, companies, chambers, employment agencies and other social partners, with a view to improving the integration of foreign graduates at German higher education institutions into the regional labour market. To help people with foreign qualifications to become better integrated into the labour market, the Economic Affairs Ministry is providing the BQ Portal online information and work platform to assist the chambers as they recognise foreign training and vocational qualifications. The "Vocational Training without Frontiers" program aims to raise awareness of occupational mobility for companies and trainees during the training courses. Mobility advisors are to give them highquality advice and help them organize periods of training abroad.

Measures to foster Organization development and business networks
In May 2017, the ministry of education and research has published a call on "Collaborations in dynamic value creation networks"[118]. as part of the research program "Innovations for the production, service and work of tomorrow". It aims at supporting manufacturing companies,

[116] http://www.bmas.de/SharedDocs/Downloads/DE/PDF-Schwerpunkte/gemeinsam-fuer-perspektiven-vonfluechtlingen.pdf?__blob=publicationFile&v=4
[117] https://dansitblog.wordpress.com/2016/04/25/duale-it-berufsausbildung-auf-dem-pruefstand/
[118] https://www.bmbf.de/foerderungen/bekanntmachung-1352.html

especially SMEs, in the development of specific, application-oriented and exemplary solutions in the form of cyberphysical systems for the planning, design, management and maintenance of complex value-added networks within the company and across company boundaries to customers and suppliers. The solutions have to be validated in a ongoing pilot as well as in terms of profitability and have to be implemented step by step in the participating production companies. The SME should be enabled to optimize these solutions independently and permanently, even after completion of the research projects. A focus of the program is on strengthening the cooperation between companies and their customers and suppliers as a socio-technical system. Internal and cross-company processes are to be developed in order to achieve a new level of flexibility in production. The use of suitable methods for the protection of the data should secure the company-specific know-how in the long term.

Mittelstand 4.0 Competence Centers

In June 2015, the Federal Ministry for Economic Affairs and Energy (BMWi) launched the funding initiative "Mittelstand (SME) 4.0 – Digital production and work processes"[119] by bulding up so-called SME 4.0-Competence Centers (Mittelstand 4.0-Kompetenzzentren). They are part of the program "Mittelstand-Digital" (see above).

This funding initiative lends digitalisation support to SMEs and the craft industry with its regional Mittelstand 4.0 Competence Centres. They help businesses to first gauge at what stage of digitalisation they are currently at, develop together with the company an individual digitalization road map and assist it in the selection and implementation of suitable measures. The Centres are also at hand to advise companies on whether a technical solution is economically viable and which security aspects must be considered.

In a first phase, BMWi has established ten regional SMEs 4.0 competence centers as well as a "Competence Center for Digital Handicrafts" and four "Mittelstand 4.0-Agencies". The ten Mittelstand 4.0 Competence Centers are located at:

- Center Hanover under the leadership of Leibnitz University, Production Center (since 12/2015).
- Center Dortmund under the direction of the Fraunhofer Institute for Material Flow and Logistics IML (since 01/2016).
- Center Darmstadt under the direction of the Technical University Darmstadt, Institute for Production Management, Technology and Machine Tools. (since 03/2016)
- Center Kaiserslautern under the leadership of the technology initiative SmartFactoryKL e.V. (since 04/2016)
- Center Berlin under the direction of the Federal Association of Small Businesses, Unternehmerverband Deutschland e.V. (since 05/2016)
- Center Chemnitz under the direction of the Technical University of Chemnitz, Institute of Industrial Engineering and Factory Systems (since 08/2016)
- Center Ilmenau under the direction of the Technical University Ilmenau, Department of Production Engineering in the Thuringian Center for Mechanical Engineering (since 10/2016)
- Center Hamburg under the direction of the Handelskammer Hamburg Service GmbH (since 11/2016)

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[119] http://www.mittelstand-digital.de/DE/Foerderinitiativen/mittelstand-4-0.html

- Center Augsburg under the direction of the Fraunhofer Institute for Machine Tools and Forming Technology, project group Resource-Efficient Mechatronic Processing Machines (since 12/2016)
- Center Stuttgart under the direction of the Fraunhofer Institute for Labor and Organizational Development IAO (since 12/2016)

One center, which is specialized in digitalization in the crafts has been established in Hannover (Heinz-Piest Institute; Hanover University) with four contact points for demonstration purposes in Oldenburg, Dresden, Bayreuth and Koblenz. These centers shall operate in their regions in order to achieve the greatest possible proximity and exchange with the SMEs located there. Moreover, they also coordinate their activities among each other and work together to achieve the highest possible resonance and wide impact for digitizing SMEs across all of Germany. The centers are supported by accompanying research (support action).

