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ICDK OUTLOOK

TEST AND DEMONSTRATION FACILITIES IN SOUTHERN GERMANY

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Innovation Centre Denmark has the ambition to elevate Danish science and innovation through collaboration with world-leading innovation ecosystems.

Southern Germany, notably Bavaria and Baden-Württemberg, are hotspots for research and innovation.

Innovation Centre Denmark in Munich (ICDK Munich) connects Danish companies, research organisations and higher education institutions with the Southern German innovation ecosystem.

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IMPRINT

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EXECUTIVE SUMMARY

Southern Germany hosts a significantly high number of test and demonstration facilities. These play an important role in transferring new technologies to a level where the local knowledge-based industry can apply the technologies in new advanced production or products. For this ICDK Outlook, we have identified and presented 57 advanced test and demonstration facilities, which can be found in a map enclosed in this report.

Most of the test and demonstration facilities focusing on technologies are related to digitalisation and Industry 4.0 as well as energy & climate. Within these technology areas, a single technology might be of interest, but there is an increasing demand for testing technologies in full scale or to carry out systemic testing of functionality, efficiency, etc. in interplay with other technologies or real-life situations.

Establishing advanced test and demonstration facilities are challenging and often call for new organisational initiatives or models. The Outlook has investigated how organisational initiatives can be a vehicle to establish advanced test and demonstration facilities to speed up the process of innovation. Seen from the perspective of the test and demonstration facilities, the key observations are:

a. *Developing the test and demonstration facility*
   - Internally, pool all relevant test and demonstration facilities under one roof in a separate entity (department) which has the responsibility to handle collaborative and economic relations with the researcher and the industry.
   - To expand the size and technological capacity, collaboration with other facilities is common but on an informal base or based on a collaborative agreement (e.g., payment according to use of the facilities).
   - The industry can be an asset as it, under favourable economic conditions, can provide the test and demonstration facility with technical equipment or by supplying real-life data.

b. *Collaborating with the industry*
   - A research/innovation project defines the collaboration, typically approved by the management of the test and demonstration facility. The facility or associated researcher carry out the project, but the project is at the same time a platform for sharing knowledge and informal technology transfer.
   - Most projects are funded by public programmes. However, some facilities operate a financial schema (vouchers) to fund projects within the industry. Such schemas can include several projects reflecting steps in an innovation process.
   - Most projects are pre-commercial (results to be published). Consequently, the industry will have to purchase specific technical results. Or, if possible, establish the (further) collaboration as a commissioned project.
   - Informal dialogue between the test and demonstration facility and the industry can be ‘formalised’ to maintain and strengthen the exchange of knowledge, e.g., by establishing an ‘association’ as a regular meeting place.

Altogether, the benefits for universities are, among others, relevant PhD-training and the possibility of publishing research papers. For the industry, the benefit is leading-edge applied research (technology transfer) and bringing the new technology to the market will still be in the hands of the industry.

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1. INTRODUCTION

New technologies emerge rapidly, and in a globalised economy, the industry becomes more and more specialised. Research and innovation call for close interaction and collaboration between universities, research and technology organisations and private companies as it opens new opportunities, developing new technologies as well as challenges. One aspect is how test and demonstration facilities can form part of such collaborations, especially in the light of a new manufacturing regime as Industry 4.0 and advanced manufacturing, but also in areas in which technical innovation will often involve prototyping and large-scale testing to find solutions to address societal challenges concerning sustainability and the green transition.

Southern Germany is characterised by world-leading high-tech corporates, strong technical universities and research and technology organisations. As an innovation ecosystem, public and private partners often engage in long-term collaboration in some kind of 'under one roof collaboration'.

Through ICDK Munich's Industry on Campus platform, the innovation centre brings Danish universities, GTS institutes, innovation clusters and private companies, as well as government organisations, together to discuss and exchange experiences with Southern German counterparts on how research and innovation can be strengthened.

This ICDK Outlook describes and maps test and demonstration facilities in the ecosystem in Southern Germany. It provides insights into the test and demonstration landscape and includes cases based on research and interviews with key players.

This ICDK Outlook primarily looks at the facilities from a "provider/operator" perspective, including how universities, research and technology organisations and companies have initiated new organisational initiatives or models so that test and demonstration facilities can be a vehicle to speed up the process of innovation into industry and society. In this way, the ICDK Outlook should serve as a tool for Danish GTS Institutes, universities, innovation clusters and companies when looking for inspiration from Southern Germany on:

- How to improve public-private collaboration on research and innovation through long-term platforms with test infrastructure as a key element, thereby linking the current mapping to ICDK Munich's Outlook report on Industry on Campus Partnerships in Southern Germany.
- Business and collaboration models, as well as funding programmes that facilitate collaboration on test and demonstration. Furthermore, we will investigate whether some of the models and programmes lead the way for further international cooperation.

This report presents a selection of the most interesting test and demonstration facilities in Southern Germany as well as some cases to illustrate collaboration models.

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2. THE INNOVATION ECOSYSTEM ON THE MOVE

The innovation ecosystem is well-developed in the federal states Bavaria and Baden-Württemberg. It is an outcome of a significant demand or need for having access to test and demonstration facilities, and the political focus is on supporting the industry to be at the technological forefront.

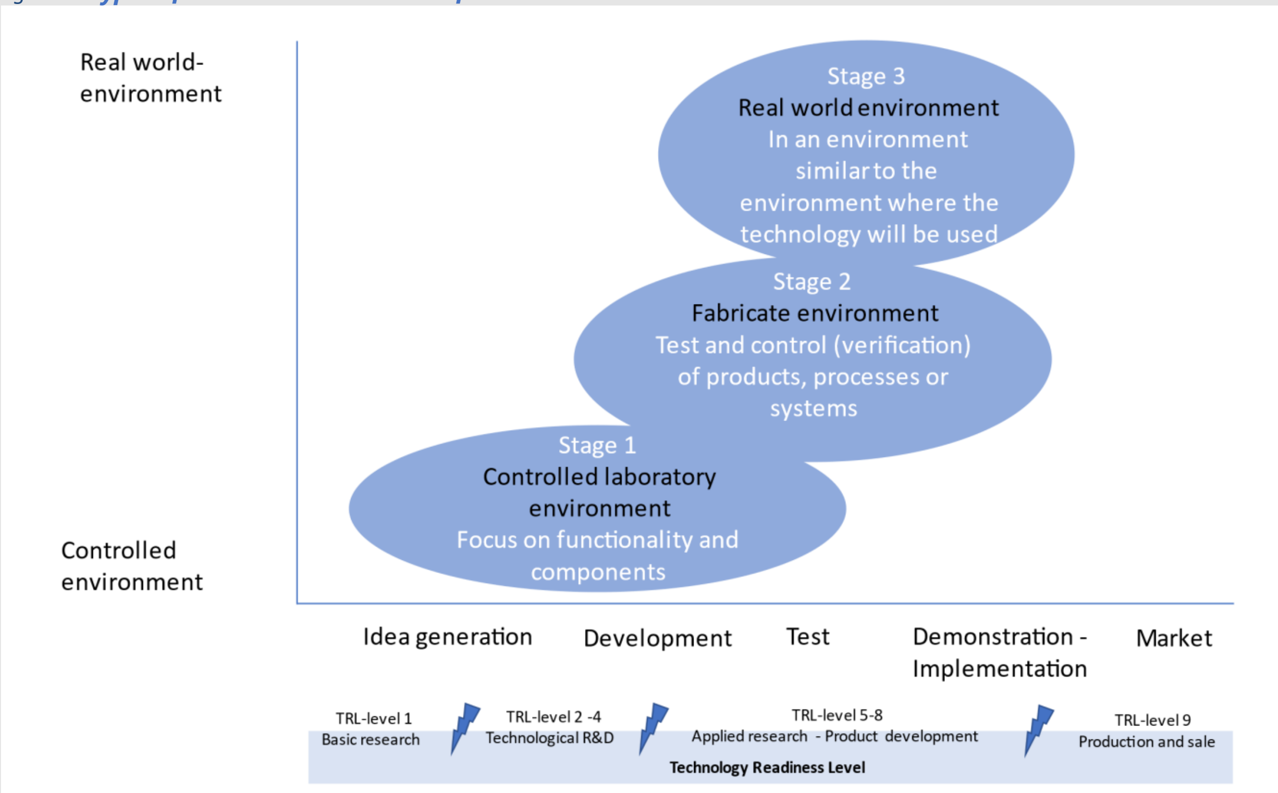
In this section, we give a brief presentation on trends affecting the development of the technological infrastructure, a political framework for strengthening the innovation infrastructure and an overview of test and demonstration facilities of interest for this Outlook.

