




First Progress Report on the Baden-Württemberg Hydrogen Roadmap

 May 2023

 Progress Report on the
Baden-Württemberg Hydrogen Roadmap

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EXECUTIVE SUMMARY

The state's Hydrogen Roadmap was approved by the Cabinet in December 2020. The state government has thus developed a timetable for the coming years to establish the state as a leading hydrogen venue. In light of the changed energy supply situation and the rapidly changing framework conditions in particular, the topic of hydrogen is seeing an additional dynamic. The progress report takes these developments into account and supplements the measures of the Hydrogen Roadmap with further fields of action in the various sectors. At the same time, the report provides information on the implementation of the roadmap.

The early establishment of a hydrogen infrastructure and hydrogen provision are central topics in the progress report and in the further implementation of the roadmap.

Climate neutrality can only be achieved if the hydrogen used is verifiably green. This must be taken into account from the outset. Other low-carbon production methods can also be used temporarily.

In Germany, especially in southern Germany, hydrogen demands exceed existing hydrogen production capacities and those that can be expected in the short term. From 2030 on, the projected demand for hydrogen in Baden-Württemberg will grow significantly from currently 3.1 terawatt hours (TWh) of hydrogen to 16.5 TWh in 2035 (see: H2 demand study on behalf of the H2BW platform; last updated January 2022). The study on sector targets in Baden-Württemberg (see: Progress Report as of May 2022) assumes a hydrogen demand of around 30 TWh in 2040. Assuming a final energy consumption of 197 TWh in 2040, hydrogen would make up a share of around 15

percent at around 30 TWh (without Power to Liquid – PtL), with the energy sector having the greatest demand for hydrogen – every second kilowatt hour (kWh) of hydrogen will be allocated to this sector in 2040. In order to meet demand, considerable import capacities and a pipe-bound infrastructure are necessary to transport the hydrogen to where it is needed.

A recent policy paper of the National Hydrogen Council from February 2023 assumes that, due to the Russian attack on Ukraine and the resulting changes in the energy markets, there will be a significantly greater demand than previously assumed for green hydrogen in Germany as early as 2030 – the forecasts assume green hydrogen demands in Germany of 53 to 90 TWh (excluding the heat market, reconversion to electricity and substitution of grey hydrogen). Higher demands can also be expected for Baden-Württemberg. The Ministry of the Environment, Climate Protection and Energy Sector will therefore carry out a new demand analysis in collaboration with transmission system operators and associations. The demand survey is supported by a broad alliance of the Ministry of the Environment, Climate Protection and Energy Sector Baden-Württemberg, the H2BW platform, network operators, the Baden-Württemberg Chambers of Industry and Commerce, as well as industry and trade associations (terranets BW GmbH, Open Grid Europe GmbH, Deutscher Verein des Gas- und Wasserfaches [German Technical and Scientific Association for Gas and Water] e.V. (DVGW), Verband für Energie- und Wasserwirtschaft Baden-Württemberg [Association for Energy and Water Management] e.V. (vfew), Unternehmer Baden-Württemberg [Baden-Württemberg Enterprises] e.V. (UBW), Verband der chemischen Industrie [German Chemical

Industry Association] e.V. Baden-Württemberg (VCI BW), Wirtschaftsverband Papier Baden-Württemberg [Baden-Württemberg Paper Trade Association] (WVP) e.V., Großabnehmerverband Energie [Bulk Energy Consumers Association] (GAV) Baden-Württemberg, TransnetBW GmbH, H2vorOrt [H2onSite]). The “Hydrogen for Baden-Württemberg” initiative is coordinated by the H2BW platform. The purpose of the demand survey is to reach many companies with information through on-site events, to raise their awareness of the topic, to motivate them to report their realistic, future H2 requirements, and thus to provide the largest and most reliable database possible for further infrastructure planning.

Baden-Württemberg is only able to produce green hydrogen itself to a lesser extent. The provision of the necessary infrastructure for the generation, storage and transport (including import) of hydrogen and hydrogen derivatives is therefore a central prerequisite for the development of a hydrogen economy in Baden-Württemberg. The appropriate prerequisites must be created for this at the European and federal level, but also in the state. Some of the latest developments at the federal and EU level are currently not conducive to this.