Additionally, four "agencies" were selected to inform and advise small and medium-sized and craft-based enterprises about the digitization process and the implementation of Industrie 4.0. They were also assigned to offer physical demonstration and testing facilities. The four selected agencies are the following:

- The Mittelstand 4.0 agency "Cloud", headed by the Fraunhofer Institute for Labor and Organizational Development (IAO), Stuttgart, supports the use and dissemination of cloud computing technologies;
- The Mittelstand 4.0 agency "Processes" led by the FTK Research Institute for Telecommunications and cooperation e.V. in Dortmund helps with the use of digital process and resource management;
- The SME 4.0 agency "Communication", headed by the BSP Business School Berlin, contributes to the dissemination of digital communication processes, knowledge management, e-learning and innovation management;
- The Mittelstand 4.0-Agency "Trade" under the direction of the ifH Institut für Handelsforschung GmbH in Cologne takes care for questions on new technologies in digital commerce, such as the e-bill and the production-linked trade.

In 2017, the „Mittelstand-Digital" initiative has been significantly extended (2015: 18 Mio., 2016: 29 mio. Euro, 2017: 43 mio Euro). BMWi intends to open up 13 more SME 4.0 competence centers to reach a higher geographical coverage.

- 8 regional competence centers: Magdeburg, (start: August 2017), Saarbrücken (September 2017), Cottbus, Kiel, Lingen, Siegen, Bremen, Rostock (starting during the next months)
- 5 thematic competence centers: Standardization (GS1Germany GmbH; started August 2017) , Planning & Building, Textiles, Usability, medium-sized ICT businesses)

VII Specific National Measures

Innovation promotion

Tax incentives

Germany is not listed in the OECD compendium for tax incentive schemes [19]. As of today, tax incentives for R&D are not implemented. However, at Hannover fair 2017, minister Wanka (BMBF) has announced that Germany wants to raise the gross domestic expenditures on R&D (GERD) from 3,0% to 3,5% which would mean additional expenditures of 3,7 bn. Euro. It was announced that this should aso reached via tax incentives for technology based R&D. In past years, several political initiatives to invent tax based R&D funding in businesses have been launched but so far been not successful.

Innovation Vouchers

In July 2017, BMWi has launched the funding program "go digital"[120] which supports SME and workshops (with less than 100 employees) to advance their own digitization in three areas: IT security, digital marketing and digitized business processes. Funded enterprises can get expertise and support from authorized consulting firms; starting with an analysis (phase 1), projects for concrete transformation measures (phase 2) can be funded. In phase 1, interested professional ICT consultant business are certified. After their authorisation, starting in fall 2017, SME can submit applications.

The BMWi program "go innovativ"[121] funds management and consulting services for the preparation and execution of product developments and technical process innovations. Services may only be provided by authorized consultants. After a potential analysis (step 1, e.g. strength and weakness profile; capacity requirements), a realization concept is worked out. Project management services are as well eligible.

In its program „KMU-innovativ"[122], BMBF wants to simplify the application and approval of grants for innovative SMEs in specific technology fields that are particularly important for Germany's future. A central piloting service helps SME to solve all questions and reliable processing periods provide planning security.

Technology transfer in structural weak regions

The BMWi program "InnoKom" aims at compensating the lack of industrial research in structural weak regions. A forerunner program INNO-KOM-"East" supported the technology transfer of nonprofit industry research facilities in eastern Germany since 2009. Since January 2017, the success model is expanded to structurally weak regions throughout Germany. Non-profit, external industrial research facilities which have the appropriate staff and equipment to investigate complex technical and scientific questions are eligible for funding under the this program. They can carry out their fundamental research projects as well as market-oriented development up to max. EUR 550,000. Also, investment measures to maintain the scientific and technical infrastructure are funded.

