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Regional Innovation Monitor Plus 2016

Regional Innovation Report

Baden-Württemberg (Industry 4.0 and smart systems)

To the European Commission

Internal Market, Industry, Entrepreneurship and SMEs Directorate-General

Directorate F – Innovation and Advanced Manufacturing

Regional Innovation Monitor Plus 2016

Regional Innovation Report
Baden-Württemberg (Industry 4.0 and smart systems)

technopolis _{|group|} in cooperation with



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PREFACE

In the context of the growth and investment package set out in the Investment Plan of the European Commission, the Regional Innovation Monitor Plus (RIM Plus) provides a unique platform for sharing knowledge and know-how on major innovation and industrial policy trends in in some 200 regions across EU20 Member States.

Launched in 2010, the Regional Innovation Monitor aimed at supporting sharing of intelligence on innovation policies across EU regions. Building upon the experience gained and results obtained during the period 2010-2012, the RIM Plus 2013-2014 provided practical guidance to regions on how to use the collected information, via a network of regional experts. Since 2014, the RIM Plus has introduced a thematic focus on advanced manufacturing.

The RIM Plus 2015-2016 evolved from a general monitoring of innovation policies towards establishing a more thematic focus in selected areas in order to contribute to improving the competitiveness of European regions.

Particularly, the RIM Plus aims through its activities and in close cooperation with the regional stakeholders and other relevant initiatives to:

- Contribute to the development of new and open spaces of collaboration and exchange on advanced manufacturing, each with a clearly defined thematic focus.
- Play an enabling role in providing evidence-based information on specific themes and bring in outside perspective from other regions.
- Map out regional practices in support of advanced manufacturing and relevant pilot/demo projects and work towards involving the relevant stakeholders.
- Provide an easy access and comparative overview of regional innovation policies and relevant actions in the field of advanced manufacturing.
- Share the lessons learned with the European Commission services to feed into the preparation of future programmes.

The main aim of 30 regional reports is to provide a description and analysis of developments in the area advanced manufacturing with a clearly defined thematic focus and regional innovation policy, taking into account the specific context of the region as well as general trends. All regional innovation reports are produced in a standardised way using a common methodological and conceptual framework, in order to allow for horizontal analysis, with a view to preparing the Final EU Regional Innovation Monitor Plus report.

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Further information:

<https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor>

Executive Summary

1. Advanced Manufacturing: Industry 4.0 and smart systems

According to the Regional Innovation Scoreboard Baden-Württemberg is one of the innovation leaders in Europe. In particular, manufacturing is very important for Baden-Württemberg's economy. In 2014, 30.3% of Baden-Württemberg's employees fell into this sector. The federal state is highly specialised in 'manufacture of machinery and equipment' as well as 'manufacture of motor vehicles, trailers and semi-trailers'. Thus, with regard to industry 4.0 Baden-Württemberg has the potential for producing and applying industry 4.0 solutions for production systems. In the former respect, also ICT should be considered. The employment share of ICT in Baden-Württemberg (3.4%) is above the national average. Several big companies are based in Baden-Württemberg that already apply or produce industry 4.0 solutions. Examples of these are SAP, Festo, ebm-papst, SEW-Eurodrive, Trumpf, Pils, Wittenstein, Sick, CAS and Seeburger.

In addition to manufacturing and IT firms, there are also many universities and research institutes active in relevant fields. Among these are the Karlsruhe Institute for Technology (KIT), the University of Stuttgart, the Fraunhofer IPA and the Fraunhofer IOSB.

Several intermediaries aim to promote the development and application of industry 4.0 in Baden-Württemberg. But also the federal government aims at boosting the production and application of industry 4.0 solutions. Lately, Baden-Württemberg's Minister for Finance and Economics expresses the aim that the *Land* becomes **lead market and lead producer for industry 4.0**. To this end, a steering committee has been installed and various activities have been started. In order to combine the knowledge and activities available in Baden-Württemberg, the Alliance Industry 4.0 was established in 2015. It is comprised of all important stakeholders in this realm. Among others, the installation of the Application Centre Industry 4.0 at Fraunhofer IPA and the Research Factory Campus East at the KIT have been supported publicly. In addition to that, several research projects receive funding from the federal government. The state's government not only focuses on promoting research and development. In order to promote the application of industry 4.0 solutions on a broad scale, 15 learning factories are to be established at vocational schools. These facilities should also contribute to spreading the technologies among SMEs.

The overview shows that Baden-Württemberg is already in a good position for producing and applying industry 4.0 solutions. However, some challenges remain:

- **Challenge 1: Sustaining Baden-Württemberg's competitiveness in view of the challenges of digitalisation and industry 4.0**

Among SMEs, the level of information about industry 4.0 solutions is very low. While many of the larger firms are quite active in developing and applying industry 4.0 solutions, there is a high level of uncertainty among SMEs with regard to the implications of digitalisation and industry 4.0 for their business. However, shaping and adapting technological change can be regarded as important for a region like Baden-Württemberg that has a strong manufacturing base.

- **Challenge 2: Facilitating industry 4.0 in all parts of Baden-Württemberg**

A characteristic of Baden-Württemberg's high-tech firms is that they are not solely located in urban areas. Also in some rural areas high-tech firms are located. Some of them fall into the category of 'hidden champions' as they are world market leaders in their particular field. Industry 4.0 solutions, however, necessitate high speed Internet connections. In this respect, there is a strong difference between rural and urban areas.

- **Challenge 3: Developing business models based on industry 4.0**

Industry 4.0 has the potential of threatening established business models. Thus, for many firms, it will not only be important to apply industry 4.0 solutions efficiently, but also to develop new business models, that e.g. combine products and Internet-based services.

2. Regional Innovation Performance Trends, Governance and Instruments

As statistical indicators show, Baden-Württemberg occupies the leading position with respect to innovation performance among EU-28 regions. The German *Land* has the highest share of its GDP spent for research and development, the highest number of patent applications per million inhabitants, and belongs to the European innovation leaders according to the Regional Innovation Scoreboard. In order to maintain this leading position, Baden-Württemberg pursues a comprehensive innovation policy approach that comprises science and research policy, technology policy, as well as SME support and the creation of innovation-friendly framework conditions. This approach includes the support of science and research through strengthening research excellence and a strong higher education and research sector, supporting young scientists, young and small and medium-sized enterprises (SMEs) with high growth potentials, and promoting science-industry networks. In addition, it refers to the targeted support of selected core fields in (1) sustainable mobility, (2) environmental technologies, renewable energies and resource efficiency, (3) health and care, (4) information and communication technologies, green IT and smart products, complemented by creative industries and aerospace, as well as key enabling technologies in a cross-sectoral perspective (e.g. microsystems technology, photonics, nanotechnology, information technology, lightweight construction).

Regional RTDI policy approach consists of various dimensions. First, it targets the science and research sector through institutional funding of universities and research institutes of the non-university sector, as well as through additional supporting programme in scientific fields. In addition, it has a strong focus on the industry-oriented research infrastructure. Secondly, the state government grants support on the level of individual projects and/or innovation actors. Thirdly, the focus on networks, clusters, knowledge and technology transfer receives high attention. These areas are promoted through targeted support for application- and industry-oriented research institutes, networks and clusters, as well as a dense network of technology transfer agencies and actors that specifically focus on regional SMEs. These broadly outlined measures are complemented by financial instruments dedicated to innovation and technology, start-up and growth phases. In addition to regional programmes, Baden-Württemberg's innovation actors benefit from national and European support measures (e.g. ESF, ERDF).

Baden-Württemberg has a differentiated science and research landscape as well as a dense network of intermediary actors. On the government level, the main responsibilities are in the Ministry for Science, Research and the Arts (*Ministerium für Wissenschaft, Forschung und Kunst*) Baden-Württemberg and the Ministry of Finance and Economic Affairs (*Ministerium für Finanzen und Wirtschaft*) Baden-Württemberg. Important regional intermediaries that focus on RTDI support comprise the *Baden-Württemberg Stiftung* (Baden-Württemberg Foundation), chambers of industry and commerce and of trades, Steinbeis transfer centres, clusters and networks, technology centres, incubators, state initiatives and agencies in specific technologies, as well as associations and trade union.

Baden-Württemberg's current innovation strategy dates from 2013 and was published by the Ministry of Finance and Economic Affairs in cooperation with the Ministry for Science, Research and the Arts, the Ministry for Rural Areas and Consumer Protection, and the Ministry for the Environment, Climate and Energy. Main target fields and objectives of the regional innovation policy are the further focus on future-oriented growth fields, the strengthening of Baden-Württemberg as R&D location, the

boosting of regional innovation activities, the support of resource efficiency and the energy transition, securing skilled employees, as well as European and international cooperation. Innovation policy implementation is strongly supported through regional dialogue-processes which embrace regional key stakeholders that discuss relevant topics and develop theme-specific recommendations.

3. Future Actions and Opportunities

With regard to Industry 4.0 and smart systems

In recent years, Baden-Württemberg's government started several activities to promote digitalisation and industry 4.0 in particular. To truly boost the economy to become a lead market and lead producer of industry 4.0 solutions the following aspects should be considered in particular:

- **Inform about IT in general and industry 4.0 in particular**

As the information level among SMEs about the chances, opportunities and challenges of industry 4.0 is on average low, easy access to information can be regarded as a first step. Offerings should focus on the firm's reality and their specific questions and demand.

- **Provide access for SMEs to shared facilities**

Providing information can be regarded as a first prerequisite. In addition to that, access to shared facilities, where the transfer of knowledge takes place and firm's can test industry 4.0 in a real factory environment can be regarded as sensible offering to truly boost the development and application of industry 4.0 solutions.

- **Establish cooperation projects along the value chain**

There are already several joint cooperation projects, however, more efforts to also involve SMEs could be an option to promote the application and development of industry 4.0 solutions among SMEs. In particular, a focus could also be on promoting cooperation projects with partners in the neighbouring regions of France, Switzerland or Austria.

With regard to innovation policy

Baden-Württemberg is a leading innovation region. In order to maintain this excellent position, the *Land* perceives various challenges. These form the base for the state's future actions and innovation efforts.

- **Maintaining and increasing efforts in research, development and innovation**

The overall picture of Baden-Württemberg's situation in RTDI is highly positive. But a closer look reveals that not only other regions and nations realise high investments in research and development, are thus catching-up, but also that research, development and innovation is not evenly distributed across the region. As a consequence, Baden-Württemberg strongly focuses on maintaining and increasing efforts in RTDI on the regional level. Strong focus is on selected future-oriented growth fields, scientific excellence, application-oriented research and transfer and international cooperation.

- **Creating stable and favourable framework conditions for innovations and being open for new developments**

A stable and favourable framework is a crucial precondition for innovation activities. Favourable context conditions refer to knowledge production and transfer, but also to legal and infrastructure aspects and financing. The state government targets these aspects with support from regional, national and European funds.

- **Integrating SMEs and their needs into the innovation process**

The Baden-Württemberg industrial fabric is to a considerable extent composed of small and medium-sized enterprises. However, a large share of R&D investments are

realised by large regional firms, while the enhancement of regional SMEs into the research, development and innovation process belongs to Baden-Württemberg's challenges and future actions. Various measures support this aspect, including vouchers for R&D services, networks and cluster and the offer of industry-oriented research and technology transfer.

1. Advanced Manufacturing: Industry 4.0 and smart systems

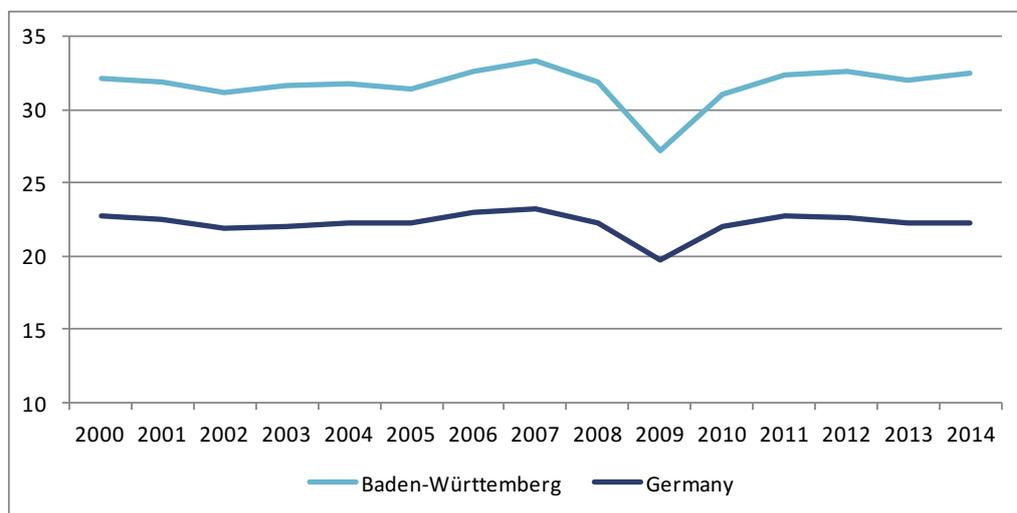
1.1 Overview of performance and trends

Baden-Württemberg is one of 16 German federal states located in the southwest of the Federal Republic of Germany. On the basis of the number of inhabitants (10.9m by the end of 2013) and surface (35,751km²) Baden-Württemberg stands at the third place compared to the other federal states. The capital city of Baden-Württemberg is Stuttgart (about 600,000 inhabitants).

The GDP of Baden-Württemberg was €438b in 2014. The number of employees was 4,266,000 (2014). 30.3% of employees were active in the manufacturing sector in Baden-Württemberg. Compared to the German average of 21.9% manufacturing (section C according to NACE Rev. 2) is comparably important. Together, 'manufacture of machinery and equipment' (28 NACE Rev. 2) as well as 'manufacture of motor vehicles, trailers and semi-trailers' (29 NACE Rev. 2) have a share employment of 11.2%. Baden-Württemberg is highly specialised in particular manufacturing industries. To name just a few, Baden-Württemberg is specialised in: 'manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks' (26.5 NACE Rev. 2), 'manufacture of metal forming machinery and machine tools' (28.4 NACE Rev. 2). With regard to Industry 4.0, also the relevance of ICT should be considered. Also in this respect, the employment share in ICT (section J according to NACE Rev. 2) in Baden-Württemberg is above the average with 3.4% compared to 3.1% at the national level.¹ According to the Regional Innovation Scorebord Baden-Württemberg is one of the innovation leaders in Europe.

Figure 1 shows the development of the share of manufacturing on gross value added in Baden-Württemberg and in Germany. Compared to the national average, manufacturing plays an important role and has a share of 32.5%. As can be seen, the economic and financial crisis hit manufacturing severely in 2009, however, Baden-Württemberg was able to recover quickly.

Figure 1 Share of manufacturing on gross value added (section C according to NACE Rev. 2) 2000 - 2014



Data source: Federal Statistical Office

Among the federal states, Baden-Württemberg contributes most to the national business R&D spending by 31.1%. In 2013, business spending on R&D was €16.3b. The

¹ Data source: Federal Employment Agency (Bundesagentur für Arbeit)

contribution of manufacturing is 88% or €14.3b. Among the manufacturing industries, 'manufacture of motor vehicles, trailers and semi-trailers' (29 NACE Rev. 2) has a share of 54.8%. In this industry, Baden-Württemberg contributes to the German total R&D spending by 45.7%. Although manufacturing plays a dominant role for business R&D spending, it is interesting to see that also information and communication (section J according to NACE Rev. 2) has a share of 48.4% on national total (€1.5b in Baden-Württemberg), mainly attributable to programming activities. With regard to company size, big companies with more than 10,000 employees dominate as they account for 60.8% of business R&D spending (German average 48.1%). Looking at R&D personnel in the business sector (101,811 FTE in total), the dominance of manufacturing is not diminished. But, from this perspective Manufacture of motor vehicles, trailers and semi-trailers (29 NACE Rev. 2) has only a share of 46.3% of R&D personnel in manufacturing. Nonetheless, this industry is still the most important player followed by Manufacture of machinery and equipment (28 NACE Rev. 2) with 15.6% and Manufacture of computer, electronic and optical products (26 NACE Rev.2) with 15.2%.²

With a view to industry 4.0, due to production strengths, changes in production processes are highly relevant for Baden-Württemberg's firms. But, as will be discussed below, since there are many innovative manufacturing firms which can be referred to as world market leaders in their realm, these firms do also shape the technological developments of the future.

1.2 Business sector perspective

In Baden-Württemberg, there are about 500,000 companies located. Amongst them, about 2,000 (0.4%) have 250 employees or more.³ Table 1 shows the biggest companies in Baden-Württemberg according to sales volume.

Table 1 List of the biggest 10 companies from Baden-Württemberg

Rank	Name	Location	Industry	Sales in total 2014 in €bn	Number of employees in Baden-Württemberg
1	Daimler AG	Stuttgart	Automotive	129.87	101,000
2	Schwarz-Gruppe	Neckarsulm	Retail	79.30	n/a
3	Robert Bosch GmbH	Stuttgart	Automotive	48.95	51,257
4	PHOENIX Group	Mannheim	Wholesale (Pharma)	22.57	1,045
5	Celesio AG	Stuttgart	Wholesale (Pharma)	22.33	n/a
6	EnBW Energie Baden-Württemberg AG	Karlsruhe	Energy	21.00	14,442
7	ZF Friedrichshafen AG	Friedrichshafen	Automotive	18.41	8,520
8	SAP AG	Walldorf	Software	17.56	n/a
9	Porsche AG	Stuttgart	Automotive	17.21	14,500
10	HeidelbergCement AG	Heidelberg	Construction material	12.61	~1,500

Source: Stuttgarter Zeitung (2015),⁴ Industrie- und Handelskammern in Baden-Württemberg

² Data source: Stifterverband für die deutsche Wissenschaft

³ Unternehmensregister Statistisches Landesamt 2012

In addition, various SMEs are highly innovative in their particular field and compared to the other federal states, Baden-Württemberg's SMEs account for 20% of Germany's R&D spending among SMEs. Behind this background generalisations are hard to make. Nonetheless, in the following some critical features will be described with a view to industry 4.0 in particular. Due to the high relevance of manufacturing in general, industry 4.0 is relevant for firms in Baden-Württemberg as producers and users.