TRENDS AFFECTING THE NEED FOR TEST AND DEMONSTRATION FACILITIES

During the last decades, we have seen significant technological development due to, e.g., increased digitalisation, new materials and ingredients, as well as societal challenges in relation to sustainability and the green transition calling for new technological solutions. At the same time, technological development has expanded the need for test and demonstration from a focus on specific solutions or products to a more systemic perspective with questions such as how the manufacturing or energy systems are working.

Test and demonstration facilities become fundamental in doing research and innovation with a technological focus. Figure 1 illustrates how different (generic) types of facilities can be of relevance in different phases of a research and innovation process.

Figure 1: ***Types of test and demonstration facilities used in research and innovation***



Source: Danish Technological Institute; https://gts-net.dk/wp-content/uploads/2020/09/Energi-Groen-omstilling-i-dansk-erhvervsliv-TDU-rapport-klar-til-udgivelse-PDF.pdf

In-house, individual companies will typically have access to only a limited capacity of test and demonstration facilities. Consequently, they will be searching for test and demonstration facilities to fill the gap of the company's own test and demonstration capacity. The search for test and demonstration facilities can be challenging as this market is not very transparent, and the demand for more technologically advanced services is growing.

At the same time, it has become more challenging, both technologically and economically, to established up-to-date test and demonstration facilities. Increased technological complexities impact organisational set-up for test and demonstration facilities. Furthermore, this leads to the question of how new organisational models be a tool to bring test and demonstration facilities into play and hereby strengthen the collaboration between RTOs/universities and the industry.

THE POLITICAL FRAMEWORK FOR STRENGTHENING THE INNOVATION INFRASTRUCTURE

Southern Germany, the backbone of the German production industry, is characterised by leading corporates and Mittelstand companies within manufacturing. The region is also home to leading technical universities and Fraunhofer institutes. There is a strong interplay between the industry and research organisations, especially when it comes to collaboration involving test and demonstration facilities.

Several political initiatives in the area of test and demonstration suggest that Germany, and in particular Southern Germany, can be of inspiration to Denmark. The Plattform Industrie 4.0 initiative of the German federal Hightech-Strategy provides an overview of test facilities across Germany. The platform also provides access to cases and projects on how test facilities have been used. Furthermore, associations of industrial partners have been established to facilitate the use of pre-competitive test centres, including within research and technology organisations.

The two southernmost federal states, Bavaria and Baden-Württemberg, are particularly interesting, not only due to their economic power and strongholds within Industry 4.0, but also due to well-developed technological infrastructure that through organisational innovation improves the access to and the use of test and demonstration facilities.

The Bavarian government's research and innovation plan, Hightech-Agenda, provides new investments in test infrastructure. The State of Baden-Württemberg's Allianz Industrie 4.0 network provides an overview of 100 Places for Industry 4.0 in industry and at Fraunhofer institutes and other research and technology organisations.

Furthermore, there is public funding available, at the federal-state level, to support collaboration on test and demonstration activities between research organisations and small- and medium-sized enterprises (SMEs) from Baden-Württemberg.[i]

AN OVERVIEW OF THE INNOVATION INFRASTRUCTURE

Our ambition is to focus primarily on the innovation infrastructure, excluding the research infrastructure. However, the boundary between the innovation and research infrastructures is somewhat blurred, not only in Germany but also in Denmark. In Germany, it is accentuated by a dedicated ambition of doing research that reaches out to be a platform for innovation by bridging the gap between research and innovation. As such, the research and innovation infrastructure can be seen as three-layered, including universities, large non-university research communities[ii] (The Fraunhofer Society (FhG), The Max Planck Society (MPG), The Helmholtz Association) and innovation institutes with close to-the-market-support (e.g. Innovationsallianz Baden-Württemberg).

Of special interest are test and demonstration facilities addressing new technological trends related to, e.g., digitalisation, Industry 4.0 and the green transition, as well as facilities addressing new organisational solutions (organisational innovation) enabling the facilities to establish close collaboration with the industry and offer technical facilities with more advantage.

The innovation infrastructure also includes test and demonstration facilities used to test that products or production processes are made or operated according to national or international standards and meet legal requirements. The aim is not to include organisations offering this kind of service; however, this kind of service might be a part of the services offered for the identified facilities.

Consequently, the mapping of test and demonstration facilities aims at presenting different kinds of test and demonstration facilities that:

- Are rooted in research as well as innovation where new, technological knowledge and insights are the outcome for developing or further development of products, production facilities or systems.
- Have applied a new organisational model enabling them to offer more advanced test and demonstration facilities or an applied systemic approach, e.g., an entire manufacturing system or an energy system.

The aim is to present a list of facilities that can be of inspiration for the Danish innovation ecosystem but not a complete inventory of all test and demonstration facilities.

We have developed a map of test and demonstration facilities in Southern Germany based on desk research and by scanning several websites.[iii] The map presents many specialised test and demonstration facilities and provides easy access to further reading.

In the following two sections, we will present a more in-depth analysis of test and demonstration facilities regarding organisational set-up that enable them to meet new technological challenges and at the same time encourage innovation and technology transfer.

3. THE INNOVATION ECOSYSTEM AT THE TECHNOLOGICAL FORE-FRONT

In this section, our perspective is on the overall structure of the innovation ecosystem. For this purpose, we have established an inventory of test and demonstration facilities.

Attention must be paid to the fact that the population of test and demonstration facilities is biased as new technologies or urgent technological issues have been a selection criterion. Facilities related to more traditional or standardised technological services might also initiate new forms of collaboration, though often more motivated by other factors than access to advanced test and demonstration facilities (see case innBW, section 4).

In the subsequent section, we present five case stories highlighting initiatives that, at the organisational micro level, have had a positive impact.

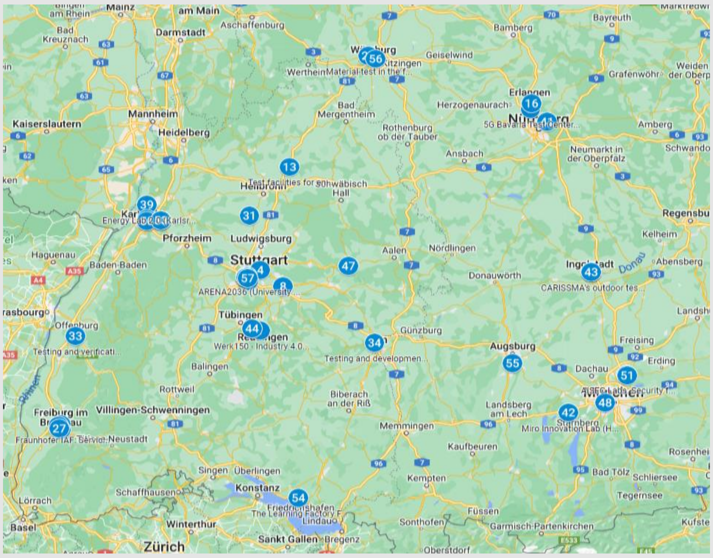
TEST AND DEMONSTRATION FACILITIES

An inventory has been established including 57 test and demonstration facilities (Figure 2). The test and demonstration facilities are concentrated around the major cities in Bavaria and Baden-Württemberg. These cities not only host universities and larger non-university research institutes but also often have established larger campus areas where other universities, research and technology organisations and training and educational institutions are co-located. Critical mass and proximity seem to encourage a successful technology transfer environment.

