

Profitable Hydrogen Economy - Baden-Württembergs' business and economic development

Alina Richter¹, Dr. Manuel C. Schaloske

¹*Alina Richter, e-mobil BW GmbH, Leuschnerstr. 45, 70176 Stuttgart,
alina.richter@e-mobilbw.de*

Summary

The State of Baden-Württemberg has established the Platform H2BW to put the theory of hydrogen and fuel cell technology into practice. Hydrogen technologies as well as green hydrogen production must be tuned up from laboratory science to a profitable and scalable technology. In this economic process, all areas of the hydrogen value chain will be developed. Within various demonstrator projects, Baden-Württemberg shows production technologies and service operations in everyday life and thereby represents a role model for other regions. In addition, industry and mechanical engineering companies are supported in the transformation process to achieve a hydrogen economy in Baden-Württemberg.

Keywords: fuel cell, hydrogen, province, provincial government, strategy

1 Introduction: Baden-Württemberg on the way to a hydrogen economy

Hydrogen and fuel cell technologies are one of the key enablers for reaching the climate goals. With its wide range of applications, hydrogen also plays an important role from an economic point of view. For Baden-Württemberg, this potential has been analyzed in the study “Potentials of the hydrogen and fuel cell industry in Baden-Württemberg” [1] by Roland Berger in cooperation with the Ministry for the Environment, Climate and Energy Sector Baden-Württemberg. There is a lot of potential in hydrogen and fuel cell technology in Baden-Württemberg. For example, 16,000 new jobs could be created in the hydrogen sector and the sales potential would be €9 billion in 2030, with a large proportion of these also at suppliers.

To promote these opportunities in the best possible way and to advance the development of hydrogen and fuel cell technologies, Germany published a “National Hydrogen Strategy” [2] in June 2020. Due to specific economic conditions in the south-west of Germany, Baden-Württemberg has developed its own roadmap as part of a stakeholder process involving more than 300 institutions. The focus of the “Hydrogen Roadmap Baden-Württemberg” [3] is set on mobility and mechanical and plant engineering in a first step, due to the local economic

conditions. In Baden-Württemberg, the automotive industry is very strong and many small and medium-sized companies act as suppliers to the OEMs. Therefore, it is very important to involve these areas at an early stage so that a transformation can take place and these areas can continue to exist. Later on, also the industry sector, as well as the energy and heat sector will be considered to reach sector coupling in the end. The roadmap includes 29 concrete goals that can lead to the positioning of Baden-Württemberg as a leading supplier of hydrogen and fuel cell technologies. These ambitions and goals can be divided into six different areas:

- Cross-sector and cross-technology objectives
- Objectives for the generation, storage, distribution sector
- Objectives for the industry sector
- Objectives for the mobility sector
- Objectives for the building sector
- Objectives for the power generation sector

The roadmap thus covers the entire value chain of the hydrogen economy. The measures are to be implemented step by step and are subject to prioritization, since not all goals can be tackled simultaneously and supported with funding from the state of Baden-Württemberg. In the hydrogen economy it is important to be aware of three 3 perspectives, which are illustrated in Fig. 1:

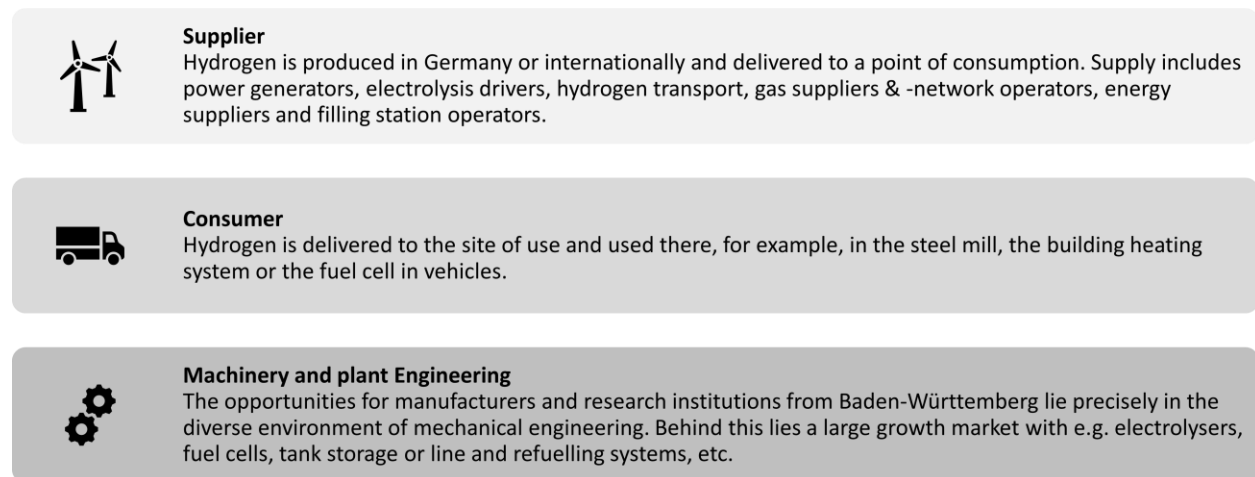


Figure 1: Three Perspectives of Hydrogen economy

2 Platform H2BW – From theory to application

In order to achieve a hydrogen economy in Baden-Württemberg and to use the potentials of the state, which were identified in the study [1], it is necessary to give the activities in the state a common roof and to bundle a cross-industry basis for all hydrogen and fuel cell activities. Based on several years of research in the field of hydrogen applications and fuel cell technology, a wide variety of highly qualified research institutions, and universities as

well as innovative companies and a large range of different industries in the state offer immense potential in economic terms for Baden-Württemberg.

For this purpose, and to bring the theoretical ambitions into practical application, the innovative Platform H2BW was established. According to the aims of the roadmap, the Platform H2BW is a new way to coordinate the collaboration between public authorities, companies, research institutions and users in Baden-Württemberg. It is also a central contact point and offers actors from different sectors a common and cross-sectoral umbrella. Overcoming various challenges, such as high production and engineering costs, in order to achieve marketability of hydrogen technology in the long term, has been another reason for the emergence of the Platform H2BW. Here, the Platform H2BW should make a decisive contribution and pave the way for new innovations.

2.1 Variety of undertakings

Due to the already existing network of the Cluster Fuel Cell BW [4], with nearly 200 partners from research, industry and associations, and the experience in transformation and innovation processes, the newly founded Platform H2BW is located at the state agency e-mobil BW.

The Platform H2BW focuses on networking the various players from business and science. The Platform addresses both technology-experienced and interested companies from Baden-Württemberg and creates a basis for joint exchange. The Platform aims at a coupling of sectors with hydrogen as versatile energy carrier. Therefore, the application in the mobility and industrial sectors but also in production, supply and distribution as well as in the fields of power generation and the building sector are addressed. The implementation of individual measures from research and development to industrialization is initiated and driven forward by the Platform H2BW by providing information on funding opportunities and strengthening networks.

In addition, local players are networked internationally so that other companies can benefit from the demonstration projects and developments in Baden-Württemberg. Fig. 2 shows the five core activities of the Platform H2BW at a glance.

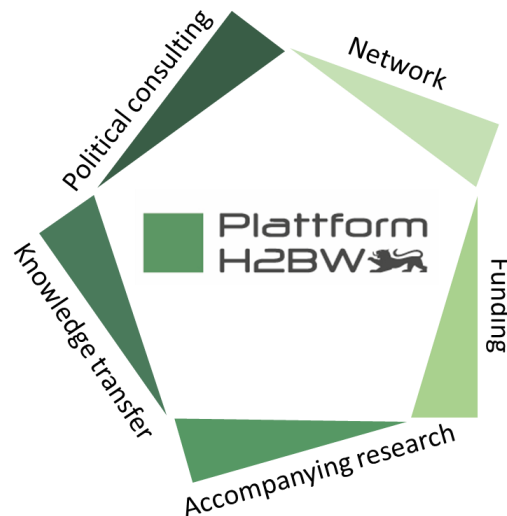


Figure 2: Platform H2BW [5]

2.2 Cross-sectoral and multilevel perspectives

In addition to the perspectives of the hydrogen economy already described - suppliers, consumers, and mechanical and plant engineering - it is highly relevant to consider sector coupling. Every single stage of the hydrogen value chain is of great relevance. Addressed in the Platform H2BW are the sectors of hydrogen production and application plus energy generation and storage. For example, hydrogen applications in mobility and industry go hand in hand with heat generation and energy production. Only by an optimal and well-thought-out linking of the multilevel perspectives it is possible to use the potential of hydrogen in the best possible way. Fig. 3 schematically shows the cross-sectoral and multilevel perspectives

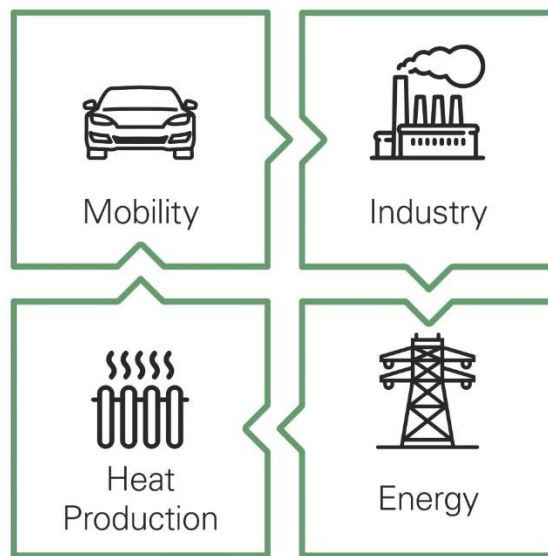


Figure 3: sector coupling [5]