As the description above showed, the automotive industry plays a very important role in Baden-Württemberg. Apart from Daimler and Porsche, important suppliers are located here, for example, Robert Bosch, ZF Friedrichshafen, Dürr, Mahle, Freudenberg, J.Eberspächer, Mann + Hummel, asf.

With regard to machine manufacturing and suppliers among others, the following can be mentioned: Festo, Voith, Liebherr, Trumpf, Heidelberger Druck, Würth, SEW Eurodrive.

As will be discussed below in more detail, Baden-Württemberg promotes industry 4.0 in various ways. One of the measures was the establishment of a competence atlas for industry 4.0 in 2014 (Ministry of Finance and Economic Affairs Baden-Württemberg 2014). The competence atlas is available also online and run by the Ministry of Finance and Economic Affairs Baden-Württemberg. It lists companies, research institutions and supporting agencies which are active in this field. According to the print version, there are about 400 actors with industry 4.0 competencies. The companies listed are, for example, Arburg, ebm-papst, Festo, Homag, Schunk, SEW-Eurodrive, Trumpf, Pilz, Wittenstein, Sick, SAP, CAS, Seeburger.

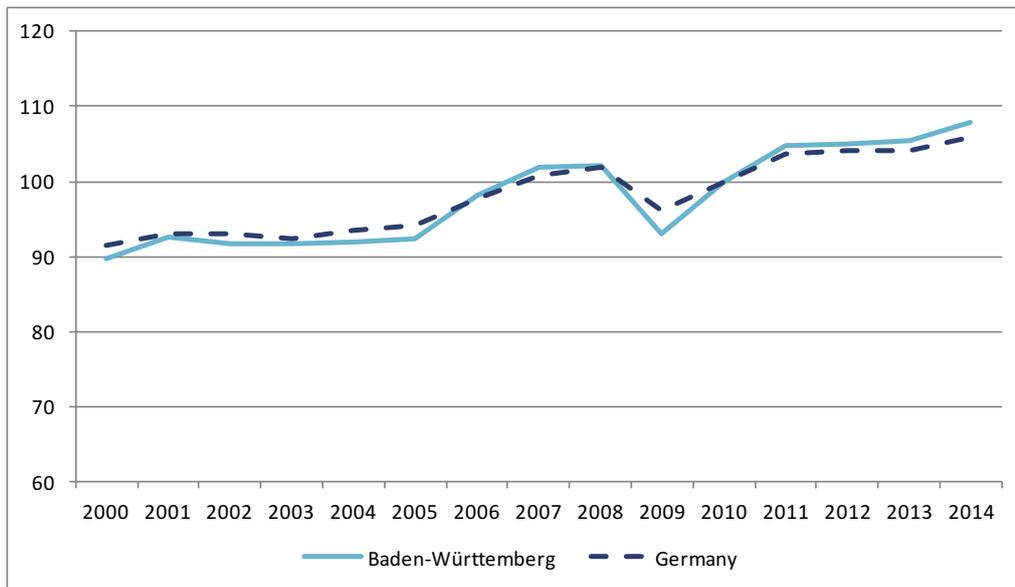
In Baden-Württemberg, there are many firms which are specialized in niche markets and function as global leaders in their particular field. Examples of these are Trumpf in laser technology, Festo in automation technology, Alfred Kärcher in cleaning systems, ebm-papst in ventilation and drive engineering, Karl Storz in endoscopes, Homag in woodworking machinery, Fischerwerke in fixings.⁵

As mentioned above, Baden-Württemberg was hit severely by the economic and financial crises. As figure 2 shows, Baden-Württemberg's GDP dropped heavily, but due to the strengths of its manufacturing sector, the pre-crisis level was quickly regained. Since 2010, Baden-Württemberg performs better than Germany on average.

⁴ https://www.google.com/fusiontables/data?docid=1WxQSgZE_Y3xztse2ODPfOaSm5VYGibYFc_VIzg3r#rows:id=1,

⁵ WirtschaftsWoche 18.11.2013 "Im Südwesten sitzen die Weltmarktführer" <http://www.wiwo.de/unternehmen/industrie/baden-wuerttemberg-im-suedwesten-sitzen-die-weltmarktfuehrer/9079480.html> (27/11/2015)

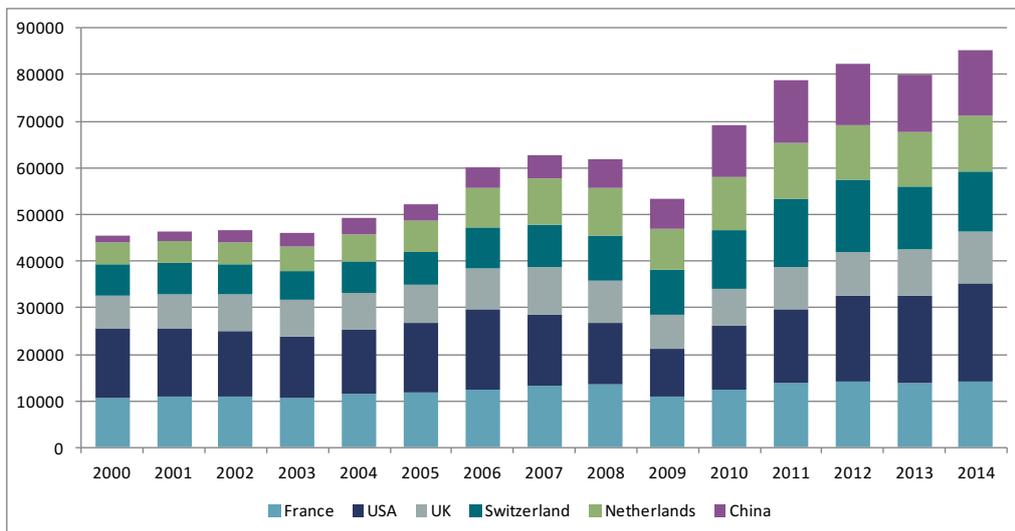
Figure 2 Development of gross domestic product of Germany and Baden-Württemberg in real prices 2000 to 2014 (2010 = 100)



Source: Statistical Office Baden-Württemberg

Baden-Württemberg's manufacturing sector is highly outward-oriented. The export ratio is 54.3% in 2014 (ratio of foreign sales on total sales). This is the highest ratio among the non-city states.⁶ Major export partners are the USA, China, France, and Switzerland. As figure 3 shows, while France has been a main export partner for many years, China became an important export partner only within the last 10 years. The most important export partner is the United States (€21b). Total export volume was €181b in 2014.

Figure 3 Development of exports with the 6 most important export partners 2000 to 2014 (in €m)



Source: Statistical Office Baden-Württemberg

⁶ http://www.statistik.baden-wuerttemberg.de/ProdGew/Indikatoren/VG_XpQuote.asp, 27.11.2015

Besides the positive trends, Baden-Württemberg sees itself in fierce competition in global markets. The leading position that firms gained in many fields needs to be secured. Due to international competition, being innovative is an essential requirement for Baden-Württemberg's firms. For example, the developments around electric vehicles might erode the competitive advantage of Baden-Württemberg's firms which so far focused on combustion-engine-powered vehicles.

Nonetheless, especially the big companies make huge efforts to secure their leading position. To this end, in view of industry 4.0, they establish new partnerships with universities, research institutions and other firms (see below), acquire other companies or found spin-offs. Examples of the latter trends are the Stuttgart based equipment manufacturer Dürr which acquired iTAC Software in December 2015. iTAC which is based in Montabaur is specialized in IT for production technologies. With the acquisition, Dürr aims to increase its competencies in industry 4.0.⁷ The company Trumpf, for example, founded a spin-off company called Axiom in 2015 to develop an operating system pre-loaded with apps for the manufacturing world. While the HQ of Trumpf is located in the vicinity of Stuttgart, the new company was established in Karlsruhe to benefit from the IT-skills, there. However, start-up activities in general and company foundations taking advantage of industry 4.0 opportunities are a rare phenomenon.

1.3 Scientific research potential

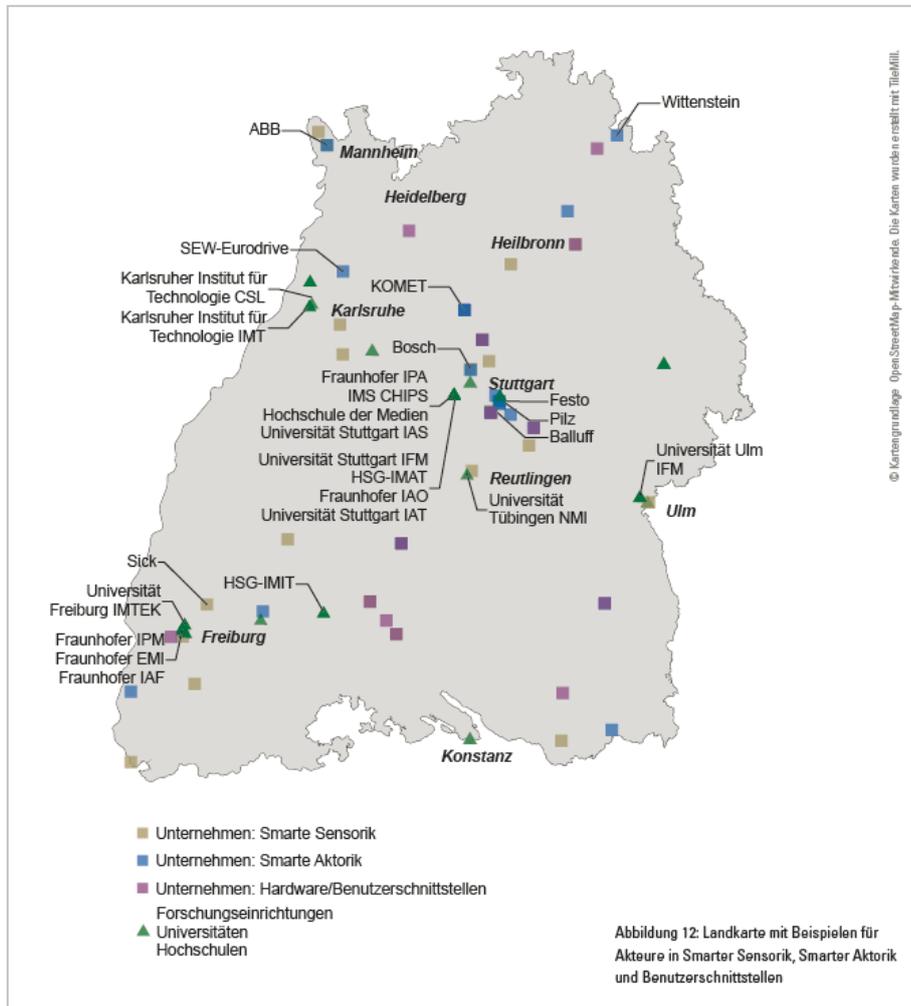
Baden-Württemberg has a rich and differentiated landscape of university and non-university research and education organisations, complemented by a complex system of knowledge and technology transfer institutions. The higher education sector comprises nine universities, 23 universities of applied sciences, six universities of education, eight colleges of arts and music, and the Baden-Württemberg Cooperative State University (DHBW) at nine locations that integrates academic studies with workplace training. Furthermore, Baden-Württemberg hosts 27 non-public universities, and three academies for film, performing arts, as well as popular music and music business. Concerning non-university research, Baden-Württemberg hosts more than 100 research facilities, such as for instance the European Molecular Biology Laboratory (EMBL) or the German Cancer Research Centre DKMZ, as well as 12 facilities of the Max-Planck-Gesellschaft, 14 Fraunhofer institutes, and seven facilities of the Leibniz Association. In addition, the Heidelberg Academy of Sciences and Humanities, two Helmholtz Centres, six institutes of the German Aeronautics and Space Research Centre DLR, 12 institutes of the Baden-Württemberg Innovation Alliance, the Centre for European Economic Research (ZEW), the Max Rubner Institute (Federal Research Institute of Nutrition and Food), and the Federal Waterways Engineering and Research Institute are located in Baden-Württemberg. The research landscape includes further regional institutes such as the German-French Institute in Ludwigsburg or the Max Reger Institute in Karlsruhe, among others.⁸

The competence atlas mentioned above also informs about the research institutions which focus either on smart sensors, smart actuators, user interfaces, software and IT infrastructure, as well as security. The actors were identified via participant lists of publicly funded projects, initiatives and so on (Ministerium für Finanzen und Wirtschaft Baden-Württemberg, Fraunhofer IPA, 2014). The following map provides an overview of the locations of the relevant actors.

⁷ <http://www.durr.com/de/presse/ad-hoc-und-pressemitteilungen-duerr-ag/pressemitteilungen/duerr-uebernimmt-industrie-40-softwarepezialisten-itac/> (16/12/2015)

⁸ Further information: <https://mwk.baden-wuerttemberg.de/de/hochschulen-studium/hochschularten/>, <https://mwk.baden-wuerttemberg.de/de/forschung/forschungslandschaft/ausseruniversitaere-forschung/> (23/11/2015)

Figure 4 Map of research institutes, universities and example companies active in smart sensors, smart actuators and interfaces



Source: Ministerium für Finanzen und Wirtschaft Baden-Württemberg, Fraunhofer IPA 2014: 29

With regard to smart sensors, the following research institutes can be mentioned: several departments of the universities in Stuttgart, Freiburg, Karlsruhe and Ulm. In addition, application-oriented development of microsystems and microelectronics takes place at the Hahn-Schickard-Gesellschaft in Villingen-Schwenningen and Stuttgart, Institut für Mikroelektronik Stuttgart (IMS CHIPS), NMI in Tübingen. With regard to research institutes of Fraunhofer, the following institutes are relevant: IPM, IAF, IPA, IOSB, ICT, EMI. Also the universities of applied sciences in Furtwangen, Esslingen and Aalen can be mentioned.

Research and development for smart actuators takes place at the universities in Freiburg, Stuttgart and Karlsruhe. Other competencies are available at the institutes of the Hahn-Schickard-Gesellschaft in Villingen-Schwenningen und Stuttgart, at the Institut für Mikroelektronik Stuttgart (IMS CHIPS). Also, the Fraunhofer institutes EMI, IAF, IPA, IPM conduct research in this field.

The topic interfaces research and development takes place at the universities of Karlsruhe, Freiburg, Tübingen, Stuttgart, Ulm as well as at the Fraunhofer IAO.

With regard to relevant software, IT infrastructure and IT security the following research institutes can be mentioned: several departments of the universities in Stuttgart and Karlsruhe, the Fraunhofer institutes IPA, IAO and IOSB as well as the FZI in Karlsruhe.

In addition, the universities of applied sciences are also very active in the relevant fields. The Alliance Industry 4.0 which will be introduced in more detail below is aiming at coordinating the various activities.

The innovation network "production work 4.0" (Produktionsarbeit 4.0⁹) is a research project of the Fraunhofer IAO focusing on the implications of industry 4.0 on workspaces. The first phase of the project lasted from October 2013 to March 2015. The second phase started in September 2015 and will last until August 2017. Partners were companies like Kärcher, MTU, SAP or Siemens as well as the trade union IG Metall and the employer organisations Gesamtmetall and Südwestmetall. While the first phase aimed at elaborating a common understanding, the second phase will focus on questions around "smart workplaces" – how will it look like?, which technologies are relevant?, what are the implications for tasks of employees – and "work organisation 4.0" – how will work organisations develop? which applications can support work processes? -. Within the project also training concepts for employees shall be developed.

1.4 Role of intermediary institutions

Several intermediaries aim to promote the development and application of industry 4.0 in Baden-Württemberg. Among these are clusters, associations, chambers of commerce and industry.

With regard to development and production the cluster **microTEC Südwest** focuses on smart production as one of its four fields of application. The HQ of the cluster is in Freiburg. The cluster has more than 360 partners located all over Baden-Württemberg. With regard to industry 4.0, many of its members have their strengths in sensors and cyber-physical systems.

In October 2015, **microTEC Südwest, Virtual Dimension Center (VDC)** in Fellbach and **Baden-Württemberg Connected e.V.** (bwcon) in Stuttgart joined forces to establish the Crosscluster Industrie 4.0. The crosscluster aims to boost interdisciplinary exchange.

Also the leading edge cluster **Software-Cluster** which stretches across the southwest of Germany is active in this field and combines its members in projects like Sinnodium or InDiNet. The joint project Sinnodium – Software Innovations for the Digital Enterprise aims to enable SMEs to provide software components, services and tools for individualised business processes by offering platforms as a permanent infrastructure. InDinet - Innovative services for the Internet of the future aims to support SMEs with regard to the economic and technical challenges that are accompanied by the integration their services within the Internet of Services.

The Karlsruhe based **CyberForum** has a focus on IT. It is a network with various activities also in job placement, qualification and supporting start-up activities. It is actively engaged in shaping policy recommendations with a view to digitalisation. In addition, the CyberForum coordinates the 13 subregional IT networks¹⁰ of the smart businessIT initiative funded by the state. The aim of smart businessIT is to bring together firms, higher education institutions and research institutes to promote business IT solutions in all companies and regions of Baden-Württemberg. The networks aim to link developers and applicants of industry 4.0 solutions. In general, CyberForum aims to raise awareness of the importance of digitalisation for business activities.

Due to its manufacturing strengths, Baden-Württemberg perceives a need to keep up with the current developments and to shape them. As shown above, already many

⁹ <http://www.produktionsarbeit.de/> (10/12/2015)

¹⁰ <http://www.smartbusiness-it.de/partner-und-netzwerke/> (03/02/2016)

firms are engaged in developing and applying industry 4.0 technologies. But, in order to support also SMEs that may not have the resources and capabilities, the Ministry of Finance and Economic Affairs Baden-Württemberg promoted the establishment of the **Allianz Industrie 4.0**.¹¹ In March 2015 the Allianz Industrie 4.0 was started. The aim is to position Baden-Württemberg as a lead provider and lead market for industry 4.0. The Allianz Industrie 4.0 is comprised of almost 60 partners. Among these are the Ministry itself, networks and clusters (like bwcon Baden-Württemberg Connected, CyberForum, Manufacture BW, Leichtbau BW, Photonics BW), research institutes (like the Fraunhofer institutes IAO, IOSB, IPA, ISI, the Hahn-Schickard-Gesellschaft, Steinbeis), industrial associations (e.g. VDI, VDMA, ZVEI), associations of the universities and universities of applied sciences, the chambers of industry and commerce, Baden-Württembergischer Handwerkstag as well as trade unions. This means that firms are represented by industrial associations, clusters, chambers or trade unions. The alliance is coordinated by the VDMA (German Engineering Federation). With respect to aspects like setting standards and norms, the alliance is in exchange with the national Platform Industry 4.0 as these topics cannot be handled at the regional level.