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[120] http://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2017/20170713-go-digital-startet.html
[121] http://www.innovation-beratung-foerderung.de/INNO/Redaktion/DE/Dossiers/go-innovativ_foerdermodell.html?cms_docId=64334
[122] https://www.bmbf.de/de/kmu-innovativ-561.html

With the program "WE!" ("WIR!") the Federal Ministry of Education and Research has created new impetus in regions with particular challenges in structural change[123]. Launched in August 2017, the program is part of the new Hightech strategy of the government. WE! is aimed at broadly based regional alliances of a wide range of actors, which jointly identify fields of innovation. With new strategic approaches, they are to transfer the existing innovation potentials of their region into the future. With the program, the region's profile will be strengthened and new perspectives for structural change will be opened.

Support for patenting and exploitation

The BMWi program WIPANO supports SME in securing and using intellectual property for economic exploitation. The program addresses innovative ideas and inventions from SME that result from public funded research. Also, the transfer of research results in norms and standards is funded.

Public Procurement Measurements

Germany has a long public procurement legal tradition grounded primarily in the budgetary systems of the various municipalities, regions and ministries[124]. As a result, the German approach to procurement is strongly focused on economic efficiency. More recently, policies aimed at fostering secondary procurement objectives such as innovation and environmental sustainability have been introduced. The procurement system is also highly decentralised and often quite complex due to Germany's federal system. It is subject to a dispersed regulatory framework that comprises delegated acts, such as ordinances and rules by non-governmental bodies, and allows for a substantial level of autonomy to the German federal states. The main institution responsible for public procurement policy is the Federal Ministry of Economy and Energy (BMWi). The comprehensive reform of procurement law undertaken in April 2016 has modernised public procurement and is boosting the level of digitisation.[125] It was the biggest reform of procurement law for more than 10 years and has made public procurement above the EU thresholds more modern, simple and user-friendly. The reformed legal framework permits contracting authorities to make more use of public procurement to support strategic objectives. In a second step, BMWi has also reformed public procurement below the EU thresholds. This gives contracting authorities and companies greater flexibility in shaping the procurement procedure.

A research for public procurement measures in the area of Industry 4.0 and digitizing European industries shows procurements predominantly by universities and research organizations, such as for example an Industrie 4.0 plant with mobile robotics unit ordered by Hochschule Karlsruhe [126]; educational services Industrie 4.0 / work 4.0 ordered by Fraunhofer Gesellschaft[127]; several orders for software development by Forschungszentrum Jülich or DLR.

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[123] https://www.unternehmen-region.de/de/wir---das-programm-2061.html
[124] http://ec.europa.eu/regional_policy/sources/policy/how/improving-investment/public-procurement/study/country_profile/de.pdf
[125] https://www.bmwi.de/Redaktion/EN/Dossier/public-procurement.html
[126] https://www.hs-karlsruhe.de/fileadmin/hska/VW/VW-BM/Ausschreibungen/1601_Mobile_Robotik_Ausschreibungsunterlagen.pdf
[127]

https://www.service.bund.de/IMPORTE/Ausschreibungen/xvergabe/2017/08/vmshh001_187865.html?nn=4641482&type=0&searchResult=true&templateQueryString=industrie+4.0

Structural Funds

According to the ICT Monitoring Tool [Website], Germany is planning the following ICT Investments under ESIF with relevance to ICT or smart manufacturing research and dissemination[128]:

- EAFRD - ICT in rural funds: 224M.

- 05 - ESF 2nd theme - Enhancing the accessibility, use and quality of information: 35 M.

- 015 - Intelligent Energy Distribution Systems at medium and low voltage levels (including smart grids and ICT systems): € 67 M.

- 044 - Intelligent transport systems (including the introduction of demand management, tolling systems, IT monitoring, control and information systems): € 71 M.

- 046 - ICT: High-Speed broadband network (access/local loop; >/= 30 Mbps): € 58 M.