2.3 Ongoing activities and achievements

The task of the Platform H2BW is to implement and accompany the goals of the Hydrogen Roadmap of Baden-Württemberg. To this end, several activities have already been launched in the first year of the Platform and more are planned.

In the area of knowledge transfer, for example, a major study was commissioned to provide an overview of the future demand for hydrogen in Baden-Württemberg. It will also look at the extent to which this can be covered by domestic production. With this information, a transformation to a hydrogen economy can be approached

consciously. In addition, a series of publications was launched to take a compact look at current topics. Short studies are commissioned and published for this purpose.

In the area of networking, the Platform builds on the existing Fuel Cell Cluster BW. In order to further expand the network and to bundle all activities in the field of hydrogen and fuel cell technology in Baden-Württemberg, the stakeholder map (Fig. 4) was created. Stakeholders can register in this map and thus create visibility. The establishment of contacts and possible cooperation is facilitated. The stakeholder map is intended to show the entire value chain and offers the possibility to filter specifically according to the different sectors and regions.

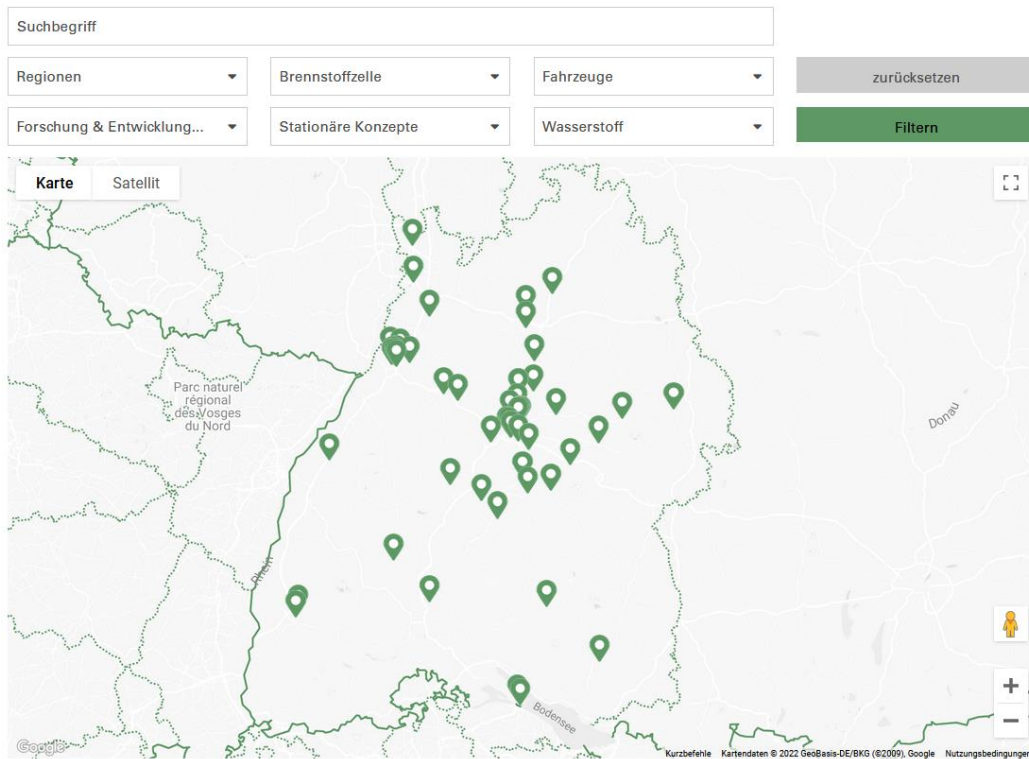


Figure 4: Stakeholder map [5]

One step towards establishing a sustainable hydrogen economy is support from the state with targeted funding programs and tenders. This can provide strategic impetus and lay the foundations for the establishment of an economic system. In addition, specific programs enable the research and testing of novel technologies. Therefore, number of activities can already be mentioned in the funding module. On the one hand, two calls have already been published in 2021. The funded projects can be found in chapter 3. Another funding program has been published in spring 2022. The new funding program is intended to accelerate the development of a hydrogen economy and, in particular, to support companies from Baden-Württemberg in their transformation to a climate-friendly economy. Among other things, the “Climate protection and value creation through hydrogen” program, called KWH2, is intended to promote pilot and demonstration projects that link the hydrogen production, storage and transport value chain in an overall context, as well as the use of green hydrogen in so-called stand-alone solutions. However, the pure substitution of, for example, grey hydrogen in industrial applications is excluded.