The aim of the alliance is to combine the skills of production technology and information and communications technology to link all the main actors and to accompany manufacturing SMEs by providing innovative transfer offerings towards industry 4.0. It builds upon existing activities of the partners, but explicitly aims to establish cooperation partners that had not been linked in the past. The alliance covers three thematic fields: cyber-physical systems, smart sensors and actuators; IT systems, networking and business models as well as production planning and steering. Each of these topics is covered by working groups focusing on the implications for work and organisation, technology and products, and transfer and application in SMEs. For each of the themes, transfer projects shall be designed.

So far, the alliance provides information on events and runs the online competence atlas which provides information on research institutes and firms. It also hosts the competition "100 places for industry 4.0".¹² The competition aims to shed light on innovation with regard to new products, components or machines, software solutions, production and organisational processes as well as new offerings. The competition is designed as an ongoing process with deadlines for submission of applications every three months. The first group of winners have been awarded in 2015. Among these are manufacturing and IT firms as well as a university of applied sciences and the Fraunhofer IOSB (see 1.9). The first experiences with the competition are very positive, as the participating firms receive a lot of attention and awareness.

1.5 Developing skills for the future

The skill development for industry 4.0 is one area in which Baden-Württemberg's state government is currently actively engaged. In this field, the federal state has a lot of power to shape the developments as education is one field of policy-making for which the federal states are responsible.

Due to the fact that industry 4.0 will imply important changes for employees at the shop floor, vocational education and training is one of the areas in which the government is active. In July 2015, the town and district councils, which run schools in Baden-Württemberg, were asked to participate in a competition to establish "learning

¹¹ [http://www.i40-bw.de/\(03/02/2016\)](http://www.i40-bw.de/(03/02/2016))

¹² http://www.i40-bw.de/100_places/awards/_Auszeichnungen.html?language=de (1/12/2015)

factories 4.0" (Lernfabrik 4.0).¹³ A learning factory 4.0 is understood as a laboratory, which is similar in construction and equipment to industrial automation solutions so that the basics of application-oriented processes can be learned. Mechanical and electrical engineering are thereby linked through professional production control systems. Target groups of learning factories 4.0 are apprentices in dual system of vocational education and training of metal and electrical engineering, as well as participants at technical schools or training courses of medium-sized enterprises in the context of offers of support associations of vocational schools and from collaborations with business organizations, universities of applied sciences and the Alliance Industry 4.0 Baden-Württemberg.

The applications should be developed together with the local economy. In December 2015, the government awarded 15 proposals and offered to provide funding of €6.5m.¹⁴ Originally, the plan was only to fund eight projects with €4.5m, but as 28 proposals were submitted, the federal state increased the volume of funding. The learning factories shall also provide regional small and medium enterprises with suggestions for implementation of typical processes of industry 4.0. They should also increase the knowledge on the topic and make its importance as well as opportunities better known among SMEs. The 15 vocational schools are located all over Baden-Württemberg. They receive between €271k and €500k from the federal state which must be complemented by local sources from the town and district councils as well as from the local economy.

With regard to higher education, the implications of industry 4.0 are also relevant. In March 2013, the Minister for Research, Theresia Bauer, established an expert commission "Engineering Science @ BW 2025" (Ingenieurwissenschaften@BW 2025; see also below). The expert commission shall give advice with regard to the future orientation of engineering sciences with a view to the economic and technical changes.¹⁵

In addition, firms may apply for a soft loan to financing further education of their employees. The programme Further Education Financing 4.0 (Weiterbildungsfinanzierung 4.0) starts in April 2016 as an offer of the L-Bank in cooperation with the European Investment Bank (EIB).¹⁶ Medium-sized companies with up to 500 employees in Baden-Württemberg can thus finance expenses for training, testing, travel expenses and wage continuation.

1.6 Major investment projects

As will be described in more detail below, industry 4.0 is a highly relevant topic for Baden-Württemberg's state government. Due to this fact, several public as well as public-private funded investments have been made. In addition, also the major companies invest heavily to keep up with current technological developments:

- Research Factory Campus East (Forschungsfabrik Campus Ost): The Research Factory Campus East is a joint initiative of the Karlsruhe Institute for Technology (KIT) and the Fraunhofer IOSB and will be established on the premises of the

¹³ <http://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/ministerium-fuer-finanzen-und-wirtschaft-startet-foerderaufruf-zu-lernfabriken-40-an-beruflichen-sc/> (1/12/2015)

¹⁴ <https://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/ministerium-fuer-finanzen-und-wirtschaft-foerdert-ingesamt-15-lernfabriken-40-an-beruflichen-schul/> (9/12/2015)

¹⁵ <https://mwk.baden-wuerttemberg.de/de/service/presse/pressemitteilung/pid/expertenkommission-ingenieurwissenschaftenbw-2025-berufen-1/> (12/12/2015)

¹⁶ <https://www.l-bank.de/lbank/inhalt/nav/foerderungen-und-finanzierungen/alle-foerderangebote/wf-wirtschaftsfoerderung/weiterbildungsfinanzierung-40.xml?ceid=126966> (05/02/2016)

KIT¹⁷. The aim is to develop methodologies which enable developing and expanding advances in new and challenging production processes. At a time when the need for an innovative product manufacturing processes are not yet fully understood and mastered, the research factory will allow developing a methodology for a mature and profitable production-process. The investment volume is €7m, half of it stemming from ERDF-funding.

- Application Centre Industry 4.0 (Applikationszentrum Industrie 4.0) at Fraunhofer IPA: The centre and the manufacturing environment allow industrial research and joint developments on cyber-physical systems. The aims are:¹⁸
 - Supporting manufacture of personalized products for industrial purposes;
 - Flexible and situation-oriented development of on-demand production scenarios for realtime manufacturing control;
 - Development and testing of innovative solutions for cyber-physical production systems; and
 - Demonstration of available solutions from research and industry.

In addition, seminars and training courses shall spread knowledge and experience with regard to industry 4.0. So far, the Application Center Industry 4.0 has a number of informative demonstrators, such as a flexible machine-cloud connection. The Land provides €3.5m of funding for the Application Center Industry 4.0.¹⁹ In addition, the business sector shall co-invest an equivalent amount of funding.

- Smart Data Innovation Lab (SDIL) at KIT: The Smart Data Innovation was established in 2014 at the Karlsruhe Institute of Technology. It is an exchange and operation platform to boost the cooperation between companies, research institutes and public authorities in the realm of big data and smart data technologies. The Smart Data Innovation Lab focuses on four topics: industry 4.0, energy, smart cities and personalized medicine.

Apart from KIT, founding partners of SDIL are Bayer, Robert Bosch, Microsoft Germany, SAP, Siemens, Software AG, the German Research Center for Artificial Intelligence (DFKI), Fraunhofer and Research Centre Jülich (Forschungszentrum Jülich). Moreover, already more than 20 other companies and institutions support the SDIL. These include companies such as Infineon, Trumpf and Volkswagen as well as the industry association Bitkom and the German Society for Computer Science (GI).²⁰ Especially SMEs shall profit from SDIL by getting access to infrastructure and know-how. The concept for the Smart Data Innovation Lab was developed by the working group "Education and Research for the digital future" of the national IT-Summit of the federal government.²¹ The Federal Ministry of Education and Research provides funding for the joint project "SDI-X: Smart Data Innovation-Processes, tools and operational concepts" of €1.75m.

- Centre for applied Research MikroSens (ZAFH, Zentrums für angewandte Forschung MikroSens) at the university of applied sciences Ulm: The

¹⁷ <http://www.future-security2015.de/servlet/is/100737/> (9/12/2015)

¹⁸ http://www.ipa.fraunhofer.de/en/industrie-40_applicationcenter.html (1/12/2015)

¹⁹ <https://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/ministerium-fuer-finanzen-und-wirtschaft-foerdert-den-aufbau-des-applikationszentrums-industrie-40/> (4/12/2015)

²⁰ http://www.dfki.de/web/presse/pressemitteilungen_intern/2014/wissensquelle-big-data-nutzen-wettbewerbsvorteile-realisieren-smart-data-innovation-lab (14/12/2015)

²¹ <https://www.kit.edu/kit/15827.php> (14/12/2015)

establishment of the centre in the realm of millimetre wave technology was announced in September 2015. The *Land* provides funding of €1.4m over a period of three years. The focus is on applications in environmental technologies, sustainable mobility and automatisisation technologies.²²

- ARENA2036 – "Active Research Environment for the Next Generation of Automobiles": ARENA2036 is a research campus (Forschungscampus²³) which was started in 2013 and is (currently) based on the strategic cooperation of Daimler, Robert Bosch, Pitz, Festo, Kuka, Bär, Faro, BASF, Siemens, DIFT, Dyna More, FKFS, the University of Stuttgart, DLR and Fraunhofer. Research and development takes place in the fields of light weight and innovative production technologies.²⁴ In 2036, the construction works for the research factory started. It will have 5,000m² of working space.²⁵ While the establishment of the strategic cooperation has been supported by the Federal Ministry of Education and Research, the construction of the research factory is also co-funded by ERFD funding.
- TRUMPF Lab: In July 2015, the machine producer Trumpf and the Fraunhofer IPA announced the establishment of a factory of the future. The strategic cooperation shall last five years. The aim is to develop production technologies of the future. TRUMPF Lab is part of the technology and innovation campus in Stuttgart (S-TEC). There, employees of Trumpf and the Fraunhofer IPA will conduct basic research together.²⁶

1.7 International cooperation

As the export data showed, Baden-Württemberg is highly outward oriented. Many firms have branch plants all over the world. What is more, it is also important to note that leading companies of Baden-Württemberg like SAP and Daimler not only produce, they also conduct research and development abroad.

To support these activities Baden-Württemberg's firms are active in European networks like EFFRA (European Factories of the Future Research Association) or euRobotics. Among the members of EFFRA are companies like Daimler, Festo, Robert Bosch or SAP. Among the members of euRobotics are Fraunhofer IPA, Fraunhofer IOSB, Karlsruhe Institute of Technology, Schunk, Pitz.

Also the government of Baden-Württemberg promotes international cooperation in certain ways. In May 2015, the Prime Minister Winfried Kretschmann lead a delegation visit to Silicon Valley. The focus of the journey was on the topics digitalisation, industry 4.0 and sustainable mobility. Apart from several government members, also 44 representatives from the private sector, higher education and research institutes were part of the delegation.²⁷

²² <https://mwk.baden-wuerttemberg.de/de/service/presse/pressemitteilung/pid/14-millionen-euro-fuer-die-hochschule-ulm/> (9/12/2015)

²³ For further information see <https://www.bmbf.de/de/forschungscampus-oeffentlich-private-partnerschaft-fuer-innovationen-562.html> (14/12/2015)

²⁴ <http://www.arena2036.de/de/> (14/12/2015)

²⁵ <http://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/neue-forschungsfabrik-der-universitaet-stuttgart-zum-automobil-der-zukunft-am-start/> (3/12/2015)

²⁶ http://www.ipa.fraunhofer.de/kooperation_trumpf.html(1/12/2015)

²⁷ <http://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/ministerpraesident-kretschmann-besucht-kalifornien-1/> (4/12/2015)

Several of the mentioned firms, higher education and research institutions are heavily engaged in research projects funded by EU. Examples of these are:

- "HORSE - Smart integrated Robotics system for SMEs controlled by Internet of Things based on dynamic manufacturing processes", from 2015 to 2020, total cost: €8.9m. The project is coordinated by European Dynamics Advanced Systems Of Telecommunications Informatics And Telematics SA (Greece). Among the 14 partners is FZI from Baden-Württemberg.²⁸
- "ReCaM - Rapid Reconfiguration of Flexible Production Systems through Capability-based Adaptation, Auto-configuration and Integrated tools for Production Planning", from 2015 to 2018, total cost €6.8m. The project is coordinated by Robert Bosch. The partners are firms from Spain Italy, Finland, Austria and Spain.²⁹
- "MANTIS - Cyber Physical System based Proactive Collaborative Maintenance", from 2015 to 2018, total cost €29.9m, The project is coordinated by Mondragon Goi Eskola Politeknikoa J.M.A. S.Coop (Spain). There are 46 partners from Spain, Finland, Denmark, Belgium, the Netherlands, Portugal, Ital, Austria, UK, Hungary, Slovenia and Germany. From Baden-Württemberg, Robert Bosch, Liebherr-Hydraulikbagger and Still.
- "Co-FACTOR - Cooperate, Communicate and Connect to boost smart Components for tomorrows Industry", from 2015 to 2017, total cost €320,000. The project is coordinated by Steinbeis Innovation (located in Baden-Württemberg). The five partners come form Germany, UK, Spain and Portugal, with Fraunhofer IPA from Baden-Württemberg.³⁰

1.8 Policy support and delivery mechanisms

Baden-Württemberg sees industry 4.0 in the wider context of digitalisation. Digitalisation in general is regarded as an important topic which offers many opportunities for the *Land*. These refer to its economy but also with regard health and society in general.

In 2013, the Ministry of Finance and Economic Affairs Baden-Württemberg and the Ministry for Science, Research and Arts Baden-Württemberg initiated a process to develop expert-based recommendations for the "Digital Agenda 2020+ BW". With the agenda Baden-Württemberg's state government wants to consistently use the possibilities of technical and organizational networking by means of ICT in order to strengthen the competitiveness of Baden-Württemberg's companies and to provide a sustainable and liveable environment for its citizens (BW Connected, CyberForum 2013 Digitale Agenda 2020+ BW). The so-called ICT-alliance (IKT Allianz) was comprised of representatives from IT clusters and networks, IT firms, research institutes, but also manufacturing firms, other clusters and networks. Together, they developed a set of recommendations. Some of these have already been implemented. In order to be able to use the changes of digitalisation, the government established the office for digitalisation within the state ministry.³¹ With regard to production, the alliance mentions that joint research projects are needed to stimulate innovations. In particular, cooperative research centres of universities, research institutes and firms like ARENA 2036 are seen as good way to boost innovation and the transfer of technology and knowledge. In addition, LivingLabs in the realm of automation should

²⁸ http://cordis.europa.eu/project/rcn/198773_en.html (22/01/2016)

²⁹ http://cordis.europa.eu/project/rcn/198385_en.html (22/01/2016)

³⁰ http://cordis.europa.eu/project/rcn/193470_en.html (22/01/2016)

³¹ <https://stm.baden-wuerttemberg.de/de/themen/digitalisierung/> (9/12/2015)

be expanded. Further more, the alliance suggests the establishment of a competence centre for "cyber-physical systems and internet services" which should function as a contact point for SMEs to develop applicable solutions.

The relevance of digitalisation for Baden-Württemberg becomes obvious when looking at the government declaration "Home, Hightech, Highspeed" (Heimat, Hightech, Highspeed) from 15.10.2014.³² According to the state's prime minister, Baden-Württemberg has excellent starting conditions to seize the opportunities of the digital revolution. Companies in Baden-Württemberg are not only part of these changes; they also drive and shape the developments on international scale. But he also mentions the fact that new business models are needed that e.g. combine products and Internet based services as a challenge. While the bigger companies are seen as being able to cope with these challenges, it is regarded as important that also SMEs also are capable to adapt to the current changes: "To support small and medium-sized companies on their way towards industry 4.0 best possible, that is our goal." To this end, the government has been establishing several projects. Examples of these mentioned in the declaration are:

- Lighthouse project "cloud computing", offering companies free access to an integrated portfolio of infrastructure services, platform services and advanced software applications.
- Research factory "campus east" (Forschungsfabrik Campus Ost) (see above)
- Smart Data Innovation Lab at the Karlsruhe Institute for Technology (see above)
- Digital Innovation Centre (DIZ, Digitales Innovationszentrum)³³ funded by the Ministry of Finance and Economic Affairs functioning as an IT-focused innovation centre for providing information and promoting knowledge transfer in particular for SMEs. The centre is run by CyberForum and FZI

While the mentioned projects focus not solely focus on industry 4.0, due to the high importance of engineering in Baden-Württemberg this topic is highly relevant in all these projects.

More specifically with regard to industry 4.0 Baden-Württemberg's Minister for Finance and Economics expresses the aim that the *Land* becomes **lead market and lead producer for industry 4.0**³⁴. In February 2015, the steering committee industry 4.0 (Lenkungskreis der Allianz Industrie 4.0) was established.³⁵ It is comprised of 20 representatives from ministries, associations, companies, science and trade unions. It functions as central steering body for the Allianz Industry 4.0 and shall also draw up further projects.