Figure 2:
Interactive map of the selected test and demonstration facilities in the federal states Bavaria and Baden-Württemberg.

http://t.ly/qnyl

Code: 'teknologisk'

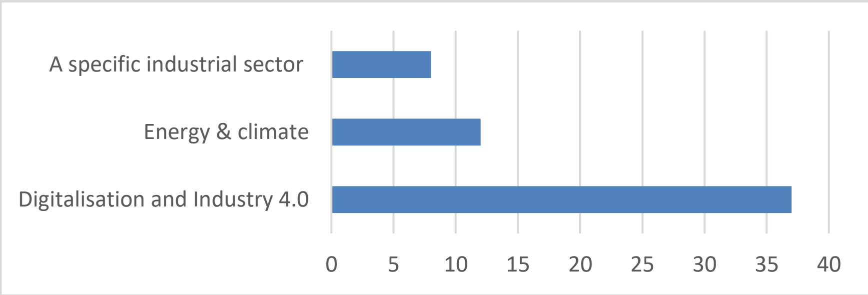


By using the QR-code/link, further information is accessible about each test and demonstration facility, e.g., name, address, contact information, technological sector (industrial cluster) in focus and a short description.

All the selected test and demonstration facilities are grouped according to their overall focus, whether the focus is on the industrial sector or the technology ((Figure 3). Most of the selected facilities have a technological focus addressing technological issues related to digitalisation/industry 4.0 and the green transition, which represents many newly enabled and critical technological areas. As such, the facilities also represent a need for new technological solutions and innovation, which also calls for test and demonstration facilities with a more systemic approach, e.g., living labs. Changes in technological approaches will often have organisational implications.

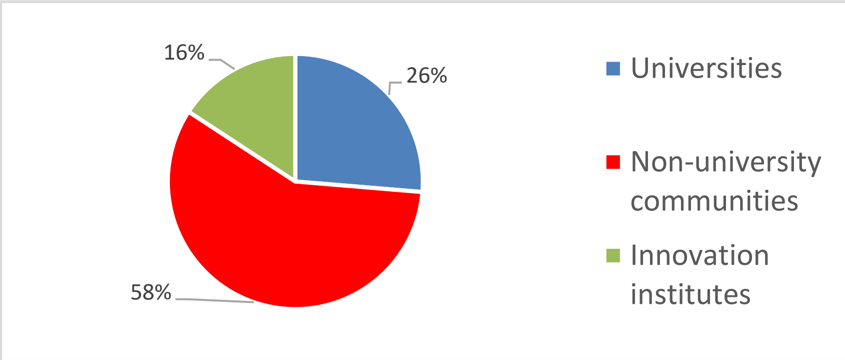
Figure 3:
Technological focus of the 57 selected test and demonstration facilities

Six of the facilities within Digitalisation and Industri 4.0 address manufacturing of automobiles



Further, the focus on new technological areas gives preference to certain parts of the innovation infrastructure, bridging the gap between basic research and innovation. The majority of the selected test and demonstration facilities are hosted by non-university research communities, probably due to their ability to handle applied research and research-based innovation and their capacity to operate advance test and demonstration facilities (Figure 4).

Figure 4:
Host organisations for the 57 selected test and demonstration facilities



All in all, it is mainly research organisations, universities and non-university communities that host test and demonstration facilities when the focus is on more advanced and complex technologies.

4. COLLABORATIVE FORMS - EXPERIENCES FROM SELECTED TEST FACILITIES

In Southern Germany, the innovation ecosystem aims to be an intersection between the technological forefront and innovation with a focus on utilisation of technology in society and industry. However, it is a major challenge to bridge the gap between basic research and bringing new technology into use. In the following section, we dive into how a focus on complex and advanced technologies and access to test and demonstration facilities becomes vital for transferring new technology into use. Notably, we identify the organisational setting and collaborative forms applied for a successful innovation ecosystem. Our interest is to present collaborative forms which improve the access to test and demonstration facilities dealing with complex and advanced technologies and the innovation process at the same time.

The collaborative models in focus are those being informal or less economically and less legally binding, as these are more easily applied by institutions with limited opportunities to operate on a free, commercial market or are excluded by entering common legal structures, including mergers and acquisitions.

This section is based on case studies mainly selected among facilities in the inventory. It has been a criterion in the selection of cases that the test facilities represent some form of organisational innovation. However, we have additionally included other organisational initiatives aimed at strengthening collaboration between test and demonstration facilities.

FORMS OF COLLABORATION

Collaboration can be a tool to establish larger and technologically advanced test and demonstration facilities as well as to improve or strengthen the access to and use of test and demonstration facilities. Regarding establishing larger and technologically advanced test and demonstration facilities, we observe that collaboration primarily involves the organisations holding the test and demonstration facilities and rarely industrial partners; industrial partners mainly focus on using the facilities (collaborative research or innovation projects) and do not consider themselves as a partner for establishing test and demonstration facilities.

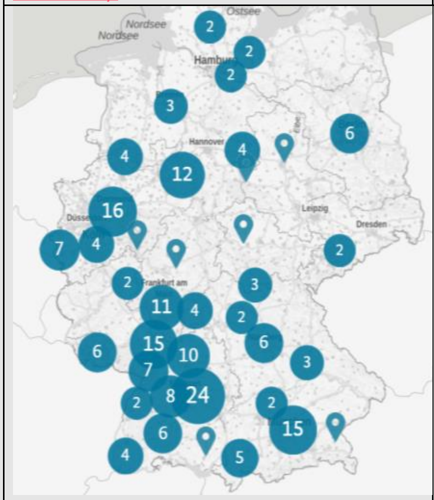
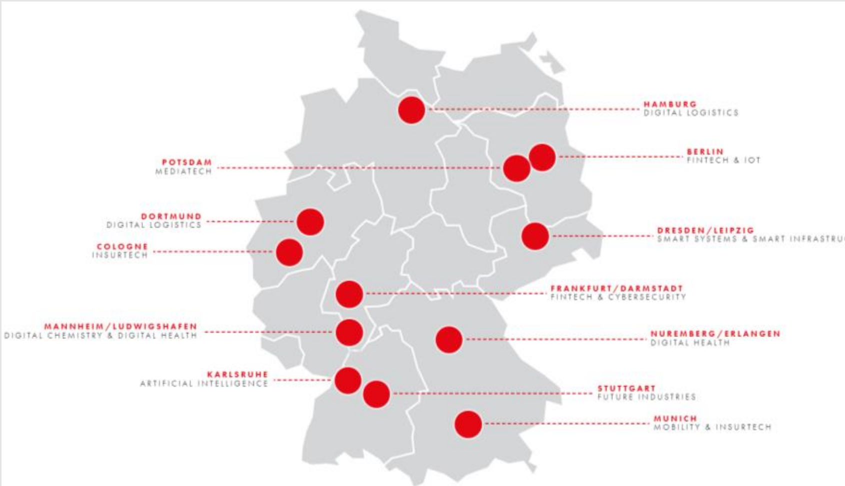
PLATFORMS – PROVIDING AN OVERVIEW OF FACILITIES

Test and demonstration facilities are often hosted by universities, non-university research communities or innovation institutes where test and demonstration facilities are not the main activity and service. It can often be a challenge to find the test and demonstration facilities. One key question is how to increase access to test and demonstration facilities, especially for more advanced or specialised demand.