This is intended to provide a reliable framework for action for policymakers and industry. A special aspect of KWH2 is that, in addition to research and development projects, investment funding is also possible.

All these activities and promotional opportunities should contribute to strengthen Baden-Württemberg's companies and research institutions and promote them in their innovative strength and support them in maintaining their leading technological position in international competition.

3 Projects are implemented along the whole value chain

One of the strategic goals of Baden-Württemberg is the strengthening of the automotive industry in south-west Germany, building up a competitive supplier industry for components, production facilities and the development and testing of quality systems in different industry sectors [3]. A large number of companies is already active in the hydrogen and fuel cell sector in Baden-Württemberg [6].

In addition to further technology development, industrial investments in new technologies and a qualified workforce are needed. In order to make this possible and to spread it into the broad field and to increase acceptance in society, projects must be established at an early stage as demonstrators and for the creation of knowledge. As such projects entail high development and investment costs, it is essential to have them promoted and supported by the public sector. An important aspect is also the transfer of the acquired knowledge to other regions and countries, which are also active in the field of hydrogen and fuel cell technology.

These projects in Baden-Württemberg cover all areas of the hydrogen value chain. At the beginning of the value chain is a project for the industrialisation of fuel cells, called **HyFab** and represents an important step towards serial production of fuel cell components and stacks. This project is based in Ulm. The strategic goals of the project focus on the strengthening of the automotive industry in Germany, especially Baden-Württemberg. Therefore, a competitive supplier industry for components and production facilities should be built up.

Another important aspect for the transformation of the mechanical industry is represented in the project **Elektrolyse made in BW**. This project is about industrial production of electrolyzers and is intended to support the mechanical and plant manufacturers in the transformation process. It includes a certified demonstrator for water electrolysis and is intended to function as an "electrolysis showcase" for electrolysis production in Baden-Württemberg.

On the other end of the value chain, a number of large demonstration projects is already being implemented. The two major projects **H2Rivers** and **H2Rhein-Neckar**, along the rivers Rhein and Neckar, function together as the biggest model region for green hydrogen in South-West Germany. **H2Rivers** is a cross-regional lighthouse project for hydrogen and fuel cell technology and will bring a huge number of fuel cell vehicles into operation, including car fleets, but also buses and the corresponding infrastructure will be built up. The H2Rivers project is making a significant contribution to the development of a hydrogen economy in the Rhine-Neckar region. It covers the entire value chain, from regenerative hydrogen production to distribution with high-pressure trailers at three new filling stations to be built and a wide range of vehicle applications. In this way, H2Rivers is helping fuel cell technology to achieve market maturity and is setting important accents in the development of a hydrogen economy. The project, which was named HyPerformer in the HyLand tender, is funded by the German Federal Ministry of Digital Affairs and Transport. In addition to H2Rivers, **H2Rhein-Neckar** aims to change local public transport in the cities of Mannheim and Heidelberg with buses to zero-emission vehicles. The investments in fuel-cell-powered buses and the corresponding infrastructure are being supplemented by accompanying research to ensure a smooth conversion of the fleets. The findings are also expected to contribute to a successful transformation process in mobility beyond the Rhine-Neckar region. The project is funded by the Ministry for the Environment, Climate and Energy Sector Baden-Württemberg. In total, the project volume of 97 million

euros illustrates the enormous size of the two projects and the model region. Of this, 36.5 million euros will be funded by the federal government and the State of Baden-Württemberg. Fig. 5 gives an overview of the project consortium and the project locations. It becomes apparent that many sectors are involved and that not only one sector can be considered individually.

H2Rivers and H2Rhein -Neckar

H₂ Production:

600 kg H₂/day (via 1.5 MW new electrolysis capacity
+ electricity from renewables (RE))

3.000 kg H₂/day (green H₂ from chemical industry,
according to CertifHy)



H₂ Distribution



Transport 1,5 t H₂/day



Industry 0.4 t H₂/day



Research



Coordination, Communication and Dissemination



* associated partner



Figure 5: H2Rivers and H2Rhein-Neckar [7]

The two projects are associated with an average demand for hydrogen of 380 tons of hydrogen per year. This can be covered by hydrogen production at the H2ub in Mannheim. Here, 400 tons of hydrogen are to be produced annually and distributed with the help of 12 innovative 700 bar H₂ trailers. These will supply both industrial partners and five filling stations built as part of the two projects. The distribution of the vehicles procured by the model region can be seen in Fig. 6. Here, the diversity is to be emphasized. Within the framework of the two projects, a wide variety of applications of hydrogen in mobility are being tested. This can benefit other regions and create knowledge that can be used for interregional knowledge transfer.