The following list provides an overview of various activities supported by the government to promote industry 4.0:³⁶

³² Government declaration: <https://stm.baden-wuerttemberg.de/de/service/presse/pressemitteilung/pid/heimat-hightech-highspeed-1/> (4/12/2105)

³³ <http://digitalisierungszentrum.com/> (03/02/2016)

³⁴ Ministry of Finance and Economics: <http://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/finanz-und-wirtschaftsminister-nils-schmid-besucht-bei-industrie-40-reise-firmen-und-forschungsins/> (9/12/2015)

³⁵ http://www.schwarzwald-baar-heuberg.ihk.de/fileadmin/IHK_root/Innovation_Umwelt/2009/Formulare/Innovation/Innovationsnachrichten/Innovationsnachrichten_10_14_final.pdf (14/12/2015)

³⁶ Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/6087, https://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/6000/15_6087_D.pdf (5/11/2015)

- Establishing the **Allianz Industrie 4.0 Baden-Württemberg** (see above). The government supports establishing the coordination centre for the alliance with €5m.
- Research Projects "Ressource Efficiency by an Advanced Engineering Platform (virtual Fort Knox)" (Ressourceneffiziente Produktionsplanung mittels einer Advanced Engineering Plattform (Virtuelles Fort Knox) at Fraunhofer IPA: Both projects focus on the development of energy and resource efficient product planning in an open and secure IT platform which can be used by SMEs
- Joint research project "SimVar" and "WiES-Pro" with collaboration of SMEs focusing on production planning over live the cycles of products
- Study on the prevalence of Industry 4.0 competencies in Baden-Württemberg (see Ministerium für Finanzen und Wirtschaft Baden-Württemberg, Fraunhofer IPA, 2014; the results with regard to science are presented in chapter 1.3)
- Project "Readiness I4.0": The project develops an online benchmarking instrument for self-assessment of "Industrie 4.0 Readiness" for companies of the manufacturing industry in Baden-Württemberg on the basis of representative operating data for the use of digital technologies in production. The project is conducted by Fraunhofer ISI.³⁷
- Web-based competence atlas (see above)
- Application Center at the Fraunhofer IPA (see above)
- Research infrastructure at the Hahn-Schickard-Institute für Mikroaufbautechnik HSG-IMAT
- Research project Point4Micro at the Hahn-Schickard-Institute für Mikroaufbautechnik HSG-IMAT
- Joint research project LEMIAN coordinated at the Hahn-Schickard-Institut für Mikro- und Informationstechnik HSG-IMIT
- Study "Kompetenzen der Zukunft in der Industrie 4.0" des Instituts für Arbeitswissenschaft und Technologiemanagement IAT der Universität Stuttgart

As mentioned above, in Germany, the federal states are responsible for education. Due to this fact, the states can play an active role in skill development. As mentioned above, Baden-Württemberg promotes the establishment of 15 learning factories 4.0 (Lernfabrik 4.0) at vocational schools where vocational apprentices are educated and trained for the demands of industry 4.0.³⁸

In the regional innovation strategy (Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013),³⁹ industry 4.0 is not mentioned specifically. However, a connection can be established. As the innovation strategy was established in 2013, industry 4.0 was not yet targeted specifically by the state's government. But, the aspects ICT, intelligent products, the application of key enabling technologies across sectors are already mentioned in the document.

In sum, Baden-Württemberg seems to establish a comprehensive set of measures to boost digitalisation and industry 4.0 comprising education and teaching, research and knowledge and technology transfer as well as promoting the exchange among all

³⁷ http://www.isi.fraunhofer.de/isi-en/p/projekte/readiness-I4.0_so.php (22/01/2016)

³⁸ <https://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/ministerium-fuer-finanzen-und-wirtschaft-foerdert-insgesamt-15-lernfabriken-4-0-an-beruflichen-schul/> (2/12/2015)

³⁹ This document corresponds to the regional Research and Innovation Strategy for Smart Specialisation (RIS3 strategy)

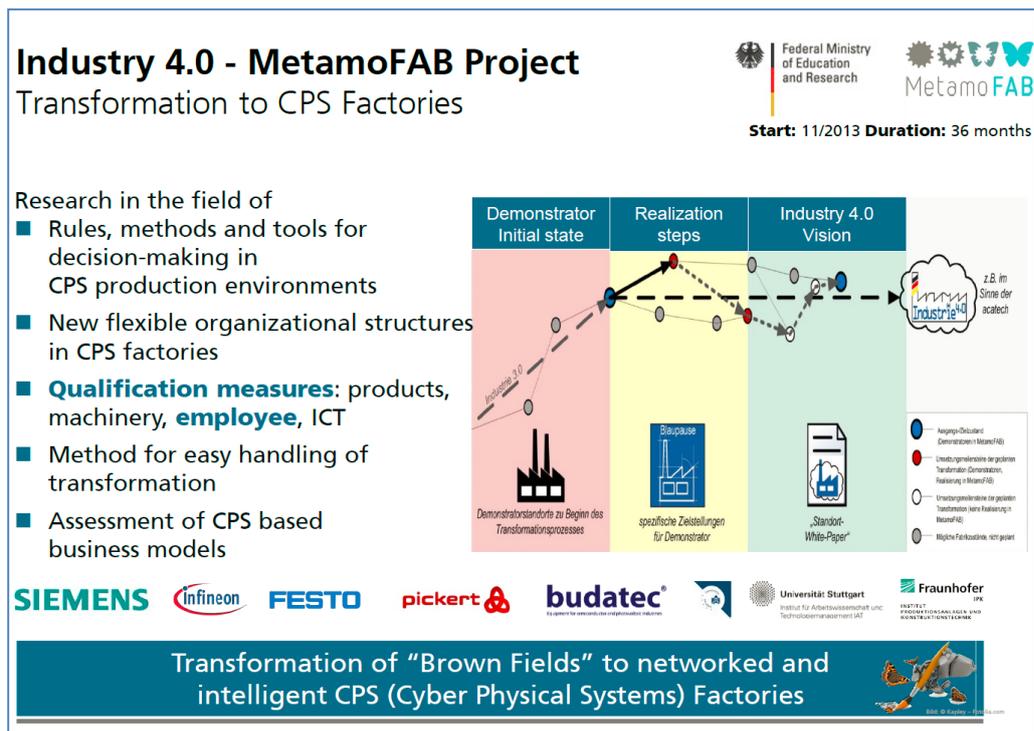
relevant stakeholders. Nonetheless, as many of the mentioned projects and initiatives only started in 2015 like the Allianz Industrie 4.0 it is yet too early for an assessment.

1.9 Good practice cases

Industry 4.0 calls for an interdisciplinary collaboration of various disciplines when establish cyber-physical systems shall be established. In this regard, although in many cases it might be too early to call them "good practice" as the sustainability needs to be demonstrated in the long run, here, examples of good practice refer to projects in which partners cooperate along the value chain. In this respect, several of the mentioned projects and initiatives mentioned above could also be mentioned here like ARENA 2036.

One further example is the MetamoFAB Project which is funded by the Federal Ministry for Education and Research by €2.45m.⁴⁰ Figure 5 shows an overview of the project. It was started in November 2013 with duration of 36 months. The aim of the project is to describe steps and find ways to integrate successively cyber-physical systems into existing modernisation and development projects and to allow businesses to develop into an intelligent and networked factory. Partners in the project are the University of Stuttgart, University of Potsdam, Fraunhofer IPK, Festo, Siemens, Pickert, and Infineon. Thus, the consortium not only includes partners from Baden-Württemberg.

Figure 5 Description of the project MetamoFAB



Source: Mehmet Kürümlüoğlu

Among others, one of the partners based in Baden-Württemberg is Festo. Festo produces pneumatic and electrical components and systems for automation. Within the project MetamoFAB, Festo focuses in particular on the efficient use of energy resources and the interface between man and machine in the context of change for the industry 4.0 (figure 6).

⁴⁰ Förderkatalog <http://foerderportal.bund.de/foekat/jsp/StartAction.do?actionMode=list> (10/12/2015)

Figure 6 Overview of Festo's engagement in the MetamoFAB Project

Industry 4.0 - MetamoFAB Project

Festo – Demonstrator Technology factory Scharnhausen



Objectives:

- Presentation of a **networked overall system** based on sensors, distributed network and decentralized control
- Design of **staff, organization and competence development** closely connected **with technology development**

Challenges:

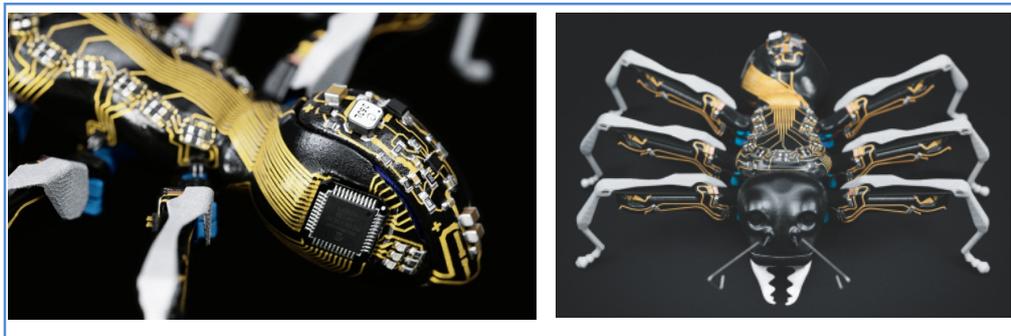
- **Consumption** measurements, continuous condition monitoring and superior control possibilities of machines
- Visualization of decentralized energy control console
- Continuous improvement process for the resource energy




Source: Mehmet Kürümlüoğlu INDUSTRY 4.0 IN THE REGION OF STUTTGART

Festo approaches industry 4.0 in various ways. One other example is the project BionicANTs.⁴¹ The aim is the fabrication of artificial ants, which are able to communicate among each other and solve problems together (figure 7). With regard to industry 4.0 this is highly relevant since "the artificial ants thus demonstrate how autonomous individual components can solve a complex task together working as an overall networked system⁴²".

Figure 7 BionicANTs – artificial ants as an example for learning from nature how to solve tasks together by autonomous individual components



Source: Festo

The example of Festo shows that there are many firms in Baden-Württemberg approaching the topic industry 4.0 in quite innovative ways. As mentioned above, the Allianz Industry 4.0 aims to shed light on these examples with the competition "100

⁴¹ <https://www.festo.com/group/en/cms/11582.htm> (10/12/2015)

⁴² <https://www.festo.com/group/en/cms/10157.htm> (10/1/2015)

places for industry 4.0" (see 1.4). By the end of 2015, 13 contest entries have been awarded.⁴³ The following examples illustrate the contest entries:

- Würth presented an intelligent container iBin: Würth is not only producer of parts, it also offers services for procurement, scanner-based storage systems and automated electronic ordering systems or just-in-time supply using Kanban container systems. The delivery to customers is made directly to the production line into production. For further digitalisation, Würth implemented sensor technology into the iBin. The implemented cameras are able to monitor the amount of screws, nuts or other parts in the bin. Thus, it is possible to further automate procurement.
- Kärcher was awarded for the project Floor Care Future (Floor Care Zukunft). The project is about installing a new assembly line that allows a very flexible production. At the beginning of the production process, a QR-code is created containing all relevant information for the production process. In addition, a RFID-Chip is implemented at the workpiece carrier containing details on the specific customer order. The data is read at each workstation. Subsequently, detailed installation instructions appear on the screen of the workstation. At the end of the assembly line, a fully functional floor cleaner is mounted and tested, while a scan of the QR code is recorded as ready in the system. Thus, it is possible to produce lot size one which was not possible before under economical considerations.

⁴³ http://www.i40-bw.de/100_places/_100-Orte.html (14/12/2015)

1.10 Leveraging the existing potential

Although the expression industry 4.0 only recently entered the discussions, the underlying activities, processes and solutions are not entirely new in Baden-Württemberg. However, they gained new impetus over the last two years. As the descriptions above showed, many of Baden-Württemberg's firms, research institutes and higher education institutions are very active in developing and using industry 4.0 solutions. In addition, they are supported by the state's government and various intermediaries like clusters and networks. However, Baden-Württemberg sees itself in fierce competition with players from the USA, China and other regions. In particular, new technologies developed there have the potential to threaten Baden-Württemberg's competitiveness. Thus, due to its manufacturing strengths it must be regarded as critical for Baden-Württemberg to keep up with technological developments around production processes. While many steps have been taken, several challenges remain:

- **Challenge 1: Sustaining Baden-Württemberg's competitiveness in view of the challenges of digitalisation and industry 4.0**

As the examples above showed, there are many companies in Baden-Württemberg, which are quite active as producers and/or users of digital solutions for/in their production processes. Looking however at the characteristics of these companies it becomes obvious that these are large companies. With a view to SMEs, however, it must be stated that their readiness level is on average low. In many cases, firms are confused about the relevance of industry 4.0 for their daily business. A nationwide survey revealed that only 18% of companies have heard about industry 4.0 at all. Especially small firms have no knowledge about industry 4.0. Among firms with 5 to 19 employees only 14% have an understanding of industry 4.0 while it is 50% among the firms with more than 500 employees. In this size group, 23% have industry 4.0 projects or are planning initiatives. There is also a big difference according to industry affiliation. About half of the firms in the industries IT, electric and machine engineering have some knowledge regards industry 4.0. In contrast to that are the retail and logistics industries (ZEW, 2015). Thus, it can be concluded that the topic is not yet prevalent among SMEs. One reason could be that there is also a certain level of insecurity perceivable among SMEs with regard to the implications of digitalisation for their activities. So far, SMEs only rarely make use of software solutions beyond ERP systems.

Manufacturing SMEs in Baden-Württemberg are often well integrated in value chains. They are highly specialised in their particular niche. However, while this is currently a strength, in the future this could increase the vulnerability if the firms are locked-in in their traditional paths. If only those companies will be competitive in the future that are able to offer advanced services and/or whose products can be integrated into value chains that are based on industry 4.0 applications, the transfer of knowledge and technology with regard to industry 4.0 and beyond can be regarded as important for sustaining Baden-Württemberg's competitiveness.

Knowledge about industry 4.0 is not only necessary at the level of the firms' management, it is also important that employees have skills that are relevant in the future. A study by the Institute for Employment Research (Institut für Arbeitsmarkt- und Berufsforschung IAB, 2015) shows that 15% of employees in Germany might be at risk as more than 70% of their duties could be replaced by computers. The results also show that industry 4.0 will speed up the structural change towards more jobs in the service sector.

- **Challenge 2: Facilitating industry 4.0 in all parts of Baden-Württemberg**

As the chapter 1.6 shows, almost all major investments are either invested in Karlsruhe when the focus is on software and IT or in Stuttgart when the focus is on production processes. On the one hand, it is of course sensible to establish research facilities close to renowned research institutes and universities in order to create critical masses. On the other hand, it is important that some expertise is available in

all parts of Baden-Württemberg. The establishment of the learning factories at 15 vocational schools is a sensible step in this respect.

What is more, industry 4.0 necessitates access to broadband Internet. In Baden-Württemberg, innovative and highly competitive firms are not only located in the city regions. There are also more rural areas in which highly innovative manufacturing firms are located like the Bodensee area. Table 2 shows the coverage of broadband technologies in Baden-Württemberg in urban, rural and intermediary areas. As becomes clear, rural areas, on average, fall behind the urban areas with regard to high-speed Internet connections.

Table 2 Broadband coverage in Baden-Württemberg

	≥ 1 Mbit/s	≥ 2 Mbit/s	≥ 6 Mbit/s	≥16 Mbit/s	≥ 30 Mbit/s	≥ 50 Mbit/s
Urban	100.0	99.7	97.3	90.2	86.4	82.0
Intermediary	99.2	98.0	91.0	74.2	65.6	58.9
Rural	96.1	93.8	80.9	54.1	41.0	31.1

Source: TÜV Rheinland (2104: 10)

In the face of these differences, the Ministry for Rural Areas and Consumer Protection Baden-Württemberg (Ministerium für Ländlichen Raum und Verbraucherschutz Baden-Württemberg) promotes the expansion of broadband connections.⁴⁴

- **Challenge 3: Developing business models based on industry 4.0**

So far, in Germany, industry 4.0 is mainly seen as way to further optimise production processes. It is about the substitution of traditional production processes by cyber-physical-systems to increase productivity and efficiency. But, industry 4.0 also facilitates opportunities for new business models.

Meanwhile, it can be assumed that a certain production volume is needed so that introducing industry 4.0 solutions make sense under economic considerations. In many cases, SMEs might fall below this level of production volume which is, of course, very specific for every firm and activity. But, in essence, for SMEs industry 4.0 might be relevant only for parts of their activities. On the other hand, in order to be compatible with their clients, it might be highly relevant for SMEs to introduce some industry 4.0 solutions. In addition, industry 4.0 will offer opportunities for new business models. At the same time, there will be business models which will not be viable in the future anymore. In essence, considering the implications of industry 4.0 for their business and taking strategic decisions will be decisive for the competitiveness of firms that are integrated in manufacturing value chains – even if they are handicraft businesses.

- **Inform about IT in general and industry 4.0 in particular**

As mentioned above, in particular among SMEs, the knowledge about industry 4.0 is very low. However, it is not only this particular field where a knowledge gap can be discovered. Also with regard to IT in general a better understanding is necessary. In particular, security aspects are often neglected. Overall, a high level of insecurity with regard to IT and digitalisation can be perceived among SMEs.

There is a lot of information available. Ministries at federal and state level provide information. Associations, chambers of commerce, clusters and networks target the topics. For example, a recent study by the Federal Ministry for Economic Affairs and Energy informs about the potentials of applying industry 4.0 solutions in medium

⁴⁴ <https://mlr.baden-wuerttemberg.de/de/unsere-themen/laendlicher-raum/breitbandausbau/> (16/12/2015)

sized enterprises (Bundesministerium für Wirtschaft und Energie, 2015). The long version has 400 pages. While it is certainly good to provide information in this way, the question is how many SMEs will spend the time for reading hundreds of pages. In this regard, easy access points or guides who inform SMEs with a view to the particular needs of the firms could be an offering contributing to close the knowledge gap. The Alliance Industry 4.0 together with the transfer partners microTEC Südwest and bwcon provide comprehensive support services for SMEs. They aim to analysing the specific needs of industry 4.0 in everyday business and to support the implement of innovation projects with their partners. This offering can be regarded as a sensible first step.

- **Provide access for SMEs to shared facilities**

As described above, Baden-Württemberg supported the establishment of the application centre at Fraunhofer IPA and installation of learning factories at 15 vocational schools. These activities can be regarded as fruitful to boost the knowledge on industry 4.0 in the *Land*. While the implementation is still at the beginning, it will be important to monitor, whether and in which way these facilities are used by SMEs.

- **Establish cooperation projects along the value chain**

The projects and activities of the different stakeholders presented above showed some examples of cooperation projects along the value chain. These can be regarded as a good way to promote industry 4.0 also in SMEs. OEMs could provide an impulse for the introduction of industry 4.0 applications within their suppliers. However, not only projects with partners in Baden-Württemberg or Germany should be considered, also projects with partners in the regions of France, Switzerland or Austria which are close to Baden-Württemberg could be beneficial. Together, the firms could establish themselves as providers of system solutions.