Several initiatives aim at making the market more transparent, typically by establishing digital platforms where the industry can search for test and demonstration facilities. In addition to such a service, different kinds of matchmaking services are offered either as a commercial service for the individual company or as an in-house service for a large RTO.

Such initiatives are common and known as an instrument in the industry and innovation policy (Figure 5). However, when it comes to efficiency regarding matching test and demonstration facilities and the industry, it seems that we are lacking systematic knowledge.

Figure 5:
Digital platform offering an overview and access to test and demonstration facilities.

Platform Industrie 4.0 Source: Plattform Industrie 4.0 - Homepage (platt-form-i40.de)	Digital Hub Initiative Source: DE Hubs / Digital Hub Germany
	

Some of the more advanced and complex test and demonstration facilities have also established their own platform or landing page on their website to provide an overview of the offered facilities and the probabilities for applying the different facilities in common projects (e.g., the case ‘Energy Lab 2.0’).

LEGAL AND INSTITUTIONAL SETTINGS - A CONSTRAINT FOR COLLABORATION

The universities represent a significant part of the hosting organisation. Based on the cases, universities have identified a potential for excellent research by having access to advanced testing facilities and real-life data or knowledge by collaborating with the industry. It is commonly seen that such test and demonstration facilities at universities are established as a separate entity, typically a non-profit organisation. Through a non-profit organisation, the universities can develop and operate a test facility, and if relevant, in collaboration with other research institutes and/or industrial partners. However, such collaborations will typically be informal or formulated as a project and not in terms of shared ownership, such as a legal entity (a company) with any economic obligations.

At the same time, a non-profit organisation can host collaborative research or research-based innovation projects independently, whether the projects are publicly or privately funded. Besides an excellent research platform, the benefits for universities are, among others, relevant PhD-training and the possibility of publishing research papers. For the industry, the benefit is leading-edge applied research (technology transfer), even though bringing the new technology to the market will still be in the hands of the industry.

AN ASSOCIATION – A STRATEGY TOOL AND A PLATFORM

The Innovationsallianz Baden-Württemberg (innBW) is an association of the ten legally independent non-profit, non-university research institutions. As an association, innBW promotes both itself (and all the institutions) as the brand and all the different services offered to their client (the industry). Internally, innBW encourages a common dialogue and collaboration which aims at strengthening the institutes’ ability for more complex and/or relevant projects or services in the industry.

UNDER ONE ROOF – ACCESS TO COMPLEX OR SYSTEMIC TEST AND DEMONSTRATION FACILITIES

In recent decades, the need for test and demonstration facilities has expanded from technical tests to tests that focus on more technical systems. To deal with complex and advanced technologies’ ‘system problems’, new and different kinds of technical facilities have been integrated into larger test and demonstration facilities or living labs.

Energy Lab 2.0 performs research on the green energy transition with a systemic approach to developing and testing new renewable energy. With an emphasis on energy grids, Energy Lab 2.0 is an integration of various storage technologies, novel grid hardware and control mechanisms and an effective interface between electricity, heat and chemical energy carriers. The systematic approach also includes the understanding of user acceptance and the enhancement of user involvement with innovative energy solutions.

FZI was challenged by having test facilities situated at several locations and not having the technical capacity (hardware) sufficient to carry out larger, innovative projects as well as systemic tests. Further, FZI could not house larger industrial projects. A reorganisation was needed. The establishment of FZI House of Living Labs reflects the need for access to larger and more technologically diverse testing facilities. To remain an attractive collaborative innovation partner, FZI House of Living Labs is in the process of scaling up their test facilities with 'real living labs'.

Smart Data Innovation Lab supports the 'Industry 4.0' transition by offering big data research and innovation providing the industry with new knowledge to develop Industry 4.0-industrial concepts. To do so, Smart Data Innovation Lab has established a unique state-of-the-art hardware and software platform. Further, Smart Data Innovation Lab undertakes research based on real-life data provided by the industry, which has called for a platform for data sharing and setting up collaborative, applied research projects with strong security procedures and a legal framework for shared and protected data.

The above cases illustrate not only a new platform for test and demonstration facilities but also a tighter collaboration between different facilities and, in some cases, also between facilities situated at different and independent host organisations.

INDUSTRY AS A STRATEGIC RESOURCE FOR DEVELOPING TEST AND DEMONSTRATION FACILITIES

The industry can be an asset for the test and demonstrations facilities, which the following cases illustrate:

At Smart Data Innovation Lab, establishing a unique technological infrastructure is rendered possible by contribution from the industry, among others, without the need for acquiring separate licensing or dealing with a complicated cost structure. Further, high-quality research has been possible due to real-life data provided by the industry making the research applicable to real problems.

In relation to FZI House of Living Labs, the FZI Friends' Association is established as a network for companies and other organisations where FZI and its members can be in contact, exchange knowledge and benefit from FZI's competence. FZI Friends' Association provides FZI House of Living Labs with input that supports the work at FZI in initiating, planning and realising new projects.

EASING THE USE OF TEST AND DEMONSTRATION FACILITIES THROUGH FUNDING OF INNOVATION PROJECTS

To ease access to a test and research environment, S-TEC applies an institutionalised and publicly funded public innovation process where enterprises can explore the potential of the new technologies. The first step is a 'Quick Check' (Proof of Concept to identify the feasibility of the technology for the enterprise), and the second step is 'Exploring projects' (short-term implementation strategy based on the Quick Check which can also include prototyping, etc.) The S-TEC coordinator evaluates the applications for these two steps. However, the enterprises defray the expenses for technologically more advanced projects.

OPERATING A TEST AND DEMONSTRATION FACILITY

In general, an entity, i.e., a department, within the host organisation operates the test and demonstration facilities, not as an embedded activity within a research or innovation department, as running a facility requires dedicated management. It is emphasised that establishing and running a large and technologically advanced facility is a challenging task as it must:

- host advanced technical equipment, which calls for ongoing investment
- be able to attract qualified technicians to maintain and operate the facility
- establish an administrative structure for collaborative projects whether the funding is public or private (commissioned project)
- facilitate an environment or a culture that encourages research and innovation as well as collaboration between researchers and the industry.

The management structure typically consists of a daily manager or coordinator supported by a steering committee. The management often must approve the research/innovation project to be performed at the facility. Professional staff will operate the test and demonstration facilities while researchers (in some cases PhD-students supported by professors) will have the responsibility for the research/innovation projects.

The test and demonstration facilities do not apply a single financial model other than making use of several funding sources such as basic public funding, public and private funding of projects (including national and foreign research and innovation programmes) and in-kind contributions from the industry (e.g., equipment, data, etc.). The host organisation will typically have an interest in hosting the facility and hereby also contribute economically by operating the facility.

To operate a test and demonstration facility as a platform for knowledge sharing and technology transfer, an ability (soft engineering) to facilitate dialogue and collaboration with other facilities and with the industry is required. Some examples are mentioned above to stress that the facilities are also an informal platform encouraging innovation even though it is up to the industry to bring the new technologies to the market.

OPEN FOR NON-GERMAN USERS OR COMPANIES

The entire German innovation infrastructure for test and demonstration facilities is technologically advanced. From a Danish perspective, some Danish industries might have an interest in gaining access to these facilities. In general, the German facilities are open-source facilities, though access can only be through joining internationally funded or commissioned projects. For commissioned projects, it seems advantageous if the Danish industry is accompanied by a Danish research organisation to ensure proper dialogue and an efficient techtrans process of the technology into a Danish setting.

The value of test and demonstration facilities is more than access to technical facilities. The organisational setup and relationships and collaboration with other test and demonstration facilities as well as with industry are key to enhancing the value of the test and demonstration facilities.