The plans for the expansion of a European hydrogen grid are largely developed by transmission system operators. Pipe-bound grid development in Germany will largely be developed from north to south, which means that parts of southern Germany will only be connected to the German hydrogen grid much later than northern Germany. For 2030, a connection to the hydrogen grid and connections to the North Sea and the Baltic Sea region can be expected in Baden-Württemberg. The hydrogen pipeline from Marseille to Germany announced by Germany and France may be an important ad-

ditional option for Baden-Württemberg. However, this option depends on the construction of the “H2Med” Mediterranean pipeline from Barcelona to Marseille and on an ongoing energy policy consensus. With their demand surveys and plans, transmission system operators make a significant contribution to the development of the transmission network in Baden-Württemberg. Important factors for the implementation are, in addition to the specific demand assessment, sufficient investment incentives and appropriate (legal) framework conditions at the EU and federal level. There has been no binding planning to date for a hydrogen grid at the national level. In addition, the distribution networks which many private customers, commercial enterprises and industrial companies in Baden-Württemberg are connected to must be included in the planning.

At the federal level, the right steps must be taken in a timely manner, especially in the area of infrastructure. The hydrogen demand and its derivatives, as well as the need for a quick pipe-bound supply to Baden-Württemberg, must be taken into account in the process. We are striving for a nationally coordinated, large-scale network, but not the establishment of a federal network company. A strategic dialogue on infrastructure development has therefore been started in Baden-Württemberg with key stakeholders.

Generation capacities must also be established in the state (isolated or cluster solutions), in particular to meet the growing demand for green hydrogen in the short and medium term up to a pipeline connection (but also afterwards). The expansion of the pipeline network must be pursued in parallel with the regional solutions. Framework conditions at the federal and EU level such as the Delegated Act pursuant to Art. 27 (3) of the Renewable Energy Directive (RED II) promote the construction of electrolyzers in Baden-Württemberg only to a very limited extent. The state government is therefore in favor of conditions that permit the construction of electrolyzers in the southwest. Where necessary, it will further strengthen the approval procedures with supporting guidelines and recommendations for action. Due to similar framework conditions and transport options that must be established, capacities through the import of hydrogen derivatives must also be taken into account, for example for the production of electricity-based kerosene (PtL).

In the case of hydrogen production, it must be ensured that no incentives are made for fossil power generation. This does not exclude the use of an overcurrent supply for the production of hydrogen. A basic prerequisite for hydrogen production is also the massive expansion of renewable energy production.

The state government has agreed on new cooperations with regions such as Andalusia and Scotland, expanded existing partnerships and networks, and made targeted delegation trips (for example to Chile) to open up options for the state in the field of hydrogen (flanking possible hydrogen imports, the import of hydrogen derivatives such as ammonia and methanol, transport routes, cooperation in the field of technology, technology export). This work will continue.

Baden-Württemberg is one of the leading hubs in the development and production of fuel cell components and sys-

tems. There is also potential for Baden-Württemberg companies in the field of manufacturing electrolysis technologies. The scaling and serial production of the above-mentioned technologies in particular are an essential field of action. Industrial production processes and scaling projects must therefore be further supported and funded in the future.

Companies in Baden-Württemberg therefore have opportunities to participate in the hydrogen boom and become leading suppliers along the entire hydrogen value chain. Plant construction and the export of technologies and components for fuel cells, hydrogen engines and hydrogen production and use in particular will develop into important business areas. In addition to the need to supply Baden-Württemberg companies with hydrogen at an early stage, international markets offer enormous export potential for hydrogen and fuel cell technologies that should be developed at an early stage.

Further cost reductions are necessary to make hydrogen competitive – these can be promoted in particular with technological developments and economies of scale. The evolution of electricity prices is an important factor in production costs and the costs of electrolysis.