- 048 - ICT: Other types of ICT infrastructure/large-scale computer resources/equipment (including e-infrastructure, data centres and sensors; also where embedded in other infrastructure such as research facilities, environmental and social infrastructure): € 1,5 M

- 078 - e-Government services and applications (including e-Procurement, ICT measures supporting the reform of public administration, cyber-security, trust and privacy measures, eJustice and e-Democracy): € 2 M.

- 079 - Access to public sector information (including open data e-Culture, digital libraries, eContent and e-Tourism): € 7 M.

- 081 - ICT solutions addressing the healthy active ageing challenge and e-Health services and applications (including e-Care and ambient assisted living): € 16 M.

- 082 - ICT Services and applications for SMEs, living labs, web entrepreneurs and ICT start-ups): € 33 M.

Which is summing up to a total of 595 mio. Euro.

The highest use of ESIF funds are made by the Länder Saxony (157 mio Euro) and Sachsen-Anhalt (152 mio. Euro).

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[128] Data were generated by a search tool from the ESIF Operational Programmes (OP) on planned ICT related investments (retrieved on 20/01/2017 from the SFC2014/Infoview database)

Facilitate access to finance

Venture Capital

In total, BMWi provides around two billion euros to strengthen the venture capital market in disruptive innovation leaps [4]. The following measures provide suitable financing offers

- With its ERP Venture Capital Fund Investments, the KfW (Kreditanstalt für Wiederaufbau)[129] returned to the venture capital market in spring 2015 as an anchor investor for funds. It has a budget for €400 million for this and invests in selected venture capital funds in Germany and Europe which invest in young, growth-oriented, technology companies
- The ERP/EIF Fund of Funds was increased from €1 billion to €1.7 billion in September 2015, helping to meet the needs of high-growth companies for venture capital in future. This includes the funding for the European Angels Fund (EAF), which was boosted from €130 million to €285 million in September 2015.
- The "INVEST venture capital grant" provides incentives for business angels to invest in young, innovative companies. The exemption of the grant from taxes on earnings introduced in 2015 has made this instrument even more attractive. In 2016, INVEST was substantially expanded, via the doubling of the eligible investment sum to €500,000, the broadening of the category of eligible applicants, and the reimbursement of taxes on capital gains.
- In March 2016, the European Investment Fund EIF together with BMWi announced new instrument to raise more venture capital in Germany. This 500 mio Euro ERP-EIF Growth Facility focuses on venture capital support for start-up and early growth phase companies in Germany and can fund them with up to 20 mio. Euro. It targets rapidly growing companies with a high demand for equity. As a result, private-sector investment is likely to reach at least EUR 1bn.
- In parallel, EIF and BMWi launched a new "coparion" fund, a spin-off from the ERP Start-Up Fund, totalling EUR 225m, aimed at companies in start-up and early growth phases.
- The third High-Tech Start-Up Fund has been launched in june 2016. The concept of the public-private partnership (Economic Affairs Ministry, KfW, industrial companies) has proved its worth, and is therefore retained. With the third fund, the HTGF will remain the most active investor in Europe. The HTGF III has a target volume of approximately 300 million euros with a share of private economic investors of 30 percent. The private share of this public-private partnership is thus to be significantly expanded with up to 30 investors. At the time of the first closing on May 31, 2017, the HTGF III already has a volume of 245.5 million euros, which was raised by the federal government (133 million euros), KfW (26.7 million euros) and 26 industrial investors (85 in total, 5 million euros).

Crowd Funding

In July 2015, the German parliament passed a crowd funding law ("Kleinanlegerschutzgesetz")[130], which primarily strengthens the position of consumers. The law has been critizised as insufficient by crowdfunding organisations and related interest groups. However, since then no further governmental activities concerning crowd are public. In April 2017, the Green party has placed a request to the parliament on the further development of crowdfunding[131]. They argument that the

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[129] https://www.kfw.de/kfw.de-2.html
[130] https://de.wikipedia.org/wiki/Kleinanlegerschutzgesetz
[131] http://dip21.bundestag.de/dip21/btd/18/118/1811888.pdf

crowdfunding market in Germany has developed positively, when looking at absolute figures (2015: waren 249 Mio. Euro). Behind U.K. (4.3 bn. Euro) and France (319 Mio. Euro), Germany is 3rd in market turnover in Europe. The growth has been 115% between 2013 and 2014 and 78% between 2014 and 2015. In relation to the other states, however, the distance has increased and U.K. has collected about 17 time more crowdfunding per capita than Germany did. According to KPMG, in a comparison per capita, Germany falls back to position 10 in Europe.[132] The Government has announced to basically keep the legal situation as it is and discuss adjustments according to the revision of the EU prospectus law.