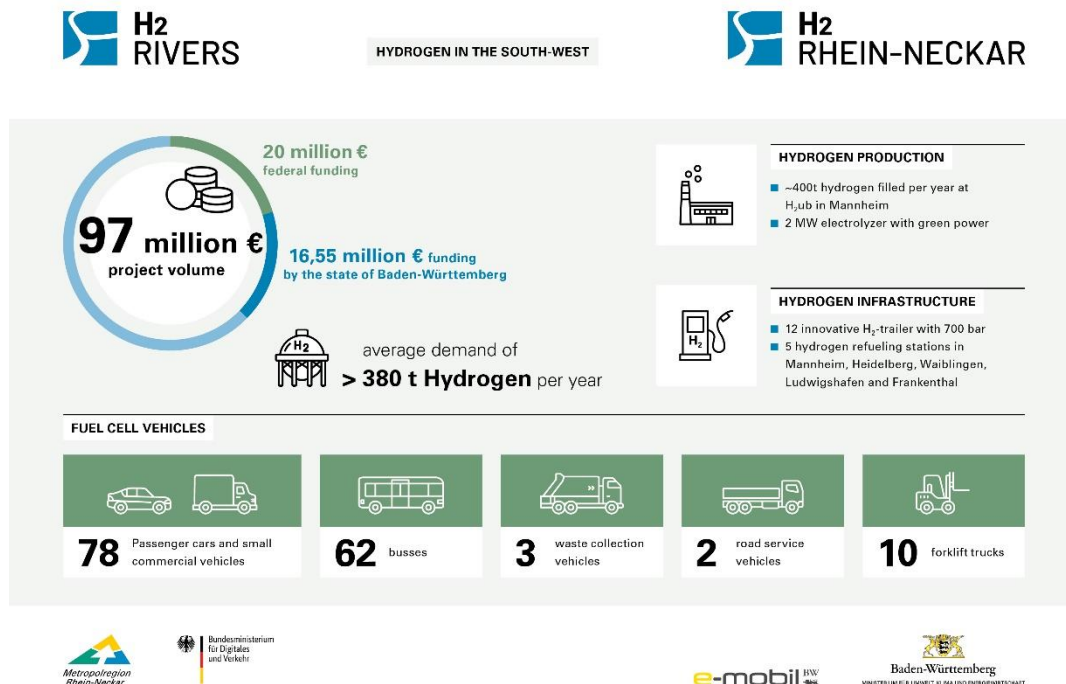


Figure 6 Important Facts H2Rivers & H2Rhein-Neckar [7]

Another demonstration project dealing with sector coupling in practice is **H2ORIZON** settled at DLR. It focusses on coupling of renewable energies, hydrogen and storage applications, space travel, heat generation and mobility. Up to 100 tons of green hydrogen are produced within the project. Fig. 7 the demonstrates the principle of sector coupling.

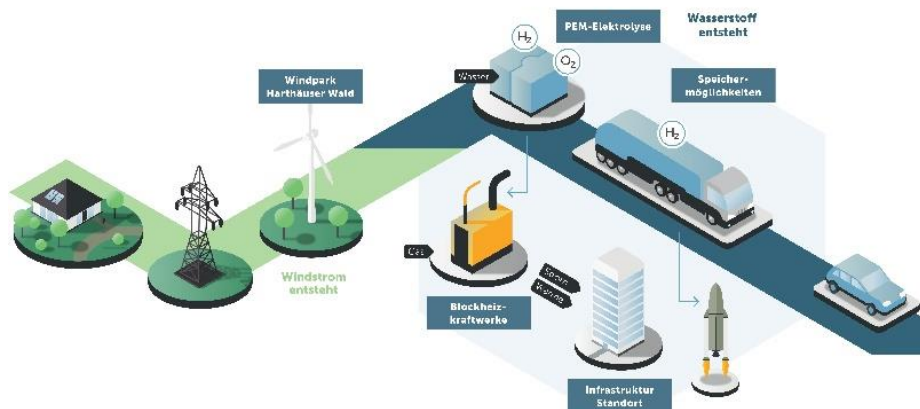


Figure 7: H2ORIZON [7]