2. Regional Innovation Performance Trends, Governance and Instruments

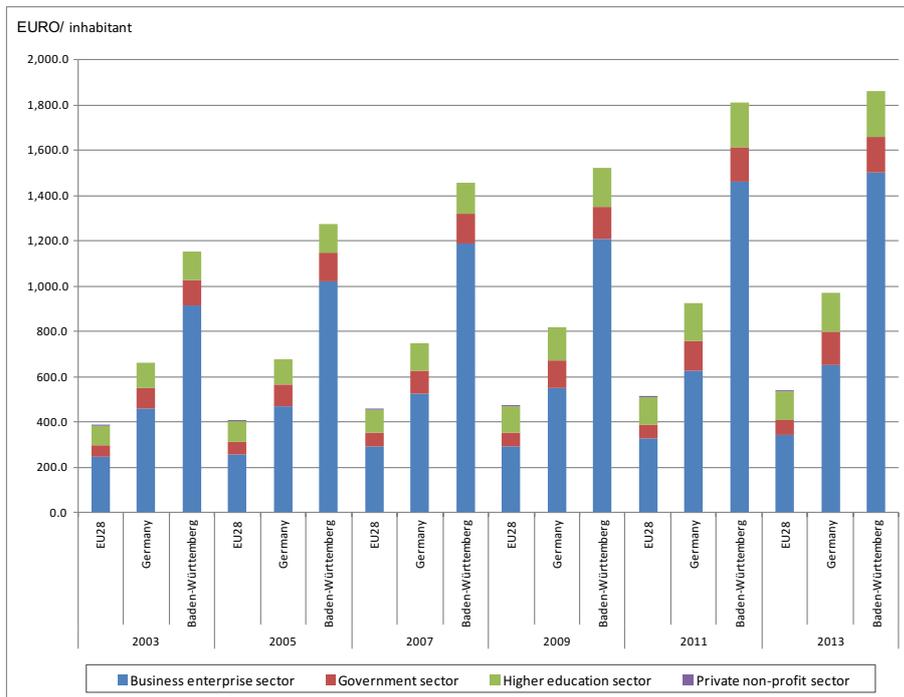
2.1 Recent trends in innovation performance and identified challenges

The intramural expenditures for research and development in Baden-Württemberg amounted to a total of €20.2b in 2013, compared to €12.3b in 2003. With 4.80% of the regional GDP in 2013, the regional figures by far outreach the national (2.83%) and EU-28 (2.03%) figures. The highest share of R&D expenditures is spent by the business sector: 80.59% or 3.87% of the regional GDP in 2013. Further 8.66% of the total R&D expenditures are originating from the government sector and 10.75% from the higher education sector. The German national equivalents are 67.18% from the business, 14.88% from the government and 17.94% from the higher education sectors (EU-28: 63.51% from the business, 12.22% from the government, 23.45% from the higher education, and 0.81% from the private non profit sectors). These figures document the high importance of Baden-Württemberg's regional economy for research, development and innovation. Figure 8 shows the development of R&D expenditures in the different sectors of activities since the beginning of the 2000s in a comparative perspective. The following main aspects become apparent:

Although total R&D expenditures – measured in terms of € per inhabitant – increase in all three territorial units, Baden-Württemberg is at the top of the considered aggregates: compared to 2003, total regional R&D expenditures (€/inhab.) enhanced increased by 61.4%, compared to 47.1% on the national and 40.9% at the European level. Not surprisingly, on the level of sectors of performance, the regional business sector shows the highest increase of its intramural R&D expenditures of 64.1% between 2003 and 2013 (compared to 41.7% on the national and 40.8% on the European scale). Baden-Württemberg also ranks on first position with respect to its increase in R&D expenditures of the higher education sector (60.1%, compared to 56.4% for Germany and 46.4% for the EU-28), while the increase of government expenditures is highest for Germany (63.4% compared to 41.2% in Baden-Württemberg and 31.3% across the EU-28). However, absolute figures (€/inhabitant) are highest in Baden-Württemberg in all sectors of performance.⁴⁵

⁴⁵ Data source: Eurostat

Figure 8 Development of intramural R&D expenditures in Baden-Württemberg, Germany and the EU-28 (2003-2013; €/inhabitant)



Data source: Eurostat

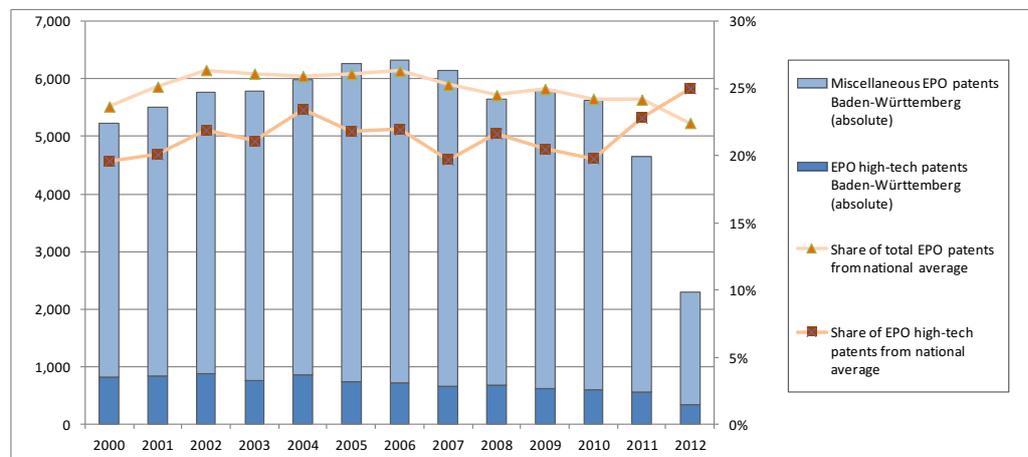
Within Baden-Württemberg, both in 2003 and 2013 the NUTS2 region Stuttgart accounts for the highest figures in private and total R&D expenditures per inhabitant, while the NUTS2 region Karlsruhe is on top with respect to government and higher education spending for R&D. This finding points at the importance of research and qualification organisations in and near the city of Karlsruhe, both in terms of higher education and non-university organisations. In contrast, the regional capital of Stuttgart and its surrounding region host various important companies of the automotive sector, but also in electrical engineering, pharma, logistics, mechanical engineering, services, trade, media and further sectors (see also table 1).

The regional R&D personnel amounted to 2.47% of the total employment in 2013. This figure highly exceeds both the national (1.49%) and the EU-28 (1.26%) figures. Not surprisingly, the high positive deviation from national and European figures is mainly due to over-performance in the business sector (1.85% compared to 0.91% in Germany and 0.68% in the EU-28). Within the federal state of Baden-Württemberg, the NUTS 2 region of Stuttgart has the highest total and business sector figures, while Karlsruhe is in first position concerning R&D personnel in the public sector. These findings mirror the sub-regional characteristics mentioned above. In the same year, 22.5% of the active population in Baden-Württemberg had a tertiary education degree and was employed in science and technology (HRSTC), compared to 20.5% in Germany. This figure slightly decreased both in Germany and Baden-Württemberg in 2014 (20.8% regional, 19.1% national). Within Baden-Württemberg, HRSTC is comparatively evenly distributed in the four NUTS2 regions, ranging from 20.9% in Freiburg to 23.4% in Tübingen (2013) and between 18.5% (Freiburg) and 21.5% (Stuttgart) in 2014. More than two thirds of the human resources in science and technology (HRSTC) of the federal state are employed in the service sector (71.9% of the total employment in 2013, 69.5% in 2014) and about one fourth (23.4% in 2013, 25.3% in 2014) in manufacturing. Not surprisingly, the highest shares of HRSTC within the service and manufacturing sectors are in knowledge-intensive services (62.8% in 2013), and in high and medium high-technology manufacturing (17.8% in 2013).

Concerning patent applications in the comparative perspective within Germany, Baden-Württemberg is on first rank both in 2013 and 2014 (patent applications per

100,000 inhabitants): In both years, 137 applications per 100,000 inhabitants originated from Baden-Württemberg; national average: 60 patent applications/100,000 inhabitants. In 2014, Baden-Württemberg stakeholders filed 30.2% of German applications at the German Patent and Trade Mark Office DPMA.⁴⁶ Since 2000, patent applications at the European Patent Office (EPO) were highest in 2006: in this year, Baden-Württemberg actors filed 6,330 European patents (26.3% of the national figure). The largest shares of regional patent applications were in IPC classes B (Performing operations; transporting: 25.6% in 2010) and F (Mechanical engineering; lighting; heating; weapons; blasting: 20.4%), showing Baden-Württemberg's strengths in the automotive and mechanical engineering sectors. Among the European NUTS1 regions, Baden-Württemberg had the highest figures of EPO patent applications per million inhabitants (exception: second position in 2011). The highest number of EPO high-tech patent applications was reached in 2002 (879 patent applications; 21.9% of the national average). Figure 9 illustrates that the number of total patent applications was highest between 2004 and 2007 before a downward trend became visible. The share of patents from the national figures (%) remained comparatively stable between 2002 and 2006 (around 26%) and then fell slightly to about 24%. The number of high-tech patent applications steadily declined in the second half of the 2000s, however on very modest levels. Considering the share of regional high-tech patent applications to the EPO since 2007 the figures show that Baden-Württemberg quickly recovered from the 2007 slump, followed by two years with decreasing application figures. Within the class of high-tech patents, by far the highest share of patents are applied for in computer and automated business equipment, and communication technology (66.82% of all high-tech patents filed from Baden-Württemberg at the EPO in 2010), followed by semiconductors.⁴⁷

Figure 9 Baden-Württemberg total and high-tech patent applications at the European Patent Office (EPO) 2000-2012



Data source: Eurostat [2012 figures: provisional]

Baden-Württemberg is classified as innovation leader in the Regional Innovation Scoreboard since 2004. Regional figures are more than 120% of the EU average in nine of the eleven indicators considered and between 90 and 120% of the remaining two indicators. The federal state ranks particularly high concerning the employment in knowledge-intensive activities (% of the workforce) and the share of SMEs that introduce product or process innovations (% of SMEs). Baden-Württemberg is among

⁴⁶ DPMA (2015): Auszug aus der Jahresstatistik 2014 des Deutschen Patent- und Markenamts, http://presse.dpma.de/docs/pdf/pressemappen/aufeineinblick_2015.pdf (20/11/2015)

⁴⁷ Data source: Eurostat

the 116 regions with low use of structural funds under RTDI priorities (European Commission, 2014).

In order to present and compare the regional innovation potential, the Statistical Office Baden-Württemberg developed an innovation index that refers to both the European and the intra-regional perspective. This index mirrors the high innovation performance of Baden-Württemberg that proves to be exceptionally successful with respect to R&D investment, persons employed in research-intensive industries and patent applications. In addition to Baden-Württemberg, Bavaria, Île de France, Berlin and Denmark make up the “top five” group of European regions with the highest innovation index 2014 figures.⁴⁸

With regard to tertiary education degrees (ISCED 5-8) in Baden-Württemberg compared to the national and the European averages, the regional figures are higher than the national and European shares, but the advanced position within the EU is declining due to an increasing Europe-wide trend since the beginning of the 2000s, and a marked decline on the German and Baden-Württemberg levels in 2014. In 2012, Baden-Württemberg had a total of 352,325 students (ISCED levels 5 and 6) which corresponds to an increase of 50% compared to 2000. Germany witnessed an increase of 33% in the same period. Relating to ISCED 5 and 6 levels students of all pupils and students, Baden-Württemberg is at 13th position of all German *Länder* (2012). Smaller states and particularly the German city states rank much higher in this respect (data source: Eurostat).

In order to provide the regional business sector, particularly SMEs, with research results, the federal state has a comprehensive system of technology transfer, including industrial research, specific agencies in associations, chambers of industry and commerce, chambers of trade, or Steinbeis Foundation transfer centres. Further, the technology transfer infrastructure includes technology centres and incubators that support technology-oriented start-ups and young companies. Additional instruments to promote knowledge and technology transfer are the support of collaborative research projects, as well as third-party funds of the higher education sector originating from regional businesses, endowed professorships, and the Agency for Invention and Patent Management TLB. Referring to specific areas of technology, Baden-Württemberg has various organisations such as the State Agency for Electric Mobility and Fuel Cell Technology Baden-Württemberg GmbH, the *Medien- und Filmgesellschaft Baden-Württemberg* (the state’s centre of excellence for creative industries, media and film), the Agency BIOPRO in healthcare and bioeconomy, or SEZ in development cooperation, in addition to a broad diversity of regional clusters and networks. The Innovation Alliance Baden-Württemberg (innBW) focuses on knowledge transfer from science to industry, and specifically targets small and medium-sized enterprises. The Alliance brings together 12 independent research institutes that engage in applied and result-oriented research in areas like sustainable mobility, environmental technologies and resource efficiency, health and care, and information and communication.⁴⁹

- **Challenge 1: Maintaining Baden-Württemberg’s position and achieving a better position concerning growth and innovation dynamics**

As shown above, Baden-Württemberg takes a leading position with respect to research, development and innovation. Nevertheless, Baden-Württemberg faces various challenges. These are for instance related to societal or economic facts, but

⁴⁸ <http://www.statistik-bw.de/Pressemitt/2014408.asp> (20/11/2015)

⁴⁹ <https://mwk.baden-wuerttemberg.de/de/forschung/forschungsfoerderung/technologietransfer/industry-on-campus/>, <http://www.technologie-lizenz-buero.com/>, <http://www.e-mobilbw.de/en/>, <https://www.bio-pro.de/de/>, <http://www.mfg.de/>, <http://www.sez.de/>, <http://www.clusterportal-bw.de/>, <http://www.innbw.de/> (24/11/2015)

also to increasing competition on the international scale. As a consequence, Baden-Württemberg has to invest in knowledge and innovation in order to maintain its position and to master the above-mentioned challenges. This is visible in R&D statistics (see Eurostat R&D data): Baden-Württemberg still holds the top position among European NUTS 1 regions and also belongs to the innovation leaders of the Regional Innovation Scoreboard. But other regions are catching up so that strengthening the R&D efforts is perceived as one challenge for the coming years. This aspect concerns science and research as well as innovation policy and covers fundamental as well as applied research, including the transfer of knowledge and technologies into the business sector.⁵⁰ Since the industrial fabric is to a high extent composed of small and medium-sized enterprises, this group of actors is of high importance both in terms of their research, development and innovation efforts, as also in terms of their focus on Industry 4.0.

- **Challenge 2: Securing and increasing the availability of skilled personnel in all parts of the state**

This challenge covers three main aspects. First of all, it refers to qualification and training of highly-skilled persons both in terms of scientific-technical fields (see also above) and also in the sector of ‘dual training’, i.e. training measures taking place in companies and in educational organisations. Secondly, it refers to the participation of various groups of people to be integrated in the labour market (young and elder people, women, formerly unemployed, persons with migration background...). The third aspect refers to the provision of skilled personnel in all parts of the state, including rural areas. This latter refers to the fact that various innovative SMEs are located in rather peripheral parts of Baden-Württemberg and feel disadvantaged concerning the attraction of skilled labour.⁵¹ In total, this challenge means having to cope with demographic change and education on the one hand and with the integration of various groups of persons into the education and industrial system on the other hand.

- **Challenge 3: Stronger involvement of regional small and medium-sized enterprises in research, development and innovation**

The regional industrial structure in Baden-Württemberg is strongly dominated by small and medium-sized enterprises: 99.6% of regional companies have less than 250 employees, and 90.8% have less than 10 employees. On the other hand, 47.2% of regional employees work in larger companies with 250 or more employees that produce 53.7% of industrial turnover (data for 2012, Unternehmensregister Statistisches Landesamt Baden-Württemberg; see also page 7). R&D units of these large companies are responsible for 93.6% of internal R&D expenses in the business sector while 6.4% of intramural R&D expenditure is realized in R&D units of regional firms with less than 250 employees. These latter figures are below the German national average (9.7% R&D expenditures in firms with less than 250 employees). On the other hand, 60.8% of intramural R&D expenses is realised in research units of Baden-Württemberg companies with 10,000 and more employees. This figure exceeds the national average (48.1%; data for 2013, Stifterverband für die deutsche Wissenschaft). Even though not all innovation is based on research and development activities, these figures indicate the need to support research and development activities in smaller companies in the region.

⁵⁰ See also <https://www.mckinsey.de/baden-wuerttemberg-braucht-initiativen-um-anschluss-die-spitze-zu-halten> (8/12/2015)

⁵¹ See for instance survey in the region of Ulm, http://www.ulm.ihk24.de/blob/ulihk24/standortpolitik/fallback1428559649631/1610426/6037050ccfab6d4c2c6aa999c922e8a3/Standortumfrage_Landkreis_Biberach-data.pdf (8/12/2015)

2.2 Institutional framework and set-up

Baden-Württemberg is one of the 16 federal states of the Federal Republic of Germany. All German states (*Länder*) have their constitutions, parliaments and regional governments. The regional parliament and government are located in Stuttgart, Baden-Württemberg's capital. The parliament has legislative power and examines the government's use of executive powers. It elects the Minister President, confirms the regional government, and elects the President and the members of the Baden-Württemberg Court of Justice. Baden-Württemberg's Government has 13 members: the Minister President and 12 ministers. The Minister President is the head of the regional government; he determines and is responsible for the guidelines of the state policy. He also represents the federal state to the outside, appoints judges and state officials and has the right to grant pardons. The State Ministry coordinates and designs the State Policy and supports the Minister President in coordinating the different ministries. Baden-Württemberg has a representation in Berlin and in Brussels. It is further represented on the Committee of the Regions, and in the Congress of Local and Regional Authorities in Strasbourg. It further engages in the Upper Rhine German-French-Suisse border region and in the *Bodensee-Konferenz* that comprises representatives of states bordering Lake Constance. The federal state is one of the "four motors of Europe", together with Rhône-Alpes, Catalonia and Lombardy and has close relationship to further European regions.⁵²

Baden-Württemberg has a long-standing tradition of strategic technology and innovation policy. The current innovation strategy of 2013 pursues the main objective to maintain the state's excellent position with respect to research, innovation and economic prosperity. In this context, research and development measures focus on an attractive higher education and research landscape, excellent university research, profile formation in scientific excellence, support for young scientists and entrepreneurial junior staff, intensified science-industry networking, and further developing the regional growth areas (sustainable mobility; environmental technologies, renewable energies and resource efficiency, health and care, information and communication technologies, Green IT and intelligent products) (Bundesministerium für Bildung und Forschung, 2014).