Investment promotion

"Germany Trade & Invest" (GTAI) is Germany's federal economic development agency. The organization promotes Germany as a business and technology location and supports companies based in Germany with global market information.

Supported by a network of 60 expert foreign correspondents abroad and benefiting form close cooperation with the German Chamber Network (AHKs), the agency supports Germany's international trade needs with comprehensive and reliable industry-specific market information.

  GTAI's website informs comprehensively on Germany's strategic digitization projects, such as "Industrie 4.0", "Smart Service Welt"[133] and IoT solutions. Together with partners, GTAI organizes technology demonstration workshops abroad, such as the "Smart Factory Industry Forum" in Chicago (2015). GTAI has also been active at Hannover fair 2016 with a full day workshop "Forming the Future in Germany: Where INDUSTRIE 4.0 is driving Innovative Industrial Value Chains".

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[132] https://www.jbs.cam.ac.uk/fileadmin/user_upload/research/centres/alternative-finance/downloads/2016-european-alternative-finance-report-sustaining-momentum.pdf
[133] https://industrie4.0.gtai.de/INDUSTRIE40/Navigation/EN/industrie-4-0

VIII Investments for Digitising European Industry

Activity (Germany)	Timeframe	Reliability	Amount (M€)
Software Systems, Knowledge technologies	2015	Officially published	108,8
Software Systems, Knowledge technologies	2016	Officially published	108,4
Communication technologies and Services	2015	Officially published	57,0
Communication technologies and Services	2016	Officially published	65,0
Electronics and electronic systems	2015	Officially published	57,9
Electronics and electronic systems	2016	Officially published	72,9
Micro systems technologies	2015	Officially published	1,4
Micro systems technologies	2016	Officially published	0,16
Nano technologies	2015	Officially published	24,8
Nano technologies	2016	Officially published	23,5
Optical technologies	2015	Officially published	100,0
Optical technologies	2016	Officially published	98,0
Production technologies	2015	Officially published	46,7
Production technologies	2016	Officially published	52,0
BMWi technology funding	2015	Info from DLR	48,9
BMWi technology funding	2016	Info from DLR	43,9
BWMi SME transfer funding (competence centers)	2015-17	Info from ministry	90
BWMi digital hubs funding	2016/17		

Other known investment relevant to DEI	59		
Micro electronics IPSEI	2017	Press release	1.000
BMWi technology funding plans for 2018-a2020	Per year	Info from DLR	59.2
Framework program microelectronics	2017-2020	Press release	400
Research facility microelectronics	2017-2020	Press release	400
Skills and qualification measures	2017f.	Press release	14

References

[1]   Ministry for Economic Affairs and Energy, "Monitoring Report DIGITAL Economy 2016,"
        https://www.bmwi.de/Redaktion/EN/Publikationen/monitoring-report-digital-
        economy2016.pdf?__blob=publicationFile&v=2, 2017.

[2]   Bitkom; VDMA; ZVEI, "Umsetzungsstrategie Industrie 4.0 - Ergebnisbericht der Plattform Industrie 4.0,"
        http://www.bmwi.de/Redaktion/DE/Downloads/I/industrie-40verbaendeplattform-
        bericht.pdf?__blob=publicationFile&v=1, 2015.

[3]   Ministry for Economic Affairs and Energy, "Digital Strategy 2025,"
        http://www.bmwi.de/DIGITAL/Redaktion/EN/Publikation/digital-strategy-2025.html, 2016.