As mentioned in chapter 2 different funding opportunities are part of the Platform H2BW. The **Green Hydrogen Model Region** funding program is accompanied by the Platform H2BW and addresses the establishment of model regions in Baden-Württemberg, where the use of green hydrogen is tested across sectors and along the entire hydrogen value chain. In addition to the production of climate-friendly hydrogen, also transport, storage and the application will be tested. Another goal is to use the Green Hydrogen Model Region to make an active contribution to raising social awareness and increasing the general acceptance of hydrogen as an energy carrier. All projects will be accompanied scientifically in order to make the generated results and findings usable. In August 2021, the Ministry for the Environment, Climate and Energy Management Baden-Württemberg invited two projects to submit a full application for funding. A total of 47 million euros from the European Regional Development Fund (ERDF) and state funds are available for the years 2021-2027. The first selected model region, **HyFiVE**, includes the Alb-Donau region with the counties of Reutlingen, Alb-Donau and the city of Ulm, as well as the neighboring counties of Ostalb, Tübingen, Heidenheim and the city of Schwäbisch Gmünd, thus combining activities in urban and rural areas. The HyFiVE model region contains four lighthouse projects that address various aspects of the hydrogen economy in the different districts. For example, different technologies of electrolyzers and the use of hydrogen in industry, transport and neighborhood solutions are being tested. The HyFiVE model region, with its four associated lighthouse projects, has around 33 million euros in funding at its disposal. An overview of the model region HyFiVE can be seen in Fig. 8.

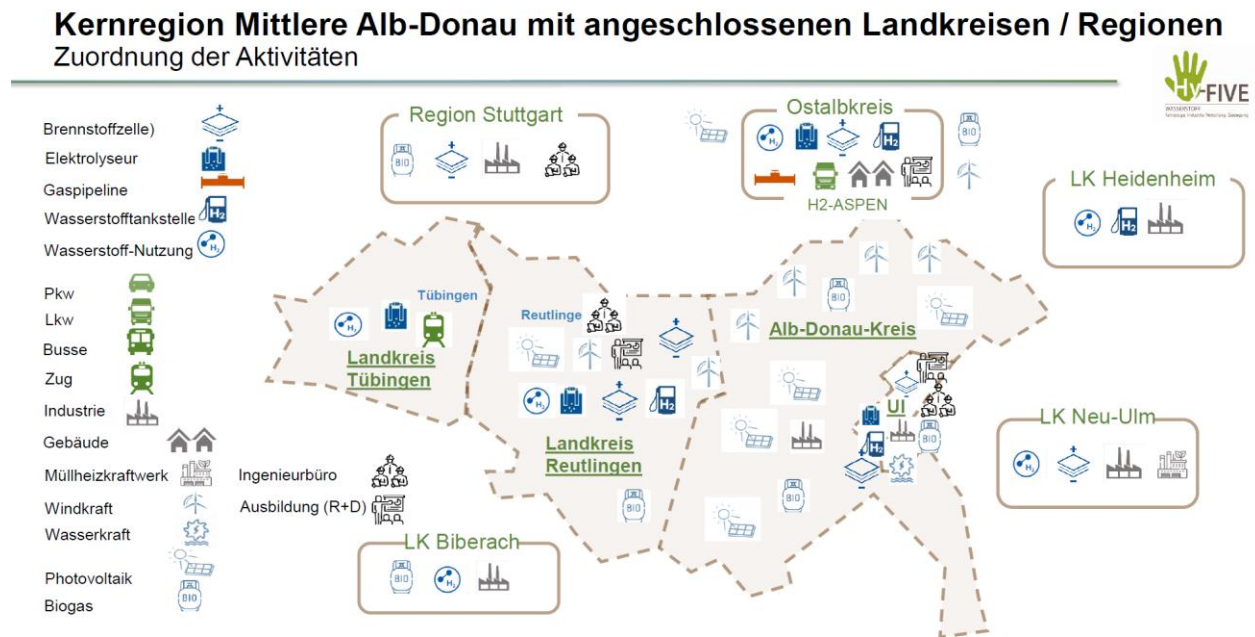


Figure 8: Model region HyFiVE [9]

The second model region selected is **H2 GeNeSiS**. In the Stuttgart region, an integrated hydrogen system is to be mapped along the river Neckar and serve as a basis for scaling up the hydrogen economy in the industrially dominated region. During the model region, three electrolyzers will be built, which will be fed by regional renewable energy. The model region relies on a wide distribution network, the H2 marketplace. In addition, a

hydrogen pipeline will be the centerpiece of the model region. H2 GeNeSiS is being funded with around 14 million euros. An overview of the model region H2 GeNeSiS can be seen in Fig. 9.