All in all, the experiences from the five cases presented below emphasise that test and demonstration facilities are more than services to solve technical problems; they are vital for encouraging more complex innovation processes.

CASE 1: S-TEC: STUTTGART TECHNOLOGY AND INNOVATION CAMPUS[IV]

The main aim of S-TEC is to bridge more basic technological research to further technological development in terms of developing applicable, new, competitive solutions for the German industry, especially in Baden-Württemberg. Conceptually, S-TEC is an innovation facility to bridge the 'valley of death' by facilitating applied research and collaborative innovation projects between research and the industry. However, S-TEC is a brand, or virtual organisation, as S-TEC sets the scene for innovation and collaborative projects, but the specific projects are hosted at the involved research and innovation institutes.

Motivation

It was observed that new technologies, e.g., Key Enabling Technologies and technologies related to Industry 4.0, were not or very slowly introduced to the market, and adapted in the industry. S-TEC was established to facilitate the development of these new technological solutions to be introduced in the industry.

The organisation for preparing new technologies for industrial use

S-TEC is established at the top of six research institutes in Stuttgart[v] as a virtual organisation and acts as an umbrella organisation with a high-profile brand for utilisation of cutting-edge technologies with the potential for industrial use. As such, S-TEC is a meeting place facilitating a dialogue on selected new technologies with industrial potential with the aim of encouraging the industry the use of technology. In common, S-TEC and the Baden-Württemberg Ministry of Economics, Labour and Tourism agree on new technologies to be further developed. In the frame of S-TEC the selected technological areas are then made ready for industrial use:

1. A development project is established at S-TEC Center, running for up to 4 years, and initiated for further technological development, especially to develop solutions and tools applicable to the industry. Such a project is formed by at least two research centres, preferably from different institutes associated with S-TEC. Within the project, technical research and testing are carried out.
2. Promising technical outcomes for industrial use are formed with a capacity of 10-15 experts from the S-TEC institutes. In total, 13 centers are established within individual research topics.[vi]

This approach is dynamic, as new technologies are constantly researched, and the most innovative and promising industrial technology will remain in S-TEC's portfolio. The development project and S-TEC centers are established as part of one of S-TEC's institutes, which is legally and economically responsible for the operation of the centre (e.g., managing resources, access to and maintenance of test and demonstration facilities, etc.).

Collaboration with the Industry

S-TEC has an institutionalised system within which the individual smaller and larger enterprises can explore the potential of the new technologies and implement them in products and/or in the production of applied research or innovation projects close to the market. The main types of collaborative projects are:

- Quick Checks – Proof of Concept to identify the feasibility of the technology for the enterprise.
- Exploring projects – Short-term implementation strategy based on the Quick Check which can also include prototyping, etc.
- Industry projects where the enterprise has further ambitions of applying the new technology.

S-TEC is the hub for networking. The Stuttgart Technology and Innovation Campus S-TEC brings companies together with scientific institutions at the Stuttgart location. Cooperation in S-TEC centers enables partners to systematically develop strategic innovation topics outside their own corporate structures. In this way, topics are approached cooperatively from different perspectives, infrastructures are shared and networks are institutionalized together.

Source: S-TEC

Funding research and enterprise projects

Baden-Württemberg Ministry of Economics, Labour and Tourism funds the initial preparation of new technologies for industrial use as well as Quick Checks and Exploring projects.

Typically, medium-sized enterprises with an established product portfolio and market apply for Quick Checks and Exploring projects. An S-TEC coordinator evaluates the application (based on a checklist) where the initial technical feasibility and possibility to assist the enterprise is assessed as well as their innovation capacity.

Industry projects are for the more technologically advanced enterprises with ambitions for expanding their business internationally. The enterprises defray the expenses for these kinds of projects, typically about 100,000 euro.

Since 2018, S-TEC has assisted the industry with more than 150 projects.

Some lessons learned

All in all, S-TEC turned out to be successful in transforming and transferring new technologies into industrial use. S-TEC has been established as an informal organisational structure that meets both society's goals and the ambitions of the industry to make use of new technologies.

Kai Kohler, Coordinator of S-TEC, underlines: 'S-TEC builds a local ecosystem where a crucial success parameter is a proximity and closeness between the involved institutes, which leads to trustful collaborative relations and openness for innovation'. Within this environment of innovation, S-TEC is a driving force bringing the different parties together in projects doing applied research and innovation. The structure of different types of projects formalised collaboration through projects clarifying the conditions for sharing and utilising knowledge (e.g., non-disclosure agreement) as well as the economic conditions (including public support), encourage or push the technological development forward.

Test and demonstration facilities are an integral part of this local structure for industrial innovation. Each institute has its own test and demonstration facilities, but in collaborative projects, these facilities come into use to address mutual ambition for innovation.

CASE 2: FZI HOUSE OF LIVING LABS[VII]

Established in 1985, applied research was a clearly defined scope of the FZI Research Center for Information Technology. At an early stage, individual research groups within the FZI set up topic-specific laboratory-like environments. Since then, intense technological development within information and communication technologies has taken place. The technological scope expanded, and so did the need for scaling up the labs (test facilities). The test facilities were situated in several departments at the FZI as the technical capacity (hardware) was not necessarily sufficient to carry out larger, innovative projects as well as systemic tests, often due to the lack of space. The establishment of the FZI House of Living Labs in 2012 reflects the need for access to larger and more technologically diverse test facilities. To remain an attractive collaborative innovation partner, the FZI House of Living Labs is constantly in the process of scaling up its test facilities, such as through the expansion with 'external living labs', e.g., the Test-Area Autonomous Driving Baden-Württemberg (TAF BW) – a laboratory for testing smart mobility concepts in a real-street environment or Smart East – smart, energy-optimized, climate-friendly quarters.

Motivation

The FZI House of Living Labs is established to be an innovative platform for collaborative research and development between researchers and the industry. The main advantage is the development and evaluation of innovative products in real-life scenarios with access to in-depth expertise and comprehensive and advanced Information and Communication Technologies (ITC) facilities, which is difficult to establish for the industry (the individual company), especially for SMEs. It is also risky to perform tests on ICT in ongoing production. Furthermore, the FZI House of Living Labs is seen as a meeting point for the transfer of knowledge (research) to the industry and input from the industry to research.

The organisation for preparing new technologies for industrial use

The FZI Research Center for Information Technology was established in 1985 as a separate non-profit organization. The FZI is an innovation partner of the Karlsruhe Institute of Technology (KIT) with the aim of doing applied research and innovation projects in collaboration with the industry; it works as a platform for transferring knowledge and technology to the industry. In 2012, the FZI House of Living Labs was established as a platform for collaborative research and development of innovative applications and one of the first Living Labs with several labs under one roof. The FZI House of Living Labs is also a facility where cross-sectional topics can be addressed, shown by the FZI Living Lab Security and Law and the FZI Living Lab Software Innovations. In 2022, the Living Labs represent seven different focus areas and are extended by additional spatially distributed real labs, e.g., the TAF BW for testing smart mobility in a real street environment, or Smart East for climate-friendly energy supply for an existing urban quarter with commercial and residential areas.

A lab manager, typically an experienced research associate at the FZI Research Center for Information Technology, is the head of each lab and is responsible for the technical infrastructure and management of the projects. As a collaboration between the labs, it is common that a coordinator is responsible for the coordination of the activities across the seven labs as well as for guided tours for visitors from industry, the public sector and politics. The FZI as a whole has 245 employees, several of whom are also working in the Living Labs of the FZI House of Living Labs.

Collaboration with the industry

Typically, the project ideas originate from more basic research, but at the FZI Research Center for Information Technology, applied research is a focus but with industrial relevance. This is emphasized by the participation of industrial partners in most projects. Often, the initiative to new projects comes from the FZI, but the FZI is open for new ideas and proposals from the industry, business, science, associations and the public sector.