[4]   Ministry for Economic Affairs and Energy, "Future of the German Mittelstand" Action Programme,"
        https://www.bmwi.de/Redaktion/EN/Publikationen/aktionsprogramm-
        zukunftmittelstand.pdf?__blob=publicationFile&v=6, 2016.

[5]   Ministry for Economic Affairs and Energy, "Industrie 4.0 und Digitale Wirtschaft - Impulse für Wachstum,
        Beschäftigung und Innovation," https://www.bmwi.de/Redaktion/DE/Downloads/I/industrie-4-0-und-
        digitalewirtschaft.pdf?__blob=publicationFile&v=3, 2015.

[6]   European Commission, "Digital Economy and Society Index (DESI)," 2016. [Online]. Available:
                https://ec.europa.eu/digital-single-market/en/scoreboard/germany. [Accessed February 2016].

[7]   Ministry for economic affairs and energy, "White Paper on Digital Platforms,"
        https://www.bmwi.de/Redaktion/EN/Publikationen/weissbuch-digitale-plattform-
        kurzfassungeng.pdf?__blob=publicationFile&v=4 , 2016.

[8]   BMVI, "Eckpunkte Zukunftsoffensive Gigabit Deutschland,"
        http://www.bmvi.de/SharedDocs/DE/Artikel/DG/eckpunkte-zukunftsoffensive-gigabitdeutschland.html,
        2016.

[9]   Federal Ministry of Education and Research, "Self Determined and secure in the digital world,"
        https://www.forschung-it-sicherheit-
        kommunikationssysteme.de/dateien/publikationen/framework-programme-self-determinedand-
        secure.pdf/download, 2015.

[10]   Plattform Industrie 4.0, "Working Paper: Aspects of the research roadmap in the application scenarios,"
        https://www.plattform-i40.de/I40/Redaktion/EN/Downloads/Publikation/aspectsof-the-research-
        roadmap.pdf?__blob=publicationFile&v=9, 2016.

[11]   Plattform Industrie 4.0, "Implementation Strategy Industry 4.0 - Report on the results of the Industrie 4.0
        Platform,"
        https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2016/januar/Impleme
        ntation_Strategy_Industrie_4.0__Report_on_the_results_of_Industrie_4.0_Platform/Implementation-
        Strategy-Industrie-40ENG.pdf, 2016.

[12] Plattform Industrie 4.0, "Progress Report - Digitization of Industrie," https://www.bmwi.de/Redaktion/EN/Publikationen/digitization-ofIndustrie.pdf?__blob=publicationFile&v=3, 2016.

[13] Plattform Industrie 4.0, "White Paper FuE-Themen Stand 2014," https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2014/april/In dustrie_4.0__Whitepaper_zu_Forschungs-_und_Entwicklungsthemen/Industrie-40-WhitepaperForschung-20140403.pdf, 2014.

[14] Federal Ministry of Education and Research, "Zukunftsbild Industrie 4.0," https://www.bmbf.de/pub/Zukunftsbild_Industrie_4.0.pdf, 2013.

[15] Federal Ministry of Education and Research, "Industrie 4.0 - Innovationen für die Produktion von morgen," https://www.bmbf.de/pub/Industrie_4.0.pdf, 2015.

[16] Federal Ministry of Education and Research, "Microelectronics from Germany – Driver of innovation for the digital economy," https://www.bmbf.de/pub/Microelectronics_from_Germany.pdf, 2016.

[17] Federal Ministry of Education and Research, "Zukunft der Arbeit," https://www.bmbf.de/pub/Zukunft_der_Arbeit.pdf, 2016.

[18] DIN/DKE, "German Standardisation Roadmap Industry 4.0," http://www.din.de/blob/95954/42935f7a165f16e341967b8a9f91c026/aktualisierte-roadmapi40-data.pdf, 2016.

[19] Federal ministry for economic affairs and energy, "Future of the German Mittelstand programme," https://www.bmwi.de/Redaktion/EN/Publikationen/aktionsprogramm-zukunftmittelstand.html, 2016.

[20] OECD, "Compendium of R&D tax incentive schemes; OECD Countries and selected economies," https://www.oecd.org/sti/rd-tax-incentives-compendium.pdf, 2017.