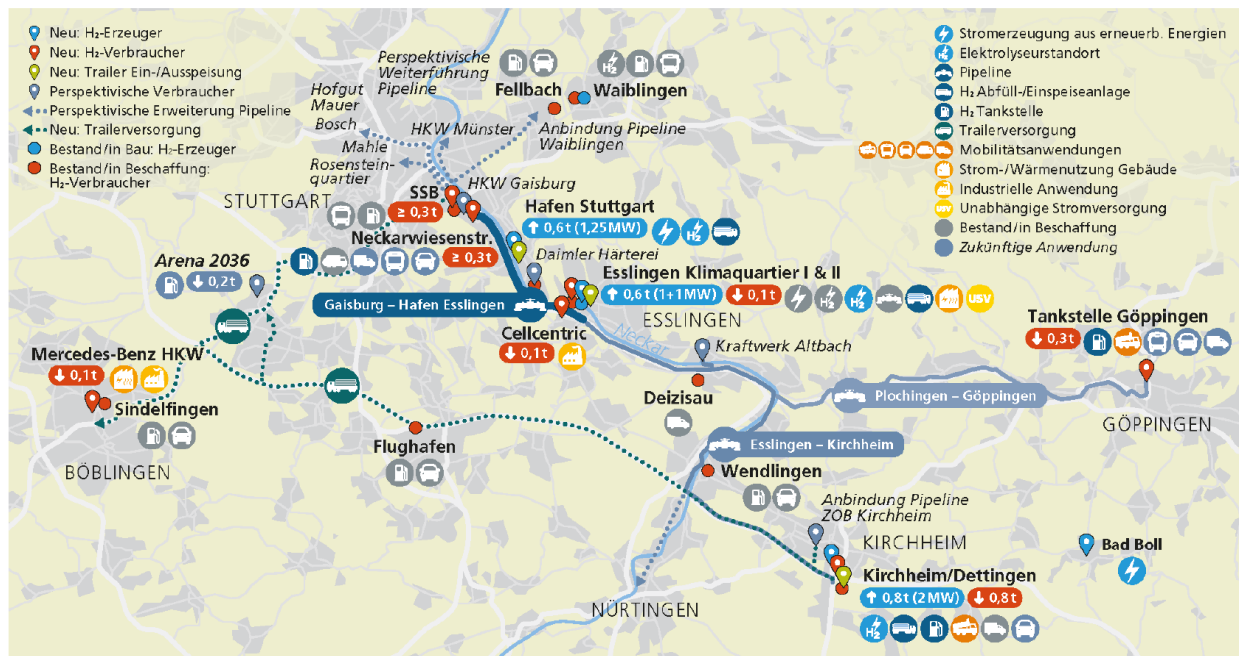


Figure 9: H2 GeNeSiS [10]

The second funding call takes up measures from the state's hydrogen roadmap, which the Platform H2BW accompanies, is the “Future Hydrogen Program BW”, called ZPH2. This funding call aims to support companies and research institutions in establishing a sustainable hydrogen economy in Baden-Württemberg. The program focuses on industrial research. Companies are supported in developing innovations in the field of hydrogen and fuel cell technology quickly as well as bringing them to market in a next step. In this way, important market shares are to be gained and secured in order to maintain the leading technological position of Baden-Württemberg companies in international competition. Among others, the program focuses on manufacturers, equipment suppliers and users in the state who want to strengthen Baden-Württemberg's innovative strength and competitive position with their contribution, i.e., a technology, a process, or a system, in cooperation with research. As announced in December 2021, 20 projects in Baden-Württemberg will receive funding from the Ministry. In total, the state of Baden-Württemberg is providing around 26 million euros for this purpose.

4 Conclusion – Transfer to other regions

All in all, Baden-Württemberg is an economically strong region with a wide range of expertise in the hydrogen sector. From SME to global players as well as strong and renowned research institutions, all are united in Baden-Württemberg. On the one hand, the aim is to establish hydrogen and fuel cell technology as a new industry in Baden-Württemberg. On the other hand, Baden-Württemberg is willing to bring the technology and components to the world with the aim to decarbonize the traffic and industry sector. With the application of hydrogen and fuel cell technology, emissions can be reduced and the demonstrator projects in Baden-Württemberg can serve as a

global showcase for real-life applications of hydrogen. Beside battery electric vehicles also fuel cell electric vehicles can make their contribution to zero emission mobility and a climate neutral system.

Other regions can benefit from the experience gained from the various projects in Baden-Württemberg. To this end, it is important to promote and maintain an international exchange. Especially regarding regulation, costs and standards, it is of enormous importance to act internationally. The most important insight from the experience of Baden-Württemberg is the cross-sectoral approach.

In order to advise the state government and to implement and further develop the hydrogen roadmap of the state of Baden-Württemberg, an advisory board was established in January 2022. Among others, the advisory board consists of 25 experts from industry, research and communal representatives. The recommendations and statements of the advisory board serve as guiding recommendations. Therefore, this instrument should also be considered for the implementation of regional strategies in other regions.