The state's total budget for 2015 is €44.0b, from which 34.9% (€15.4b) are dedicated to education, science, research and culture (corresponding to an increase of 4.9% compared to the preceding year). This includes funding of the higher education sector (€4.2b; +7.9% compared to 2014) and funding for science, research and development in the non-university sector (€501m; +7.3% compared to 2014). Activities in science, research and innovation are further co-funded by EU Structural Funds, particularly ERDF (nearly 50% from the ERDF Operational Programme 2007-13 was foreseen for those areas, and nearly 80% of the 2014-20 OP) (Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013).⁵³

The Ministry for Science, Research and the Arts (*Ministerium für Wissenschaft, Forschung und Kunst*) is responsible for regional higher education institutions, the majority of non-university research institutions, scientific libraries and archives, as well as Arts and cultural institutions in the federal state. The Ministry co-funds and supports their activities, promotes innovations and pushes the further development of regional science, research, arts and culture. The Ministry's staff comprises a total of about 300 persons. It is organised in five departments, among them 'universities and clinics' and 'research, technology transfer, young scientists, ICT, EU affairs'. The

⁵² <https://www.landtag-bw.de/cms/home/der-landtag/parlament.html>, <https://stm.baden-wuerttemberg.de/de/ministerium/>, <https://www.baden-wuerttemberg.de/de/regierung/landesregierung/> (16/12/2015)

⁵³ See also http://haushalt.service-bw.de/HaushaltBW/HaushaltBW_Fkt.html (25/11/2015)

strategic elements pursued by the Ministry include (among others) increased institutional funding of regional universities (“Perspektive 2020”), strengthening the IT infrastructure at universities, supporting access to information and targeted support of the research infrastructure (“Digitalisation and eScience”), supporting key technologies in the context of energy transition, introducing new models for education and qualification, recommendations for the positioning of engineering sciences, universities and non-university research institutions (Expert Commission ‘Engineering Sciences@BW 2025’), supporting universities in acquiring third-party funds and internationalisation, supporting cooperation, technology transfer and research at universities of applied sciences, and supporting young scientists and professors. In terms of technology transfer, the Ministry for Science, Research and the Arts contributes with two programmes: (1) “Young innovators” supports technology transfer through spin-offs from university and non-university research institutes; (2) “Industry-on-Campus” (see above) supports strategic cooperations between universities and companies on university campus. Further, the government co-funds supra-regional measures such as for instance the Excellence Initiative which is organised by the German federal and state governments. Universities located in Baden-Württemberg participate with a budget of €571m between 2012 and 2017, from which about one quarter is co-funded by the state of Baden-Württemberg (Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg, 2014).⁵⁴

As largest ministry of the regional government, the Ministry of Finance and Economic Affairs (*Ministerium für Finanzen und Wirtschaft*, MFW) employs more than 800 persons in nine departments. The ministry’s responsibilities comprise financial policy, taxation, skilled labour, small businesses and economic policy, as well as industry, innovation and industry-oriented research, among further tasks.⁵⁵ With respect to innovation support, the Ministry’s main areas of activity are:

- Supporting the industry-related research infrastructure of the region;
- Dialogue process ‘Technology Transfer’, resulting in a joint declaration for further developing technology transfer in Baden-Württemberg (see below concerning the dialogue-oriented policy approach);
- Supporting innovation projects in individual companies as well as collaborative research activities;
- Cluster policy and supporting networks;
- Regional dialogue;
- Key enabling technologies; and
- Selected branches and sectors.⁵⁶

⁵⁴ See also <https://mwk.baden-wuerttemberg.de/de/startseite>, <https://www.bmbf.de/de/die-exzellenzinitiative-staerkt-die-universitaere-spitzenforschung-1638.html> (25/11/2015)

⁵⁵ <http://mfw.baden-wuerttemberg.de/de/ministerium/organisation-und-aufgaben/>, <http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/> (25/11/2015).

⁵⁶ <https://www.baden-wuerttemberg.de/de/service/presse/pressemitteilung/pid/landesregierung-rueckt-innovations-und-technologiepolitik-in-zentrum/>, http://mfw.baden-wuerttemberg.de/fileadmin/redaktion/m-mfw/intern/Dateien/Downloads/Industrie_und_Innovation/Gemeinsame_Erklarung_Technologietransfer.pdf, <http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/industrie-und-innovation/projektfoerderung/>, <http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/industrie-und-innovation/cluster-politik/>, <http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/industrie-und-innovation/regional-dialog/>, <http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/industrie-und-innovation/schlueseltechnologien/>, <http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/industrie-und-innovation/ausgewaehlte-branchen/> (25/11/2015)

As a cross-cutting theme, Industry 4.0 is considered a core priority. The state has the vision to become a leading location for Industry 4.0 (see also Alliance Industry 4.0 above).⁵⁷

Main innovation and technology-oriented supporting programmes of the MFW are (1) Innovation vouchers, (2) Innovation funding (before September 2015: Technology funding). Each year, the state awards important regional innovation projects in regional small and medium-sized enterprises from manufacturing, trades and technological service sectors with the Innovation Award. Further supporting measures concern funding of agencies in specific key enabling technologies (e.g. BIOPRO), regional clusters, the RegioWin competition as regional dialogue process for supporting development processes in Baden-Württemberg's sub-regions, technology transfer managers, and funding for industry-related research.⁵⁸

Activities with respect to RTDI support are coordinated within the Baden-Württemberg regional government. In addition to the Ministries for Science, Research and the Arts and of Finance and Economic Affairs, the *Baden-Württemberg Stiftung* (Baden-Württemberg Foundation) funds projects in research, education and culture. Its main objective is to ensure the region's sustainability as an attractive location with opportunities for future generations. Founded in 2000 and based on a foundation capital of about €2.3m, the non-profit organisation funded projects with a total budget of €737m in 2014. In the research pillar, it complements the state's research support and focuses on application-oriented basic research in life sciences, photonics, miniaturisation, ICT, environment and energy, as well as new processes and materials.⁵⁹

A further important actor in the innovation and technology context is the Baden-Württemberg State Bank, *L-Bank*. The Bank fulfils the general mission to support the regional economy, housing space, as well as families, education and social projects, and infrastructure. Economic development support includes promoting small and medium-sized enterprises, start-ups, thus new and established companies in their growth and development phases, with a broad range of funding instruments. The main technology and innovation support programmes are (1) InnovFin70, L-Bank's new (since September 2015) guarantee scheme for SMEs in cooperation with the European Investment Fund (EIF), (2) Innovation funding for supporting R&D expenses in SMEs (in cooperation with the national KfW Bank), (3) Start-up support (*Gründungsfinanzierung* and *Startfinanzierung 80*). A further instrument is related to technology parks: L-Bank supports service-oriented infrastructure (including laboratories, clean rooms, day care centres) in four locations in Baden-Württemberg; support consists in providing real estate and risk assumption for investments.⁶⁰

A core element of Baden-Württemberg's innovation policy refers to the regional cluster policy. The state supports these activities through financial support of innovative projects in clusters, supporting cluster internationalisation, cluster events and analyses, qualification measures for the cluster management, publications, and information. A central stakeholder is the ClusterAgentur (Cluster Agency) Baden-Württemberg that engages in qualification measures for cluster managements, and supports the Ministry of Finance and Economic Affairs in implementing the state's

⁵⁷ <http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/industrie-und-innovation/schluesel-technologien/industrie-40/> (25/11/2015)

⁵⁸ <http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/industrie-und-innovation/>, <http://mfw.baden-wuerttemberg.de/de/service/>, <https://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/20-punkte-programm-zur-staerkung-des-technologietransfers> (24/11/2015)

⁵⁹ <http://www.bwstiftung.de/> (25/11/2015)

⁶⁰ <https://www.l-bank.de/> (25/11/2015)

cluster policy. The cluster atlas is an inventory of existing cluster initiatives in Baden-Württemberg that provides basic information about all 118 regional clusters, networks and state agencies; further information is provided by the cluster database.⁶¹

Finally, Baden-Württemberg International (bw-i) is the state's competence centre for internationalising business, science and research. Its activities are in supporting companies, universities and research organisations in their internationalisation activities, to open up foreign markets and to position the Baden-Württemberg location on a global scale. The institutional set-up is complemented by a comprehensive technology transfer system, including contact points at industrial organizations such as Chambers of Trade and Commerce, Chambers of Trades, and business associations, industry-oriented research institutes, Steinbeis centres, as well as technology centres and parks, and incubators.⁶²

2.3 Regional innovation policy mix

Being embedded in the political guidelines of the current Baden-Württemberg government, the state's innovation policy is based on long-term oriented higher education, research and technology policy that comprises the whole innovation process from basic to applied research, technology transfer and development, including scientific and vocational training and qualification. The focus of Baden-Württemberg's innovation policy since the beginning of the 2000s has been on systemic networking of innovation-related stakeholders, and on cluster policy. Various new actors, regional agencies as well as technology and innovation centres were established as service facilities that support innovation actors in new target fields. Since about five years ago, the state's innovation policy has been focusing on selected growth fields with the most promising potentials for the development of the region. Baden-Württemberg's innovation policy is based on close dialogue processes between policy, science, industry, and further intermediary actors as trade unions and expert groups (Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013).

The basic philosophy of Baden-Württemberg's RTDI policy consists of the further development of Baden-Württemberg's science and research, including the transfer of knowledge to the regional economy and society, and scientific qualification. In order to support innovation activities based on internationally competitive basic research, the state promotes a broad range of scientific disciplines and themes, however aiming at creating critical mass in those areas. The basic vision is the support of high-quality research in a large range of fields and simultaneously supporting excellence.

A further target of the state's innovation policy concerns environmental technologies and resource efficiency as foundation for sustainable development and as anticipated market potentials for regional activities. Technology policy – as part of Baden-Württemberg's innovation policy – has three main areas: first, it strongly focuses on non-university industry-oriented research and applied research at regional universities. A second focus is on technology transfer, particularly for the benefit of small and medium-sized enterprises, and the third area refers to the promotion of individual businesses, such as for instance through innovation vouchers. Technology policy takes the identified four future-oriented fields with above-average growth potentials (sustainable mobility; environmental technologies and resource efficiency; health and care; information and communication technologies and Green IT) into account.

⁶¹ <http://www.clusterportal-bw.de/>, <http://www.clusterportal-bw.de/clusterdaten/clusterdatenbank/clusterdb/Cluster/list/> (25/11/2015)

⁶² <http://www.bw-i.de/>, <https://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/industrie-und-innovation/wirtschaftsdialog-technologietransfer/> (25/11/2015)

Concerning the process of economic and innovation policy design and implementation, the state strongly uses dialogue processes involving business, unions and further actors. This leads to stronger participation, acceptance and improvement of the regional innovation climate. Finally, the state advocates favourable context conditions for firms and their innovation activities (e.g. sustainable regulatory policy based on the regional strategy in environmental technologies and resource efficiency). Baden-Württemberg's innovation policy is conducted as inter-departmental approach (Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013). The main starting points and levers for RTDI support are:

- **Institutional funding for science and research:** higher education institutions (responsibility of Ministry for Science, Research and the Arts), as well as for non-university research organisations (responsibility of Ministry of Finance and Economic Affairs), including the institutes of the InnovationAlliance, of Fraunhofer, and the regional locations of the national aeronautics and space research centre DLR;
- Support of projects in individual companies and collaborative activities: this funding line refers to innovation vouchers, the ESF coaching programme, and Young Innovators. Further support is granted through the recently introduced Innovation Funding Programme and InnovFin70. **Innovation vouchers** were introduced in 2008 as a supporting measure for regional small and medium-sized enterprises and their activities to develop and implement new or improved products, processes and services. These vouchers are designated to be used for purchasing research services from national or international universities, research organisations or (private) R&D departments. The instrument was broadened and now contains a specific version for high-tech companies and for SMEs in creative industries. **External coaching** support refers to managing the various challenges that SMEs face in structural change processes, including innovation, restructuring, climate-friendly activities, business handover, qualification, growth of women-led firms, and securing skilled manpower. The **Young Innovators** Programme targets start-up activities from universities and research organisations. Further direct support for research and development activities in small and medium-sized enterprises is granted through the **Innovation Funding Programme** that targets innovation expenditures for introducing new products, services or processes. This regional programme is based on the (national) innovation programme of KfW, the national development bank. L-Bank's specific regional engagement consists in improving the conditions of KfW's ERP Innovation Programme through redemption bonus. In September 2015, the new guarantee programme **InnovFin70** was launched by the state bank and Baden-Württemberg's Guarantee Bank (*Bürgschaftsbank*) with the European Investment Fund. At the core are small and medium-sized enterprises. L-Bank intervenes through providing deficiency guarantee to the financial institution that provides loans (underpinned by warranty of the European Investment Fund) (see also table 3).
- Further support is granted in Baden-Württemberg's four specific **growth areas** (including collaborative research projects integrating universities, research organisations and businesses) as well as dedicated organisations and networks (e.g. European Enterprise Network).
- In the field of innovation-oriented research policy, the state grants support for **Industry-on-Campus** projects that target long-term strategic partnerships between science and industry. Collaborators of both types of actors work on jointly defined themes. Funded by participating universities and companies and partly with financial contribution of the state, these joint projects are carried out in physical buildings on the university campus. Synergies between basic research, applied research and development are expected to boost technology development and transfer. Further, knowledge transfer especially to SMEs is targeted through strengthening application-oriented research activities particularly at universities of applied sciences. Government support consists of institutional funding for

universities of applied sciences on the one hand, and on the specific promotional programme “Support of technology transfer between universities of applied sciences and SMEs” (focus on energy efficient technologies and processes and resource-savings in materials) on the other hand. So far, the state has invested about €3m for this programme.⁶³

- Finally, the state engages in supporting cooperation activities on the (sub-) regional level, precisely in **clusters, leading-edge clusters and sub-regional initiatives**. Baden-Württemberg has a dedicated cluster policy (see above). Networks and clusters have been supported since the beginning of the 2000s, and in 2006, the regional government established a specific unit for cluster policy. Clusters are thus seen as infrastructure support for regional SMEs, and are used as a broad instrument with a wide coverage, both in territorial regards and in thematic/ technological means. In 2014, the state founded the ClusterAgentur Baden-Württemberg that aims at fostering cluster development in the dedicated strategic growth fields of the region. Cluster activities are financed through ERDF means (see table 3); further support is granted for cluster internationalisation. In order to emphasise cluster quality, the label “Cluster Excellence Baden-Württemberg”, awarded after independent evaluation, was introduced. Further regional support is granted for regional leading-edge clusters which were selected in the frame of the national programme (up to €5m for each of the five leading-edge cluster or cluster parts located in Baden-Württemberg). In addition, the RegioWIN competition focuses on strategy developments by actors in Baden-Württemberg’s sub—regions (cities, municipalities; see table 3). In January 2015, eleven development concepts and 21 flagship projects were awarded by the Ministers of Economic Affairs, Sciences and Rural Development.⁶⁴

⁶³ <https://mwk.baden-wuerttemberg.de/de/forschung/forschungsfoerderung/technologietransfer/forschung-an-hochschulen-fuer-angewandte-wissenschaften/> (4/12/2015)

⁶⁴ Supporting programme “Internationalisation of Cluster Initiatives” since 2010; managed by Baden-Württemberg International; annual budget: €140,000. Further information: <http://www.bw-i.de/unternehmen-cluster/cluster-und-netzwerke.html> (7/12/2015), Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/2071, http://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/2000/15_2071_D.pdf, Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/7409, https://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/7000/15_7409_D.pdf (4/12/2015), <http://www.clusterportal-bw.de/cluster-exzellenz/cluster-exzellenz-baden-wuerttemberg/> (7/12/2015), <http://regiowin.eu/>, <https://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/landesregierung-praeamiert-11-regionale-entwicklungskonzepte-und-21-leuchtturmprojekte/> (16/12/2015)

Table 3 Regional Innovation Support Measures

Title	Duration	Policy priorities	Budget	Organisation responsible	More information
Innovation vouchers	Since 2008	4.1 Direct funding to business R&D and innovation 4.3 fostering start-ups and gazelles	Approved budget 2008-2013: €14.5m	Ministry of Finance and Economic Affairs Baden-Württemberg	https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/support-measure/innovation-vouchers-o http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/mittelstand-und-handwerk/innovationsgutscheine/
InnovFin70	Since 9/2015	4.1 Direct funding to business R&D and innovation		L-Bank (State Bank Baden-Württemberg), Baden-Württemberg Guarantee Bank	https://www.l-bank.de/lbank/inhalt/nav/foerderungen-und-finanzierungen/alle-foerderangebote/wf-wirtschaftsfoerderung/innovationsfinanzierung.xml?ceid=125704
Innovation Funding	Since 9/2015	4.1 Direct funding to business R&D and innovation		L-Bank (State Bank Baden-Württemberg)	https://www.l-bank.de/lbank/inhalt/nav/foerderungen-und-finanzierungen/alle-foerderangebote/wf-wirtschaftsfoerderung/innovationsfinanzierung.xml?ceid=125704
Coaching for small and medium-sized enterprises (ESF 2014-2020)	2015-2020	4.2 Organisational, process and other non-R&D innovation		Ministry of Finance and Economic Affairs Baden-Württemberg (department European Social Funds), L-Bank	http://www.esf-bw.de/esf/uploads/media/Merkblatt_Coaching_KMU_151201.pdf
Young Innovators	Since 1995	4.3 Fostering start-ups and gazelles		Ministry for Science, Research and the Arts Baden-Württemberg	https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/support-measure/young-innovators-o
Industry-on-Campus		2.1 R&D cooperation projects between academy and		Ministry for Science, Research and the Arts Baden-Württemberg	https://mwk.baden-wuerttemberg.de/de/forschung/forschungsfoerderung/technologietransfer/industry-on-campus/

Title	Duration	Policy priorities	Budget	Organisation responsible	More information
		industry 2.3 Knowledge transfer structures between academic and industry			
Cluster policy	Since 2006	5.1 Cluster development	Foreseen budget: €2m (2014-2020; ERDF)	Ministry of Finance and Economic Affairs Baden-Württemberg	https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/support-measure/cluster-policy-baden-wuerttemberg http://www.clusterportal-bw.de/
RegioWIN	Since 2013	5. Innovation climate and business eco-system 7. Others	Foreseen budget: €65m (2014-2020, ERDF)	Ministry of Finance and Economic Affairs Baden-Württemberg, Ministry for Science, Research and the Arts Baden-Württemberg, Ministry for the Rural Area and Consumer Protection Baden-Württemberg	https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/support-measure/regiowin http://regiowin.eu/

Source: RIM Plus Repository (Baden-Württemberg), online documentation of L-Bank, Ministry of Finance and Economic Affairs Baden-Württemberg, Ministry for Science, Research and the Arts Baden-Württemberg.