The funding of five IPCEI projects allocated to Baden-Württemberg, which are of major importance to industrial policy in Baden-Württemberg, is an important contribution to climate neutrality. With the IPCEI projects, the state has the opportunity to decisively advance the development of hydrogen technologies and to benefit from the market boom in the long term by maintaining value creation in the state and securing jobs. The funding of as many high-quality projects as possible is therefore of the utmost interest to the state.

Because hydrogen will remain a scarce, valuable raw material for the foreseeable future, its use is expected to focus on those areas that have no other alternative on the path to climate neutrality.

Hydrogen is a backup option in the power supply. By 2040 at the latest, the complete transition (fuel switch to hydrogen) must be completed in order to ensure climate neutrality in Baden-Württemberg. At around 70 percent of the guaranteed output, gas power plants will make a significant contribution to supply security in the transformed, climate-neutral electricity system in 2040. While the output of coal and nuclear power plants will be completely eliminated, the output of gas power plants will almost double today's output.

For the various industrial sectors in Baden-Württemberg, the use of hydrogen is seen both materially and energetically as an alternative to fossil fuels for high-temperature heating processes. The transformation process of the economy, which has an increased demand for hydrogen and its derivatives, towards climate-neutral production is imperative and will continue to be supported by the state government.

The use of hydrogen technologies in the mobility sector, especially in heavy-duty transport, is an essential key to effectively implementing climate action in transport. The roadmap for reFuels for Baden-Württemberg continues to follow a path towards greenhouse gas neutrality for aviation, shipping and the non-electrifiable parts of freight transport, which is ultimately also based on hydrogen and imported hydrogen derivatives as a basic component when it comes to industrial standards. Potentials for reFuels for the passenger car fleet can also be seen.

In addition, the development and standardization of the hydrogen tank infrastructure gives Baden-Württemberg industries in the automotive and mechanical engineering sectors the opportunity to place their products on the market. In order to develop a branched tank infrastructure network and be able to connect these across national borders, alliances and partnerships in the European area are essential.

Overarching topics such as social acceptance, applied research and specialist training form the basis of successful implementation of the hydrogen economy and must be consistently pursued.