The projects are typically implemented by research associates as the driving force.

The outcome of the projects typically aims at presenting a solution or a prototype (proof of concept). The prototype serves as a platform for the exchange and the generation of new ideas, as well as for technological development, integration, investigation and testing. Furthermore, the FZI supports companies in bringing innovative solutions and prototypes to market maturity and, if necessary, connects them with network partners who support them financially.

Besides the collaborative projects, FZI events and visits, the FZI is also attached to the industry through the FZI Friends' Association. The FZI Friends' Association is a network for companies and other organizations where the FZI and its members can get in contact, exchange knowledge and benefit from the FZI's competence as well as support the work at the FZI in initiating, planning and realizing new projects.

Funding of projects

In 2021, the FZI had 190 projects of which 120 projects were publicly funded projects, implemented as collaborative projects between the FZI and companies. 70 projects were directly commissioned projects, where the industrial partner bears the cost and in return has the rights to use the outcome of the project.

Some lessons learned

The main ambition of the FZI House of Living Labs is to be an attractive technology transfer partner for the industry through implementing concrete innovation projects with the aim of developing new technology to a prototype level applicable to the industry. Coordinator of the FZI House of Living Labs, Natalja Kleiner, points out two critical success factors:

"To be an attractive innovation environment for the industry, the FZI House of Living Labs must give the industry access to highly skilled researchers and advanced state-of-the-art test and lab facilities. To be successful in this manner, the FZI has been able to update their lab facilities technologically and, what is just as important, added organizational innovation to the development. Seven labs are co-located under one roof, but each lab has a clear technological scope. However, internal coordination secures collaboration between the labs and their different technological scopes."

As the FZI House of Living Labs mostly focuses on industrial partners in the projects, which is also important for funding, the FZI House of Living Labs must be very visible among potential industrial partners. Events, visits and the FZI Friends' Association are important factors. However, it is often observed that the research associates go into the industry after finishing their PhDs and in the future become clients.

CASE 3: ENERGY LAB 2.0[VIII]

Energy Lab 2.0 is a research infrastructure for renewable electrical (wind and solar), thermal and chemical energy where the main topic is the functionality of the energy system. The focus is on how to improve transport, distribution and storage and how to use electricity, thus creating the basis for the energy transition (Power-to-X). All in all, Energy Lab 2.0 does research in the green energy transition, which calls for a systematic approach to test and demonstration. Energy Lab 2.0 is established as a collaborative project managed by a steering committee, and a staff of professionals operates the entire network of facilities. Energy Lab 2.0 is a facility for doing research. However, collaborative projects with the industry continue to be the main part of Energy Lab 2.0 if research remains in focus.

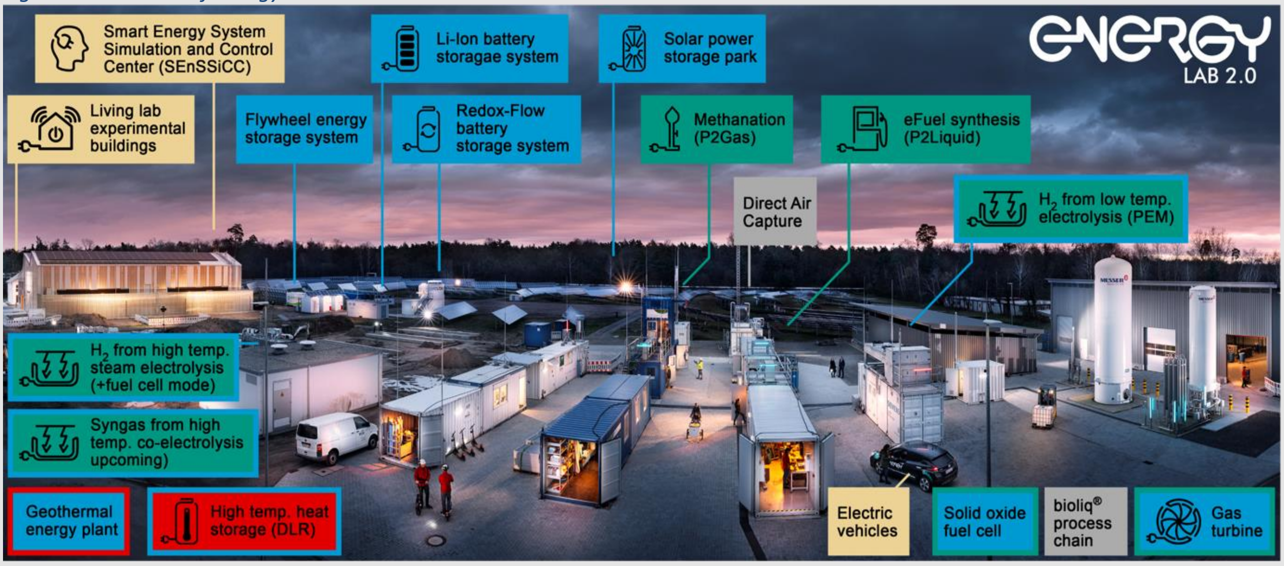
Motivation

The increasing need for renewable forms of energy requests more than just new technologies but research on the entire energy system, e.g., the components and their interaction, technologies for green energy transition, transportation, mobility and storage technologies, grid architectures and control systems. Energy Lab 2.0 was established to meet these needs by facilitating a systematic approach to energy research and testing for research in different fields and with different approaches.

A professional organisation for research and development within a renewable energy system

With an emphasis on energy grids, the integration of various storage technologies, novel grid hardware and control mechanisms and an effective interface between electricity, heat and chemical energy carriers, Energy Lab 2.0 adopts a systematic approach to developing and testing new renewable energy. Further, the systematic approach includes the understanding of user acceptance and the enhancement of user involvement with innovative energy solutions in smart areas. Most of the laboratories and facilities are located at the Karlsruhe Institute of Technology (KIT) (Figure 1).

Figure 1: Overview of Energy Lab 2.0



Source: Energy Lab 2.0 (Photo: Markus Breig, KIT).

Energy Lab 2.0 is established as a cooperative projectix initiated by The Helmholtz Association.[x]

Energy Lab 2.0 is referred to as an ‘open use platform’, however with the ambition to do research from a relatively basic technological level to bring new technologies forward to the benefit of society. Consequently, research is in focus, where publicising the results is a key issue.

Energy Lab 2.0 has been operational since 2020. A steering committee is responsible for the overall strategy and development as well as the day-to-day management, implying that the steering committee evaluates and approves all new research projects based on their relevance and feasibility. A professional and permanent staff (not PhD students) operates and maintains the entire test facility which provides the facility with stability in terms of resources and competencies. As a result, access to utilise the facilities is restricted to projects that have been given approval and by using qualified employees to conduct tests, etc.

The main activity at Energy Lab 2.0 is research projects in collaboration with several research institutes, either at KIT and its partners or together with external research institutes. All research is defined as projects with their own external funding from Germany or EU research programmes, for example.

Collaboration with the Industry

Even though the scope of Energy Lab 2.0 is research, industry-oriented projects can use the Energy Lab 2.0. However, the projects must have research-related value and quality as publication is an integrated part of these projects. Some elements of these projects might be governed by a nondisclosure agreement; however, Energy Lab 2.0 is not a service facility where individual enterprises can demand support for innovation projects (commercial activities). The industry-oriented projects often originate from existing relationships (partnerships) between researchers and companies and a common interest in renewable energies and energy systems, typically among larger corporations with, e.g., car manufacturing, energy supply, public utilities, etc. Within these projects, informal relationships develop and become a forum for discussing industry-oriented topics of high relevance for innovation in individual companies. The industrial partners will typically fund 50 percent of the cost. Such projects count for 30 to 50 percent of the research activity at Energy Lab 2.0.