2.4 Appraisal of regional innovation policies

Baden-Württemberg's main challenge relates to securing and maintaining its outstanding position as an attractive and efficient innovation region in the national, European and international context in order to stay competitive and to further develop its economic potentials. This objective requires a comprehensive and holistic view of innovation and economic development that integrates the different dimensions of innovation and emphasises a comprehensive policy approach. The interdepartmental approach to the current innovation strategy is based on this philosophy, leading to a policy approach that refers to basic and applied research as well as industry-oriented research and development, networking and innovation in a systemic perspective. The regional government conceives this comprehensive policy approach as encompassing:

Science and research policy to strengthen regional research, support knowledge transfer in the regional economy and society, and to support scientific qualification and training of young people. Science policy aims at supporting a broad range of disciplines, however guaranteeing critical mass for each of the science fields. The basic vision is to provide high quality in all supported fields and simultaneously to promote fields of excellence. Internationally competitive science and research is conceived as a basic precondition for the production of knowledge. Fundamental and application-oriented research are interlinked and connected, and thus form the base for innovation and economic success. The vision of a systemic innovation process that connects science and industry leads to target cooperation between the research and the business sectors, for instance through new forms of cooperation such as in Industry-on-Campus projects, through networks and clusters and through demand-oriented research in university (e.g. universities of applied sciences) and non-university research institutes (among them for instance Fraunhofer institutes or the Innovation Alliance Baden-Württemberg). The contribution of the Innovation Alliance to strengthen the competitiveness of small and medium-sized enterprises in Baden-Württemberg is revealed by an evaluation study from 2008.⁶⁵

In terms of **thematic/ technological focus**, the state prioritises the areas of environmental technologies and resource efficiency. Economic and technology policy has a focus on four future-oriented fields mentioned above. Technology policy targets the **non-university research infrastructure** that focuses on industry-oriented research, as well as applied research in regional universities. Further, it focuses on improving **technology transfer** particularly for the benefit of small and medium-sized enterprises and on support for individual firms (e.g. innovation vouchers, see above).

These priorities are complemented through **collaborative approaches** and **state-wide initiatives in research and technology development**. Instruments in this respect are collaborative projects between university and non-university research institutes and industrial firms in e-mobility and environmental technologies, in addition to state-wide initiatives. The supporting programme "Promoting technology transfer between universities of applied sciences and SMEs" (Ministry for Science, Research and the Arts Baden-Württemberg) targets highly relevant topics for regional businesses that are treated by networks of research and business actors (e.g. Robert Bosch Center for Power Electronics⁶⁶).

Financial support to innovation activities is provided through various measures on the base of loans, guarantees and contributions (see above). Further programmes target business investment in specific areas such as in energy efficiency. Key actors in

⁶⁵ <http://www.baden-wuerttemberg.de/de/service/presse/pressemitteilung/pid/evaluationsbericht-zur-arbeit-der-wirtschaftsnahen-forschungseinrichtungen-uebergeben/> (14/12/2015)

⁶⁶ <http://www.rbzentrum.de/> (11/12/2015)

terms of management of funding support are L-Bank, the ERP Programme of KfW, regional guarantee programmes, equity supply of L-Bank and *Mittelständische Beteiligungsgesellschaft* and the regional Seed Funds.⁶⁷

Basically, the regional government attributes a core position to (institutional) funding of the regional research infrastructure. In the view of budgetary restrictions, this focus is considered of outmost importance with regard to sustainability and impact on innovation and business activities.

In terms of **skills** and the challenge of future skills shortage in the region, the government pursues various measures to secure the provision of skilled employees for the regional industry. As all 16 German federal states, Baden-Württemberg has full responsibility for policies in education and qualification (see also above). This includes school and higher education policy, as well as policies to promote vocational training and further education. Among other aspects, the state's Higher Education Act from 2014 emphasises stronger cooperation between different faculties and with external research organisations both in qualification and research.⁶⁸ Further, practice-oriented studies at Universities of Applied Sciences or the Baden-Württemberg Cooperative State University, as well as courses of study accompanying professional activities are strengthened. In 2013, Baden-Württemberg was on last position among the German federal states concerning the share of university graduates (57.1%) and on first position with respect to graduates from Universities of Applied Sciences (42.9%) (Wissenschaftsrat, 2015). In its overall vision of dialogue-oriented policy (see also page 43), the State Government established the *Fachkräfteallianz* (Alliance Skilled Employees) in 2011. Headed by the Minister of Finance and Economics Baden-Württemberg, the Alliance brings together business organisations, trade unions, regional agencies of the Federal Labour Office, associations of municipalities, the rural women council, and the state. The Alliance defined ten core objectives that address aspects like strengthening vocational training and further education, increasing employment of women and older persons, reducing unemployment, better integrating people with migration background into the labour market, rising level of employment, increasing employment in engineering fields, fostering immigration and establishing regional alliances. Primary goal of the Alliance is to develop and implement measures for securing the provision of skilled employees in Baden-Württemberg, particularly in small and medium-sized enterprises (Ministerium für Finanzen und Wirtschaft Baden-Württemberg, 2012).⁶⁹

More specifically targeting regional **small and medium-sized enterprises**, the state government addresses innovation performance and competitiveness as main general objectives of its policy. It views shortage of skilled employees, scarcity of resources, transformations in energy supply (*Energiewende*), or digitalization as important future challenges for regional SMEs. In order to strengthen the location of Baden-Württemberg for industrial production and SMEs, three main areas are considered pertinent: (1) the focus on four future-oriented fields and innovative core areas (see above) that have high impacts on the region's strong sectors; (2) cross-sectional measures like vocational training, export support, support of firm foundations, and giving new impulses; (3) fostering key enabling technologies such as microsystems technologies, lightweight construction, resource efficiency, biotechnology and new materials. High RTDI policy priority is attributed to the

⁶⁷ Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/2071, http://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/2000/15_2071_D.pdf (4/12/2015)

⁶⁸ <https://mwk.baden-wuerttemberg.de/de/hochschulen-studium/landeshochschulgesetz/>, (11/12/2015).

⁶⁹ See also <http://fachkraefteallianz.region-stuttgart.de/netzwerk/fachkraefteallianz-baden-wuerttemberg/>, http://mfw.baden-wuerttemberg.de/fileadmin/redaktion/m-mfw/intern/Dateien/Publikation/Arbeiten_und_Leben/Fachkraefte/Fachkraefteallianz_BW_Ziele_Bilanz_und_Massnahmen_2015.pdf (11/12/2015)

regional research infrastructure, to innovation transfer activities, clusters and networks, e-mobility, digitalisation, environmental technologies and resource efficiency. In addition, ESF funds focus on vocational training, entrepreneurship and business succession, knowledge transfer and networking, as well as equal opportunities. ERDF funds are invested in supporting measures on the territorial level. This includes industry-oriented infrastructures, projects fostering innovative communal development or the RegioWIN competition (see above), among others (Ministerium für Finanzen und Wirtschaft Baden-Württemberg, 2015a). Important innovation policy instrument that specifically target small and medium-sized regional enterprises are the innovation funding programme and innovation vouchers; between 2008 and 2013, about 3,100 voucher proposals were submitted and more than 2,340 vouchers were granted. Since its introduction in 2008, the instrument was extended and now includes high-tech start-ups and creative industries (Ministerium für Finanzen und Wirtschaft, 2014).⁷⁰ Further measures with dedicated SME focus refer to start-up and export consulting – including the Young Innovators programme⁷¹ - participation at fairs and exhibitions, support for training and apprenticeship, and technology-specific measures such as in energy efficiency. In addition, financial instruments and specific consulting is offered for this group of regional enterprises. Until September 2015, the programme ‘Technology funding’ supported regional SMEs’ investments in innovative technologies. From January to October 2011, 118 proposals for loans were submitted.⁷² Since September 2015, innovation expenses can be supported in the context of the innovation funding programme.

Monitoring and evaluation is implemented at different levels in Baden-Württemberg. First of all, it takes place in the light of regional statistics that mirror the state’s development. Placing the region in a supra-regional perspective allows assessing the regional situation in a broad dimension and at defining possible future trends and developments. In this respect, the R&D monitor and the innovation index Baden-Württemberg are core instruments. They are prepared and provided by the Regional Statistical Office that not only provides the statistical data, but also prepares analyses both on the intra-regional level as well as in a comparative perspective across the European Union.⁷³ Secondly, the regional government or further stakeholders – such as for instance the *Baden-Württembergischer Industrie- und Handelskammertag*, the Baden-Württemberg Association of Chambers of Industry and Commerce⁷⁴ or regional Chambers of Industry and Commerce – conduct and/ or award studies in RTDI-specific themes that are then discussed on the state government level. Likewise, individual measures are evaluated by external experts such as the evaluation of Innovation Voucher instrument in its pilot phase by the *Institut für Mittelstandsforschung* Mannheim (Institute for SME Research Mannheim) and the Centre for European Economic Research (ZEW) Mannheim

⁷⁰ The granted volume of support was about €2.2m in 2010 and €1.7m in 2011 (January to November); Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/879, http://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/0000/15_0879_D.pdf (14/12/2015)

⁷¹ Evaluation report: Leibniz Universität Hannover, 2010. Total volume in 2010: €602,000, in 2011 (January to November): €729,000, Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/879, http://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/0000/15_0879_D.pdf (14/12/2015)

⁷² Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/879, http://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/0000/15_0879_D.pdf (14/12/2015)

⁷³ <http://www.statistik.baden-wuerttemberg.de/Veroeffentl/8033yy001.asp>, http://www.statistik.baden-wuerttemberg.de/VolkswPreise/Indikatoren/IX-FE_innovatIndexLARG.asp

⁷⁴ <http://www.bw.ihk.de/>

(Wirtschaftsministerium Baden-Württemberg, 2010). Further examples are the studies *Leidet der Wirtschaftsstandort Baden-Württemberg an einer Investitionsschwäche?* (Does Baden-Württemberg suffer from weaknesses in investment? Institut für Angewandte Wirtschaftsforschung e.V. IAW 2015, the regional cluster atlas (Ministry of Finances and Economic Affairs Baden Württemberg, 2015), Reports on regional SMEs or Economic Facts and Figures (Ministerium für Finanzen und Wirtschaft Baden-Württemberg, 2015a, 2015b), the study “Industry 4.0 for Baden-Württemberg” (Ministerium für Finanzen und Wirtschaft Baden-Württemberg, Fraunhofer IPA, 2014), the study “Branch and technology profiles in the Karlsruhe Technology Region” (Industrie- und Handelskammer Karlsruhe, 2012), the study “*Industrieller Mittelstand: Spitzenstellung in Gefahr?*” (IHK Region Stuttgart, 2014), or the study “Strategic Alignment of Scientific and Industrial Research in Baden-Württemberg (Baden-Württemberg Stiftung gGmbH, 2010), to name just a few. In addition to scientific reports and analyses of statistical data, the measures are monitored internally based on reports of beneficiaries.⁷⁵ Further, the regional government presents model projects and examples such as for instance in its regular annual reports on Innovation Vouchers (see Ministerium für Finanzen und Wirtschaft, 2014 for the 2014 report). This list is to be complemented by evaluation studies co-funded through ERDF means. Besides ex-ante and mid-term evaluations of the regional Operational Programme, these include cluster support, new funding instruments and start-up activities.⁷⁶

A third flow of information and discussion is realized under the heading of **dialogue-oriented policy approach**, which was tested since 2007 and the introduction of dialogues in logistics and cluster policies, and since 2011 became a crucial element of the state’s economic and innovation policy. In this respect, the regional innovation strategy considers: “the close link of fact-based expert knowledge and a policy of being heard as core element of the innovation strategy Baden-Württemberg” (Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013). The basic principle refers to close relations and exchanges between various regional stakeholders under specific themes and topics. Also, expert groups are temporarily convened for giving their expertise and advice to specific issues, partly in relation to dedicated studies. Examples are the Expert Commissions or the Innovation Council (see also below).

2.5 Policy good practice

In the following, two different examples for good policy practice are given. The first one refers to the specific promotional measure of innovation vouchers, while the second example is broader and details the Baden-Württemberg policy approach of dialogue orientation.

Innovation vouchers

Baden-Württemberg was the first German federal state that introduced innovation vouchers as an instrument to strengthen innovation capacities of small, very small and medium-sized enterprises located in the region. The basic philosophy of this measure is to support SMEs (up to 100 employees) in their innovation efforts through funding external support for SMEs’ innovation activities. With this instrument, Baden-Württemberg’s Government follows the mission of ‘demand-oriented’ innovation policy: it does not pre-define specific technological or sectoral core areas and thus targets specific demands of regional SMEs and their innovation efforts. As a second

⁷⁵ See for instance Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/879, http://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/0000/15_o879_D.pdf (14/12/2015)

⁷⁶ All studies can be downloaded on the regional ERDF website: https://www.lgl-bw.de/lgl-internet/opencms/de/Microsite_EFRE/EFRE_B-W/Evaluation

guideline, the instrument pursues the goal to be easily implemented in a non-bureaucratic way. Thirdly, beneficiaries are free to choose the supplier of the desired R&D service worldwide, are thus not restricted to specific private or public R&D institutions. Innovation vouchers were in a first phase introduced in the frame of a pilot project, followed by an external evaluation. Based on its (promising) findings, the instrument was maintained and further developed (extended through voucher B – High-tech and C creative industries). As the evaluation showed, more than 130 proposals were submitted when the measure was introduced, due to information diffusion in the launching phase. The number of proposals then decreased, but witnessed an increasing trend since the end of 2008 and increasing awareness and familiarity with the instrument. While nearly half of all proposals in this phase were submitted from companies located in agglomeration areas of Baden-Württemberg (mainly the Stuttgart region: City of Stuttgart, Ludwigsburg, Esslingen), about one fourth of applications originated from rather rural areas. However, when weighting these (absolute) figures with the number of eligible companies, the Stuttgart agglomeration is ranks in the middle range, while Tuttlingen and Schwarzwald-Baar in south-eastern Black Forest and south-western Swabian Alb are on first positions. By far the highest share of applications was submitted in manufacturing (62.2%), followed by business-oriented services (21.0%). During the pilot phase, the average number of employees of applicants was 12.6 persons. Interestingly, less than one third of applying companies reported former cooperation experience with R&D facilities; and most applicants (76%) did not benefit from innovation support before. By far the highest share of innovation projects (about 88%) target product innovations, 8% aimed at completely new products. Concerning the specific subject of the innovation voucher applications, feasibility studies (31%), market analyses (22%) and technology search (20%) were the highest priorities for voucher A, while construction services (33%), prototyping (31%) and product testing (28%) received priorities for voucher B.⁷⁷ Concerning the R&D facilities contacted, 55.2% were private companies and 19.6% belonged to the higher education sector. Though the instrument did not restrict the type of R&D facility to be selected as service provider, regional proximity proved to be of high relevance: 77.5% of applicants planned to cooperate with a R&D supplier from Baden-Württemberg. 19.5% wanted to cooperate with a German partner outside Baden-Württemberg, while 3.0% target a foreign supplier of R&D support. These figures show that the instrument not only promotes innovation activities in regional SMEs, but also contributes to cooperation with external R&D providers on the regional, national and global scale. As the Annual Report 2014 witnesses, about 70% of applications are prepared from companies that did not cooperate with R&D facilities before. Innovation vouchers were in the meantime introduced in further German federal states and also in other countries (India, Australia) (Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013, Wirtschaftsministerium Baden-Württemberg, 2010).

Dialogue-oriented innovation policy

The underlying philosophy of Baden-Württemberg’s innovation policy is a “continuous development process, taken in dialogue with partners from industry, science and civil society.” (Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013: 2). Innovation is understood in its broad sense, i.e. including social, ecological and technological dimensions, and innovation policy instruments are discussed and

⁷⁷ Innovation voucher A targets scientific work for developing an innovative product, service or for process innovations, while voucher B is directed at application-oriented research and development activities. More information is available at <http://mfw.baden-wuerttemberg.de/de/mensch-wirtschaft/mittelstand-und-handwerk/innovationsgutscheine/innovationsgutscheine-a-und-b/> and <https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/support-measure/innovation-vouchers-o>

further developed with regional partners from the above-mentioned sectors. Following this philosophy, the dialogue orientation is a basic element to successfully design and implement regional policy and to provide new impetus in the state through participation and consensus. Of high importance are joint actions between the policy sector and private businesses, associations, Chambers of Industry and Commerce and of Trades, networks and clusters, science, trade unions and further stakeholders on the supra-regional level (Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013). In addition to this element of “being heard”, Baden-Württemberg provides expert knowledge and links these two types of information. Expert knowledge is provided by different bodies that are initiated with specific objectives for a specific time period. Examples for those bodies are the Zukunftskommission Wirtschaft 2000 (Future-oriented Commission Economy 2000), the Innovation Board, the Innovation Forum or the Innovation Council as most recent body. This latter operated between 2007 and 2010 and conceived various recommendations in six working groups which targeted different themes.⁷⁸ Selected recommendations concerned the identification of four core areas with high development potential (see also above; these areas still take a core position today), the improvement of knowledge and technology transfer through better networking and interlinkages (particularly for SMEs), and Training and securing skilled employees. Based on these recommendations, the regional government conceived various measures. Among them are for instance state-wide initiatives in the defined future-oriented fields and agencies as well as theme-specific calls for (collaborative) projects (see for instance state initiative electronic mobility, state agency e-mobility, complemented through supporting instruments such as innovation vouchers, support of research and transfer, procurement, infrastructure development, model demonstrator projects),⁷⁹ and the Clusterportal Baden-Württemberg as state-wide innovation and cooperation platform. Further measures which are based on the Council’s recommendations refer to the further support of Industry-on-Campus initiatives, promoting science-industry cooperation, strengthening innovation capacities in SMEs or qualification measures.⁸⁰

The current regional government does not foresee to implement a further Innovation Council in the near future. Instead, it strengthened the dialogue-oriented economic policy in Baden-Württemberg. This policy concept is implemented through continuous exchanges between the ministries and representatives of regional science, industry and society. Following this vision, the Government organized various summit

⁷⁸ Six working groups (1. Baden-Württemberg 2025: Economy, Society, and Industrial Change; 2. Strategies to counter skills shortages; 3. State-Economy-Science-Culture: Framework Conditions for Innovations; 4. Universities and Research Institutes as Partners of Industry: Knowledge and technology transfer; 5. Strengthening Innovation Capacities of Small and Medium-Sized Enterprises; 6. Ecology & Economy – Mobility and Environment) worked on the Council’s programme. This working programme had the following core fields: Shaping favourable framework conditions to secure Baden-Württemberg’s innovation capacities and competitiveness; Identifying technological areas with high development opportunities in Baden-Württemberg; Strategies to cope with skills shortages; Strengthening flexibility and efficiency of knowledge and technology transfer between science and industry; Identifying new drivers for innovation at the intersection of state, economy, science, and culture; Strengthening innovation capabilities in small and medium-sized enterprises; Supporting start-up activities, especially in high-tech fields; Innovation-friendly climate in the general public and in policy; Innovation alliances at the interlinkage of economy and ecology. Cf. Staatsministerium Baden-Württemberg, 2010.