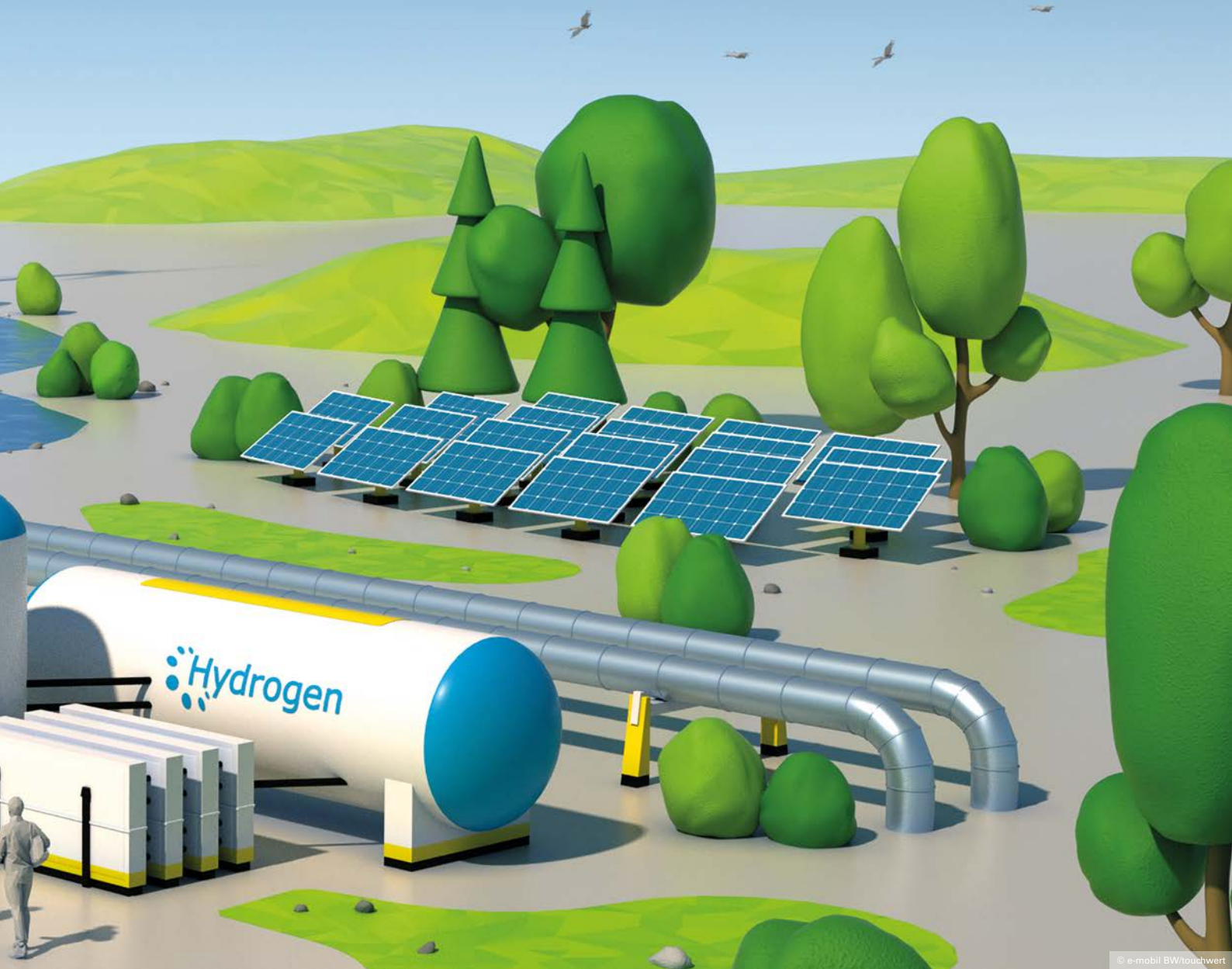
With the strong player landscape in Baden-Württemberg, a large number of relevant demonstration and lighthouse projects have already been generated. The implementation of these projects contributes decisively to further development in the field of hydrogen. As a result, around 500 million euros in funding is already active in projects in the state. Baden-Württemberg is thus very well positioned – especially scientifically and technologically – for the hydrogen boom and will build on it in a targeted manner.

The state government is supported and advised by the BW Hydrogen Advisory Board, a high-level committee with experts in the business, science, municipality and trade associa-

tion sectors, which has developed a seven-point plan with specific recommendations for action. The state government will review the valuable recommendations and implement them based on its options.

The further development of the Hydrogen Roadmap takes into account the draft of the BW energy concept as well as the partial results of the research project “2030 Sector Goals and Climate-neutral Baden-Württemberg by 2040” for the implementation of climate action targets. On the subject of H₂-based fuels, the state government has adopted the reFuels Roadmap, which contains detailed statements. Hydrogen-based derivatives, which are addressed in the reFuels Roadmap, also play a role in the following topics. They must be taken into account in further considerations.





PART I: FURTHER DEVELOPMENT OF THE BADEN-WÜRTTEMBERG HYDROGEN ROADMAP

1. Introduction

The state of Baden-Württemberg has set a goal of becoming climate-neutral by 2040. The Hydrogen Roadmap of the state of Baden-Württemberg published in December 2020 provides the framework for supporting compliance with the climate targets through the use of hydrogen and fuel cell technologies and thereby further strengthening Baden-Württemberg as an industrial and technological hub. As raw material and energy sources, green hydrogen and its derivatives will make an important contribution to a sustainable supply of raw materials and energy. As an energy source, it can be used in particular in areas where the direct use of renewable electricity is not economically or technically promising.

Hydrogen and fuel cell technologies play a crucial role

- in achieving climate action targets in various sectors,
- in securing and transforming the industrial, economic and technological hub of Baden-Württemberg,
- in medium-term diversification of the energy system,
- in sector coupling.

A large number of the measures outlined in the Hydrogen Roadmap have already been implemented. Important projects are outlined in Part II.