Some lessons learned

Prof. Dr. Veit Hagenmeyer, Co-founder of Energy Lab 2.0, highlights that the mission of Energy Lab 2.0 is the technological development in a systemic perspective and states: ‘The comprehensive scale of the test facilities covering the entire energy system is a unique advantage for energy research’. However, it has taken several years to get Energy Lab 2.0 up and running. A critical factor in this phase has been economic stability as it is crucial for the investments in technical equipment, for recruiting the professional staff and for encouraging an open collaborative research culture and systemic research approach among researchers. Even though Energy Lab 2.0 is research and not innovation (technological service), research-oriented corporations seem to benefit from Energy Lab 2.0 as the systemic approach provides new insight into the functionality of the energy system based on renewable energy. However, how to solve further technological development (innovation) and scaling up new insights on the functionality of the energy system remain a major challenge.

CASE 4: SMART DATA INNOVATION LAB[xi]

The Smart Data Innovation Lab (SDIL) has bridged several challenges in meeting the industry's need for big data research and innovation. A unique state-of-the-art hardware and software platform has been established through contributions from the industry and national government without the need for acquiring separate licencing or dealing with a complicated cost structure. Further, SDIL has access to unique ICT competences, has established a legal security structure to protect data and has access to real-life data provided by the industry. Hereby, SDIL has become a platform for collaborative projects between academia and industry, searching for hidden value in big data to the benefit of society and industry.

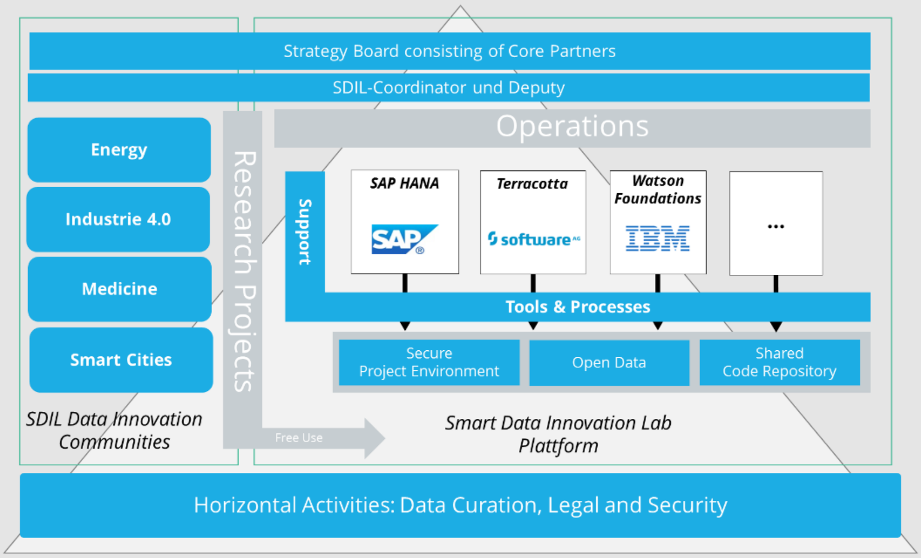
Motivation

Increasing digitalisation conceptualised in the Fourth Industrial Revolution, Industry 4.0, has resulted in a more data-driven innovation and integration of the value chains. At the same time, research on machine learning and big data is progressing. However, academic research does not often have easy access to industrial data, e.g., on a systemic level, while the industry has been calling for new knowledge to develop Industry 4.0 industrial concepts. SDIL was established in 2014 as part of a high-level national initiative, and the infrastructure for pre-commercial research was fully operational in 2015, offering a platform for bilateral secure data-sharing and setting up collaborative, applied research projects. The overall aim is to close the gap between research and innovation and hereby accelerate innovation-based on big data.

SDIL – a collaborative platform to overcome barriers for advanced digital innovation.

The figure below gives an overview of the SDIL platform where four determining factors have been essential for the attractiveness of SDIL:

- A unique technological infrastructure is rendered possible by contributions from the industry among others without a need for separate licencing or dealing with a complicated cost structure.
- Unique competences, mainly within Industry 4.0, smart infrastructure and medicine[xii], are available at the Steinbuch Centre for Computing (SCC) of the Karlsruhe Institute of Technology (KIT) as well as through other university researchers associated with SDIL.
- Access to real-life data provided by the industry makes the research deal with real problems.
- Establishment of strong security procedures and a legal framework to share and protect data (to be analysed locally in a protected environment) and data deleted afterward.



SDIL operates legally as a part of the Karlsruhe Institute of Technology (KIT), while the whole project is comprised of a collaboration of multiple core partners: KIT, the Forschungszentrum Jülich, the German Centre of Artificial Intelligence, the Fraunhofer Society, SAP, IBM and Software AG. A steering committee of these partners is responsible for the overall management of SDIL, including the overall legal structure for SDIL, and the collaboration with the industry and other researchers. The steering committee also uniformly approves all new projects through relevance, funding and the legal agreement which regulates hardware and software use, confidentiality, liability and exploitation.

Collaboration with the Industry

SDIL is a university-based facility for researchers to perform research in collaboration with the industry with access to real-life data. Consequently, SDIL has been a platform primarily for pre-commercial research and innovation, where the projects are defined by the researchers and, as publicly funded research, the researcher might publish the outcome, typically the "success stories" with an overall and anonymous presentation of the outcome.

The German government has supported companies and SMEs by funding research targeted at their needs. Projects will typically include only one industrial partner, as experience has shown that sharing data between several industrial partners is a challenge by contradicting the fast execution of projects on standard terms.

The outcome, or value creation, of the project will typically be a curation of data, tools, algorithms and new knowledge of relevance for the participating industrial partner. By being a partner in a research project, the industry can, for example, learn about algorithms and their functionality; however, if a company wants to use the outcome of a funded project, an algorithm, it must pay. Apart from publicly funded research, SDIL can be used for research directly funded by the industry to secure IP from the start.

Funding research and enterprise projects

In the long run, SDIL requires a mix of public and private funding, covering either the cost to develop and maintain the SDIL infrastructures or to fund research projects, etc.

The infrastructure is funded by the German research ministry, Karlsruhe Institute of Technology, and private funding of the participating industrial partners (free hardware and licenses for software). Funding of the research projects is mostly done through cascade funding (German or EU programmes) or direct funding from the industrial partners in the projects.