⁷⁹ https://mvi.baden-wuerttemberg.de/fileadmin/redaktion/m-mvi/intern/dateien/PDF/Landesinitiative_Elektromobilit%C3%A4t_IL.pdf (15/12/2015). Further activities in e-mobility are the support for clusters and the leading-edge cluster electronic mobility south-west, as well as support for new institutes or research laboratories. See Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/6504, https://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/6000/15_6504_D.pdf (15/12/2015) for further information in all future-oriented fields

⁸⁰ Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/6504, https://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/6000/15_6504_D.pdf (15/12/2015)

meetings with sector-related, territorial or theme-oriented focus in Baden-Württemberg in order to further develop regional innovation policy. Based on the Innovation Council's recommendation of more strongly focusing on sustainability as a common principle in the regional economy, policy and science, the Government established the Board for Sustainable Development with 39 representatives of diverse organisations and interest groups in the state. The concept of Baden-Württemberg's sustainable development includes all dimensions of sustainability, thus comprises the ecological dimensions, but also refers to social aspects, industry, welfare, education, technology assessment and various further fields.⁸¹

There are various examples for dialogues in the context of dialogue-oriented economic policy of Baden-Württemberg, such as for instance the Alliance Skilled Labour (*Fachkräfteallianz*) mentioned above or the Expert Commission engineering sciences (see also above) or sectoral dialogues in automotive and mechanical engineering, to name just a few (Ministerium für Finanzen und Wirtschaft Baden-Württemberg, VDMA, IG Metall Bezirk Baden-Württemberg, 2014, Ministerium für Finanzen und Wirtschaft Baden-Württemberg, 2015c).⁸² In August 2015, the Minister of Finance and Economic Affairs and key stakeholders from associations, and unions presented the results of the Dialogue Industry. This consultation process of business, employer and employee representatives resulted in recommendations for the further development of the industrial location Baden-Württemberg. Main areas are related to the attraction of skilled experts for industrial sectors, strengthening innovation and start-up activities, shaping attractive conditions for industrial activities, and improving industrial acceptance. These are embedded in a coherent vision for future development and include the state's vision on digitalization aspects and Industry 4.0 (Ministerium für Finanzen und Wirtschaft Baden-Württemberg, 2015d).

Summarizing, this policy approach focuses on the participation of relevant regional stakeholders, as well as awareness-raising for crucial topics. It is conceived as direct exchange process fed by the different concerned actors and representatives. It can therefore be characterized as consensus-oriented bottom-up process that involves the broad public and society, leading to well-accepted and consistent recommendations. Besides this effect, the participating organisations act as multipliers to diffuse the recommendations within their organisations and networks.

2.6 Possible future orientations and opportunities

Though belonging to the group of innovation leaders in Europe, Baden-Württemberg faces various challenges for the future development of the region and for maintaining its high rank as industrial location and innovation region. Possible future orientations respond to the challenges and specific conditions that the state faces.

- **Maintaining and increasing efforts in research, development and innovation**

With respect to research, development and innovation, Baden-Württemberg holds a leading position in Europe, as Eurostat statistical indicators, the Baden-Württemberg innovation index and the Regional Innovation Scoreboard prove (see also above and

⁸¹ Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/6504, https://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/6000/15_6504_D.pdf (15/12/2015), Landtag Baden-Württemberg, 15. Wahlperiode, Drucksache 15/2071, http://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP15/Drucksachen/2000/15_2071_D.pdf (4/12/2015), <http://www.nachhaltigkeitsstrategie.de/>

⁸² See also <https://mfw.baden-wuerttemberg.de/de/service/presse-und-oeffentlichkeitsarbeit/pressemitteilung/pid/automobilialog-in-stuttgart-minister-schmid-bespricht-mit-unternehmensspitzen-die-zukunft-des-auto/> (15/12/2015). See the Regional Innovation Strategy for an overview: Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013: 18.

BAK Basel Economics AG, 2011). However, going deeper into statistical details also shows that (1) R&D activities are not evenly distributed among all types of business actors in Baden-Württemberg, (2) other European regions catch-up, and (3) innovation success is to an increasing extent determined on the global scale.

In this respect, it seems important for the region to maintain and even increase its R&D and innovation efforts in the future. While R&D investments of larger manufacturing companies are already high and above-average, there is still potential for the large group of regional small and medium-sized enterprises (see also below) and for knowledge-intensive services. Though Baden-Württemberg has a long industrial tradition and sees itself as industrial region, the service sector also has large innovation potentials, provides highly-qualified jobs and produces high shares of regional value added: In 2014, the manufacturing sector contributed with 35.0% of Baden-Württemberg's value added while services had a share of 59.8% (trade, logistics, hotel and restaurant industry, information and communication: 18.2%, financial services, insurances, business services, real estate: 23.4%, public services, education, health, private households: 18.2%. the remaining shares are generated by construction (4.6%) and agriculture (0.5%); Statistical Office Baden-Württemberg). This shows that both manufacturing and services are important elements of the regional industrial structure and that both of these sectors generate innovations – with different shares of formal internal R&D efforts. Thus, innovation not exclusively refers to manufacturing or to services, but to both as they are interlinked. This is of particular importance in the light of Industry 4.0 where machines, processes and services are interconnected.

A further important factor in this respect refers to internationalisation. Competitive advantage cannot be achieved on the regional or national level anymore, but is determined on a global scale. Germany and Baden-Württemberg are active international players (see also page 9), but access to international knowledge refers to the engagement in European and international research networks and collaborative ventures. It seems to be important to involve a broad range of regional actors into international activities, be it in the context of education and qualification, research, science and technology, and cultural aspects that can bring people together and pave the way for future efficient crossborder cooperation. Baden-Württemberg has various programmes and actors that engage in this field (e.g. European Territorial Cooperation/ Interreg).

The targeted support of future-oriented fields with regional growth potentials is an important key area of Baden-Württemberg's innovation policy. It is complemented by further innovative core areas (aerospace, creative industries) and key enabling technologies, as conceived in the Coalition Agreement, the Regional Innovation Strategy and the ERDF Operational Programme 2014-2020 (Ministerium für Finanzen und Wirtschaft Baden-Württemberg et al., 2013, Bündnis 90/ Die Grünen Baden-Württemberg, SPD Baden-Württemberg, 2011, Ministerium für Ländlichen Raum und Verbraucherschutz Baden-Württemberg, 2014). This is consistent with the principle for focussing policy efforts and public funds on the most promising fields. It is further consistent with specialisation requirements. On the other hand, the state government is aware of new emerging fields with potentials for further development. This is mainly realised through continuous exchanges with regional experts and stakeholders.

- **Creating stable and favourable framework conditions for innovations and being open for new developments**

Creating and maintaining favourable context conditions for innovation activities to be realized is a crucial ingredient for innovation. This includes a broad range of factors such as the production of knowledge and technologies, the provision of innovation funding, the organization of cooperation activities, etc. It also refers to legal aspects and to factors that reduce uncertainty in innovating companies. Among these are for instance contractual fundamentals of cooperation, particularly in a transnational perspective, qualification aspects or requirements for introducing Industry 4.0 in different types of companies. In addition, the definition and application of standards is

an important topic, as are the questions of validating inventions, and the EU patent. In principle, creating favourable framework conditions for regional companies requires constant exchanges with innovation actors in order to get information on their specific needs and barriers to innovation.

Favourable framework conditions also refer to infrastructure of any kind. The regional government has a strong focus on science and research as basic element for innovation. Providing the whole region – agglomerations and peripheral parts of the territory alike – with favourable infrastructure conditions is of high importance. This strongly refers to the issues of digitalization and the availability of broadband throughout the whole territory, which is of particular importance in the Industry 4.0 context. In this respect, the regional government launched the Broadband Initiative that aims at further developing access to fast Internet particularly in rural areas.

Favourable framework conditions are also required in the leading topic of the current regional government: transformation of the energy system as a contribution to the ecological modernization of the production system. This transformation process requires the further development of renewable energies and increased energy efficiency. The support of these aspects, the implementation of state-wide strategies and the provision of incentives are crucial for creating innovation-friendly framework conditions. The regional government considers this through targeted support from regional funds, combined with EU funds (Ministerium für Ländlichen Raum und Verbraucherschutz Baden-Württemberg, 2014).

- **Integrating SMEs and their needs into the innovation process**

As shown above and in various indicator-based analyses of Baden-Württemberg in a comparative perspective, R&D and innovation-related data give a very positive picture of the federal state. However, a more detailed look reveals that small and medium-sized enterprises are not fully integrated in the research, development and innovation chain, neither on the regional, nor on the national and particularly on the international scale. To cite some indicators: Baden-Württemberg SMEs invest less in R&D and innovation and are less active concerning patent applications. The Baden-Württemberg industrial fabric is strongly dominated by this group of companies, including various “hidden champions” that are successful producers in niche markets on the national and international scale. Thus, regional SMEs have potentials for further increasing the regional innovation performance. The regional government launched various measures for supporting the regional *Mittelstand* (see above) and to improve the framework conditions for innovation activities in this specific group of industrial actors (e.g. industry-oriented research infrastructure, technology transfer, etc.). A further important factor is their integration in regional cluster initiatives in order to pave the way for (formal) cooperation activities and to integrate them in innovative value chains as a vehicle for them to make use of their flexibility and specialised knowledge in specific areas.

Appendix A Bibliography

1. Baden-Württemberg Stiftung gGmbH (Hrsg.) (2010): Strategische Forschung 2010. Autoren: Rainer Frietsch, Knut Koschatzky, Niels Weertman. Fraunhofer-Institut für System- und Innovationsforschung ISI, Elsevier. Studie zur Struktur und Dynamik der Wissenschaftsregion Baden-Württemberg. Schriftenreihe der Baden-Württemberg Stiftung Forschung; Nr. 49. Fraunhofer-Verlag, Stuttgart.
2. BAK Basel Economics AG (2011): Innovationskraft Baden-Württemberg: Erfassung in Teilregionen des Landes und Beitrag zum Wirtschaftswachstum. Basel.
3. Bündnis 90/ Die Grünen Baden-Württemberg, SPD Baden-Württemberg (2011): Der Wechsel beginnt. Koalitionsvertrag zwischen BÜNDNIS 90/DIE GRÜNEN und der SPD Baden-Württemberg. Baden-Württemberg 2011-2016. Stuttgart.
4. Bundesministerium für Bildung und Forschung (BMBF) (2014): Bundesbericht Forschung und Innovation 2014. Bonn, Berlin.
5. European Commission, Directorate-General for Enterprise and Industry (ed.) (2014): Regional Innovation Scoreboard 2014. Report prepared by Hugo Hollanders, Nordine Es-Sadki, Bianca Buligescu, Lorena Rivera Leon, Elina Griniece, Laura Roman.
6. Bundesministerium für Wirtschaft und Energie BMWi (2015): Erschließen der Potenziale der Anwendung von Industrie 4.0 im Mittelstand. Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie. Agiplan GmbH, Fraunhofer IML, ZENIT GmbH. Bundesministeriums für Wirtschaft und Energie: Berlin.
7. IHK Region Stuttgart (ed.) (2014): Industrieller Mittelstand: Spitzenstellung in Gefahr? Analyse zur Innovationsfähigkeit kleiner und mittlerer Unternehmen in der Metropolregion Stuttgart. Autoren: Christoph Zanker, Oliver Som, Daniela Buschak, Fraunhofer-Institut für System- und Innovationsforschung ISI. Stuttgart.
8. Industrie- und Handelskammer Karlsruhe (Hrsg.) (2012): Regionale Branchen- und Technologiestrukturen im IHK-Bezirk Karlsruhe. Auswertung und Analyse einer Untersuchung des Fraunhofer-Instituts für System- und Innovationsforschung (ISI) im Auftrag der Industrie- und Handelskammer Karlsruhe im Jahr 2011. Autoren: Thomas Stahlecker, Elisabeth, Baier, Esther Schricke, Oliver Rothengatter. Karlsruhe.
9. Institut für Arbeitsmarkt- und Berufsforschung IAB (2015): Industrie 4.0 und die Folgen für Arbeitsmarkt und Wirtschaft. Szenario-Rechnungen im Rahmen der BIBB-IAB-Qualifikations- und Berufsfeldprojektionen. IAB-Forschungsbericht 8/2015.
10. Institut für Angewandte Wirtschaftsforschung e.V. (IAW) (2015): Leidet der Wirtschaftsstandort Baden-Württemberg an einer Investitionsschwäche? Forschungsprojekt im Auftrag des Ministeriums für Wirtschaft und Finanzen Baden-Württemberg. Abschlussbericht. Tübingen.
11. Leibniz Universität Hannover, Institut für Wirtschafts- und Kulturgeographie (2010): Wissenschaftliche Begleitforschung zum Förderprogramm „Junge Innovatoren“. Auftraggeber: Ministerium für Wissenschaft, Forschung und Kunst des Landes Baden-Württemberg. Stuttgart.
12. Ministerium für Finanzen und Wirtschaft Baden-Württemberg (2012): Förderprogramme und regionale Maßnahmen zur Fachkräftesicherung in Baden-Württemberg. Allianz für Fachkräfte Baden-Württemberg. Stuttgart.
13. Ministerium für Finanzen und Wirtschaft Baden-Württemberg in Kooperation mit Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg, Ministerium für Ländlichen Raum und Verbraucherschutz Baden-Württemberg,

- Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg (2013): Innovationsstrategie Baden-Württemberg.
14. Ministerium für Finanzen und Wirtschaft Baden-Württemberg (2014): Innovationsgutscheine für kleine und mittlere Unternehmen. Jahrbuch 2014. Stuttgart.
 15. Ministerium für Finanzen und Wirtschaft Baden-Württemberg (2015a): Mittelstandsbericht 2015. Stuttgart.
 16. Ministerium für Finanzen und Wirtschaft Baden-Württemberg (2015b): Wirtschaftsdaten Baden-Württemberg 2015. In Zusammenarbeit mit dem Statistischen Landesamt Baden-Württemberg. Stuttgart.
 17. Ministerium für Finanzen und Wirtschaft Baden-Württemberg (2015c): Fachkräfteallianz Baden-Württemberg. Ziele, Bilanz und Maßnahmen 2015. Allianz für Fachkräfte Baden-Württemberg. Stuttgart.
 18. Ministerium für Finanzen und Wirtschaft Baden-Württemberg (2015d): Gemeinsam in die Zukunft – Industrieland Baden-Württemberg! Industrieperspektive Baden-Württemberg 2025. Stuttgart.
 19. Ministerium für Finanzen und Wirtschaft, Verband Deutscher Maschinen- und Anlagenbau e.V. VDMA, IG Metall Bezirk Baden-Württemberg (2014): Maschinenbaudialog 2014. Bericht und Fortschreibung. Stuttgart.
 20. Ministerium für Finanzen und Wirtschaft Baden-Württemberg, Fraunhofer IPA (2014): Strukturstudie „Industrie 4.0 für Baden-Württemberg“ Baden-Württemberg auf dem Weg zu Industrie 4.0. Stuttgart.
 21. Ministerium für Ländlichen Raum und Verbraucherschutz Baden-Württemberg (2014): Innovation und Energiewende. Operationelles Programm des Europäischen Fonds für regionale Entwicklung (EFRE) in Baden-Württemberg 2014-2020. Stuttgart.
 22. Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg (2014): Bericht zum Staatshaushaltsplan für 2015/2016. Stuttgart.
 23. Ministry of Finance and Economic Affairs Baden-Württemberg (2015): Regional Cluster Atlas Baden-Württemberg. Overview of cluster-related networks and initiatives. Created by ClusterAgentur Baden-Württemberg. Stuttgart.
 24. Staatsministerium Baden-Württemberg (Hrsg.) (2010): Innovationsrat Baden-Württemberg 2007-2010. Abschlussdokumentation. Stuttgart.
 25. TÜV Rheinland (2014): Bericht zum Breitbandatlas Mitte 2014 im Auftrag des Bundesministeriums für Verkehr und digitale Infrastruktur (BMVI). TÜV Rheinland Consulting GmbH. Berlin.
 26. Wirtschaftsministerium Baden-Württemberg (2010): Innovationsgutscheine für kleine und mittlere Unternehmen. Jahrbuch 2010. Stuttgart.
 27. Wissenschaftsrat (2015): Empfehlungen zum Verhältnis von Hochschulbildung und Arbeitsmarkt. Zweiter Teil der Empfehlung zur Qualifizierung von Fachkräften vor dem Hintergrund des demographischen Wandels. Drs. 4925-15, Bielefeld.
 28. Zentrum für Europäische Wirtschaftsforschung ZEW (2015): Für viele Unternehmen in Deutschland ist Industrie 4.0 noch ein Fremdwort. In: ZEW News, November 2015.

Appendix B Stakeholders consulted

1. Oliver Refle, Gruppenleiter Abteilung Reinst- und Mikroproduktion, Fraunhofer IPA (11 November 2015).
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3. Dr. Christiane Klobasa, Gennadi Schermann, Clustermanagement CyberForum (2 February 2016).
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