With a large number and density of lighthouse projects, Baden-Württemberg is one of the leading hydrogen regions in Germany. Large model and demonstration projects in the state show how hydrogen can be used for everything from generation, transport and logistics to various applications in mobility, heat generation for districts, as a raw material for the production of synthetic derivative products or in industry. These real laboratories are not only used for technology development, but are also intended to function as showcases for hydrogen applications and make hydrogen accessible.

Committed players at the local, regional level, in communities and districts and beyond, as well as stakeholders in industry and research, make a particularly significant contribution to the success of the hydrogen economy in Baden-Württemberg. National and international alliances, the expansion of regional and European networks and an increase in cluster work are intended to ensure that Baden-Württemberg can further expand its lead position. For example, RegioClusterAgentur Baden-Württemberg supports cluster initiatives and the regional economy in identifying new skills needs and transformation paths and developing new approaches for coping with structural change.

Against the backdrop of the energy crisis, triggered by Russia's war against Ukraine, hydrogen is seeing an additional dynamic in the context of supply security in Europe. It is therefore necessary to adjust the path taken in the roadmap and ensure that Baden-Württemberg's great economic potential is further exploited with a growing hydrogen and fuel cell economy. These changes require an inventory analysis, the expansion of existing fields of action (especially in the areas of infrastructure and hydrogen supply), as well as an adjustment of the target horizon of the Hydrogen Roadmap. The period up to 2030 is therefore taken into account below, where short- and medium-term measures are presented.

2. Responding to changing framework conditions

The right framework conditions must be established for the rapid hydrogen boom. The time frame for making the decisions necessary for this has become tighter for several reasons: The goal of climate neutrality, which must be achieved with the use of hydrogen, among other things, will take effect in Baden-Württemberg as early as 2040. The massive changes in the energy system associated with the war against Ukraine require a much faster contribution from green hydrogen. The business hub of Baden-Württemberg is under considerable competitive pressure, which has been further increased by the Inflation Reduction Act in the USA. And not least of all, the upcoming investment decisions on whether to invest in the development of the hydrogen infrastructure, in applications or in production plants require considerable implementation time. In order to effectively usher in the hydrogen boom, more flexibility in the framework conditions is essential.

European level

At the European level, the so-called gas market package (amending the Gas Directive and the Transmission Regulation) is in negotiations. It is crucial that the proven proprietary unbundling regulations for the gas grid also apply to the joint regulation of natural gas and hydrogen grids. This means in particular that the so-called ITO model (ITO: integrated transmission operator), i.e. the model of an independent network operator in the group, remains an option without a time limit (so-called vertical unbundling). In addition, there must not be a separation of the networks under company law (horizontal unbundling). Otherwise, the de facto result would be expensive double structures and investment barriers. For many network operators, investments in the development of new hydrogen grids and the conversion of existing ones would be economically unattractive, and thus the development of the hydrogen infrastructure would be delayed.

On February 13, 2023, the EU Commission published the Delegated Act pursuant to Art. 27 (3) of the Renewable Energy Directive (RED II), which sets out the criteria for green hydrogen in the transport sector. A policy decision beyond the transport sector applies to these criteria; they are therefore of considerable importance for the speed and economy of the hydrogen boom. Even if it would have been desirable to open up the criteria further, it is crucial that planning security for companies and investors is established in a timely manner. The requirements must be implemented quickly at a national level without intensifying them further. For imports from third countries that are not connected to the EU emissions trading system (ETS) in particular, there are currently unanswered regulatory questions that affect essential business models.

Another important decision is made at the European level with the Alternative Fuels Infrastructure Regulation (AFIR). Negotiations are currently in progress in a so-called trilogue between Parliament, the Commission and the Council. This regulation is of great importance for the future infrastructure for hydrogen refueling. Among other things, minimum standards are set for the future filling station infrastructure.