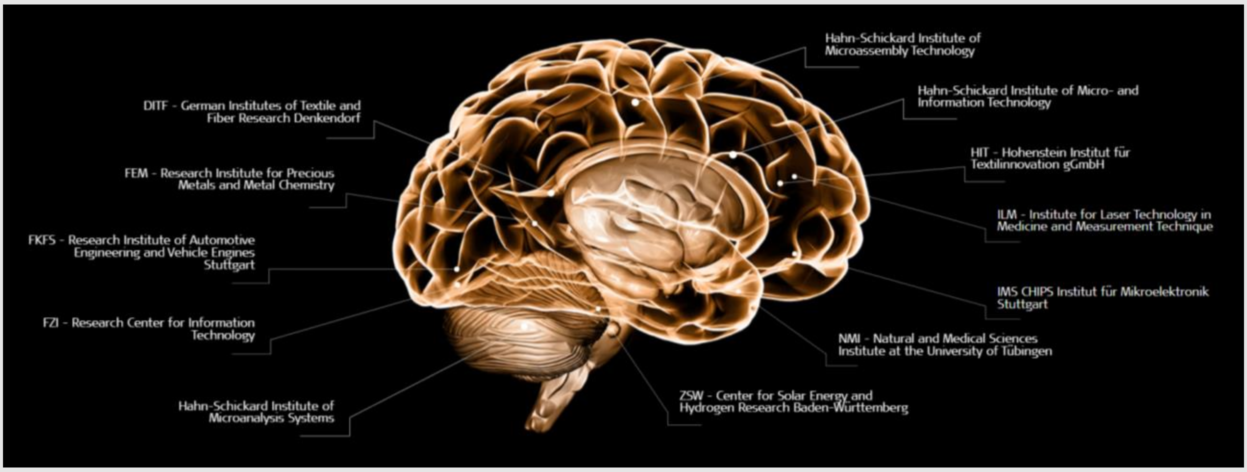
Some lessons learned

A unique technical platform is essential for SDIL to do big data and AI research efficiently. However, establishing research and innovation infrastructure, which is neither part of the basic research infrastructure nor fully commercial, is faced with a significant challenge in raising investment for technical equipment and sustainably maintaining it. At the start, SDIL has overcome this challenge as private vendors of hardware and software put critical technology at SDIL's disposal with favourable economic conditions. Today, more funds are received to run short-term research projects that would otherwise not be possible. Furthermore, SDIL today is integrated into other research infrastructures (namely the BW Uni-Cluster 2 serving local universities) to cut maintenance costs despite being a dedicated infrastructure.

All in all, SDIL is primarily a big data and AI research platform that targets applied research and publishes their results. However, innovation is a substantial feature of SDIL as the collaboration with the industry includes a strong element for knowledge and technological transfers. Lab Leader Dr. Till Riedel points out that 'relevance and potential benefits for the individual company are achieved by using data from the company in a 1:1 collaborative project in a confidential setting within SDIL'; and continues, 'The projects hereby become a learning and acceleration platform for both companies and researchers. It is commercial in the sense that companies may pay to obtain rights on specific outcomes or if they want to use it for innovation outside funded research. In this way, SDIL has balanced the requirement of being a research infrastructure and at the same time being highly relevant for the industry'.

CASE 5: INNOVATIONSALLIANZ BADEN-WÜRTTEMBERG (INNBW)[XIII]

The innBW is an association of the 10 legally independent non-profit, non-university research institutions (represented by 12 institutes). Each institute under the umbrella of innBW support SMEs through application-oriented research, including access to test and demonstration facilities. The focus is on technology transfer aiming at adapting new technology and research to meet the needs for technological innovation in the industry, especially SMEs. As an association, the main role of innBW is to be an interest group handling the institutes' political interests as well as promoting innBW as the brand, and, internally, strengthening common dialogue, strategy and collaboration. innBW is keen on securing for the institutes the best conditions for being technology transfer institutes, among others, by being the spokesman for the need for public funding, including funding for the investment in test and demonstration facilities. However, innBW can only by means of soft power encourage collaboration and sharing of test and demonstration facilities between the institutes.



Motivation

The 12 institutes, when compared to the German universities and large non-university communities (e.g., Fraunhofer-Gesellschaft), are rather small institutions in the research landscape of Baden-Württemberg. In 2010, innBW was established to improve the institutes' public images, strengthen their political influence (to maintain public financial support) and increase their visibility in the regional research landscape. Originally, innBW was a relatively loosely organised, but in 2020, innBW was reorganised and became an association with statutes and a secretariat to obtain a more formalised collaboration and a stronger position in the innovation landscape.

The organisation for preparing new technologies for industrial use

innBW must be understood as both an association and as the institutes under the umbrella of innBW. The objective of innBW as an association is to further establish and develop alliances at regional and national EU levels with a focus on creating favourable funding and political framework conditions. Further, an important task is as supportive PR by organising events and fairs as well as increasing visibility, enabling innBW to be a central contact point, especially for the enterprises addressing the institutes.

Internally, innBW is a supportive capacity facilitating training courses, working groups and dialogue to strengthen the market relevance of innBW and to promote cooperation and networking among the institutes. innBW is not involved in any research/innovation projects as these projects are anchored in the institutes. innBW is regulated by a set of statutes and a strategy approved by its members. An executive board is responsible for implementing the strategy supported by an executive office managed by a 50% part-time employee.

The institutes associated with innBW offer a range of services across the entire development process, from the idea to market entry, aiming at developing market-ready products, processes and services within health care, sustainable mobility, energy and environmental technology and information and communication[xiv]. In total, the institutes have more than 1,500 employees, a turnover of 182 million EUR and handle more than 4,500 company projects (45 % from SMEs) and over 500 public research projects per year.

However, innBW represents a decentralised structure where the institutes operate (economically) independently under the innBW umbrella. All projects and services offered to the industry are in the hands of the individual institutes either as individual industrial projects or joint projects. A contract for each project regulates the collaboration (economy, responsibility and tasks, including use of test facilities) and can hereby encourage synergy between the institutes. However, the institutes do not share test facilities (open access or common test facilities) or have a common strategy for developing the test infrastructure.

Funding of innBW

The institutes under the umbrella of innBW mainly operate under commercial business conditions as the projects are funded by the industry and, to a lesser extent, by public research programmes. However, each of the ten institutions receives basic funding, an average of just under 20% of the total turnover from the state of Baden-Württemberg. InnBW as an association receives annual public funding of 75,000 euro, and the remaining costs to run the association are covered by its members.

Some lessons learned

In the research and innovation landscape of Baden-Württemberg, innBW has an obviously impotent role in positioning the institutes among others as a 'bridge' between basic university research and innovation. Chairman of the Executive Board, Prof. Dr. Alfons Dehé stresses that 'innBW as such has become more visible which is crucial in the increased competition of new clients and public means.'

innBW is also a strategic platform for development and collaboration between the institutes. However, innBW is an association of independent institutes and faces some challenges which at the same time also are success criteria of innBW, e.g., external and internal communication, ability to make compromises, internal strengthening of the institutes' knowledge and promoting collaborative projects.

Even though innBW works to the benefit of all the institutes and for the development of individual or specially joined projects, there is no open access to test facilities between the institutes. Development of and investment in test and demonstration facilities is in the hands of the individual institutes, and mergers are out of the question. On the other hand, innBW could call for further public funding to meet the need for investment in test facilities, though in considerable competition with universities and large non-university organisations.

INNOVATION
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NOTES

[i] E.g.: Zusammenarbeit in Quick Checks und Exploring Projects - Fraunhofer IPA
[ii] Non-university research Organizations - Research in Bavaria (research-in-bavaria.de)
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[iv] **Main sources for the case S-TEC**:
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[v] Fraunhofer Institute for Manufacturing Engineering and Automation IPA, Fraunhofer Institute for Industrial Engineering IAO, Fraunhofer Institute for Building Physics IBP and University of Stuttgart represented by: Institute of Industrial Manufacturing and Management IFF, Institute for Energy Efficiency in Production EEP and Institute of Human Factors and Technology Management IAT
[vi] An overview of the S-TEC centers: https://s-tec.de/zentren/
[vii] Main sources:
Interview with Coordinator of the FZI House of Living Lab, Natalja Kleiner
https://www.fzi.de/erleben/house-of-living-labs/
[viii] **Main sources for the case Energy Lab 2.0**:
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09073-energy-lab.pdf (pv-magazine.com)
[ix] Karlsruhe Institute of Technology (KIT), the Helmholtz Centres Forschungszentrum Jülich (FZJ) and the German Aerospace Center (DLR).
[x] https://www.helmholtz.de/en/about-us/who-we-are/
[xi] **Main sources for the case Smart Data Innovation Lab:**
https://www.sdil.de/en/homepage
Smart Data Innovation Lab – SDIL
Interview with Lab Leader Dr. Till Riedel
[xii] For a list of projects see: https://www.sdil.de/en/projects
[xiii] **Main sources for the case Innovationsallianz Baden-Württemberg (innBW)**:
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