It becomes apparent that the various perspectives of hydrogen and fuel cell technology must be thought of together. Likewise, the involvement of the various research institutions and companies is an important factor in the success of the transformation. If they are not involved in the process at an early stage, this can prove problematic. Baden-Württemberg has had good experience with the stakeholder process for developing the hydrogen roadmap and can recommend this as a procedure to other regions.

5 Outlook – Baden-Württemberg is becoming a hydrogen state

The Platform H2BW is an important instrument to bundle all hydrogen activities in Baden-Württemberg and is intended to help exploiting the region's full potential target. Currently, the projects are being funded by various funding bodies, which makes sense at this early stage of hydrogen economy. But the aim should be, for example, to bring vehicles on the road without funding and make it economically viable.

In addition, the development of infrastructure plays a decisive role in building up a hydrogen economy. In view of rapid developments in technology and current circumstances, the roadmap must be adapted as necessary so as not to lose relevance. In total, the state of Baden-Württemberg is providing funding of 20 million euros for the years 2022 to 2025. This will enable further projects to be created and thus the step from research and development towards market maturity to be tackled. However, the open-mindedness of companies in Baden-Württemberg is also needed to tackle the transformation toward a hydrogen economy. Likewise, the question of where hydrogen will come from in the future must be clarified at an early stage. This requires energy partnerships, among other things. Baden-Württemberg is on a very good path and will thus become a hydrogen state.

References

- [1] *Potenziale der Wasserstoff- und Brennstoffzellen-Industrie in Baden-Württemberg*, https://um.baden-wuerttemberg.de/fileadmin/redaktion/mum/intern/Dateien/Dokumente/6_Wirtschaft/Ressourceneffizienz_und_Umwelttechnik/Wasserstoff/200724-Potentialstudie-H2-Baden-Wuerttemberg-bf.pdf, accessed on 2021-09-09
- [2] *Die Nationale Wasserstoffstrategie*, https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/die-nationale-wasserstoffstrategie.pdf?__blob=publicationFile&v=20, accessed on 2021-09-09
- [3] *Wasserstoff-Roadmap Baden-Württemberg*, https://um.baden-wuerttemberg.de/fileadmin/redaktion/mum/intern/Dateien/Dokumente/2_Presse_und_Service/Publikationen/Wirtschaft/Wasserstoff-Roadmap-Baden-Wuerttemberg-bf.pdf, accessed on 2021-09-09
- [4] *Cluster fuel cell BW*, https://www.e-mobilbw.de/fileadmin/media/e-mobilbw/Englische_Publikationen/Cluster_BZ_Infolyer_EN.pdf, accessed on 2021-09-09
- [5] *Plattform H2BW*, <https://www.plattform-h2bw.de/>, accessed on 2021-09-09
- [6] *Competence Guide: Experts for new mobility solutions in Baden-Württemberg*, https://www.e-mobilbw.de/fileadmin/media/emobilbw/Englische_Publikationen/Competence_Guide_Experts_for_New_Mobility_Solutions_in_Baden-Wuerttemberg.pdf, accessed on 2021-09-09
- [7] *H2Rivers & H2Rhein-Neckar*, <https://www.h2rivers.de/> accessed on 2022-04-20
- [8] *H2ORIZON*, <https://www.h2orizon.de/> accessed on 2022-04-20
- [9] *HY-FIVE Modellregion Grüner Wasserstoff Baden-Württemberg e.V.*
- [10] *H2 GeNeSiS, Wirtschaftsförderung Region Stuttgart GmbH*

Authors



Alina Richter studied Aerospace Engineering at the University of Stuttgart with specialization in materials, manufacturing processes and space applications. As a student, she gained experience at STIHL and the German Aerospace Center (DLR). Since 2021 she has been in charge of the coordination and initiation of projects in the field of hydrogen and fuel cell technologies also on European level at the State Agency for New Mobility Solutions and Automotive Baden-Württemberg, e-mobil BW.



Dr. Manuel C. Schaloske started at e-mobil BW as general manager for fuel cell technology and commercial vehicles in July 2010. Since 2013 he has led the Cluster Fuel Cell BW, since the beginning of 2018 he is Director of Energy at e-mobil BW, the State Agency for New Mobility Solutions and Automotive. In March 2021, he also took the lead of the Plattform H2BW.

He studied chemistry at the University of Cologne and gained experience in the industrial and basic research. During his diploma thesis at the former DaimlerChrysler AG, he did research on fuel cells and later gained experience in inorganic solid-state research during his PhD at the Max Planck Institute for Solid State Research.