For aviation and the use of power-to-liquid kerosene (PtL kerosene), the ReFuelEU Aviation Regulation is being prepared as part of trilogue negotiations. Among other things, it is intended to set quotas for the admixture of sustainable aviation fuels (SAFs) and PtL15 kerosene. Synthetic kerosene can currently be added up to an upper limit of 50 percent. For the year 2030, quotas between 0.7 percent and two percent for PtLs and quotas of five to six percent for SAFs are being discussed. These will increase to eight to 13 percent for PtLs and 32 to 37 percent for SAFs by 2040. Exceeding these values requires research due to the density requirements as well

as considerable investments in resources and personnel. The possible admixture quotas in aviation (SAFs and PtLs) are based on the framework set by the European Union and the federal government. A more ambitious state solution requires targeted resources.

It has been shown that there is a need for additional incentives for companies to achieve investments in clean technologies such as hydrogen in a timely manner and to keep them in Europe (and in Baden-Württemberg). As a result, on February 1, 2023, the EU Commission proposed further relief in state aid law as part of the industrial plan for the Green Deal until the end of 2025 and presented it to the member states for consultation. The other measures from the industrial plan for the Green Deal, such as the net-zero industry law, which could also include specifications and targets for production capacities in the hydrogen/electrolyzer sector, will continue to be pursued. The proposals, such as simplified and accelerated approvals and simplified aid rules (e.g. higher notification thresholds), move in this direction and need to be reviewed to see whether their impact is far-reaching enough. From a state perspective, additional aid to compensate for funding in third countries should not only be limited to disadvantaged EU regions, as the Commission proposes. Due to the time delays in the IPCEI Hydrogen (IPCEI: Important Projects of Common European Interest), the Commission's announcement to streamline and simplify the IPCEI procedures should be supported. This is urgently needed from a state perspective.

The state government will continue to present its positions through the federal government and directly in Brussels (including within the framework of the Strategic Dialogue for the Automotive Sector) in order to help shape the framework conditions at the EU level for the hydrogen boom and its derivatives.

Federal level

At the federal level, the hydrogen boom was initiated in the right way based on the National Hydrogen Strategy. However, the changed framework conditions require an accelerated, strategically adapted and financially effective approach.

This includes in particular a timely decision on the expansion of the national hydrogen grid and the necessary investment incentives to create planning security for the rapid expansion and conversion of the transmission network. This is all the more true since, due to the current legal situation, the 2022-2023 gas network development plan that is being coordinated cannot become a binding obligation with regard to the construction and scope of a hydrogen grid.

Investment incentives could take the form of risk hedging in the start-up phase as proposed by the German Energy Agency dena. The alternative model for a national hydrogen grid with state participation must be openly discussed and should not lead to delays in network expansion. Such a model would have to ensure that the projects or connections planned by the transmission system operators for Baden-Württemberg continue to be implemented and that the state is permanently given a say. The distribution system operator level would also have to be included. We are striving for a nationally coordinated, large-scale network, but not the establishment of a federal network company.

Germany needs a balance between production-oriented and consumer-oriented hubs for hydrogen production. If the wrong framework conditions are set for this, not only would the hydrogen boom in Baden-Württemberg be slowed down in the next few years, but the business hub would also be weakened. However, Germany will also have to rely on imports to keep the price level for the use of hydrogen and its derivatives low. Future investments could be made at alternative loca-

tions abroad. The implementation of the Delegated Act on the Implementation of RED II (see above) at the federal level therefore must not contain stricter criteria for green hydrogen, and the framework for import from third countries must be established in a timely manner. The structure of federal funding programs and tenders must be designed in such a way that they make electrolyzers possible in the southwest. The basis of planning for power grids must also take into account locations for electrolyzers in the south. Overall, a significant increase in the funding offers available to all regions in Germany is necessary. With a second round of IPCEI Hydrogen, further major strategic projects could be realized.

The state government will continue to articulate the demand for an early and comprehensive connection to a national and European network to the federal government and will advocate for the appropriate framework conditions.

State level

The state will continue to strongly support the hydrogen boom with strategic processes that tap into the diverse player landscape, through network formation, consulting and communication, and through subsidies. Please refer to the following chapters. Financially effective measures will be implemented as part of a sustainable and forward-looking financial policy. Such a financial policy also requires responsible use of financial resources. Scope will therefore initially have to be created for new or continued measures by reallocating existing funds/sites. Insofar as additional financial funds/sites are required, implementation is subject to the condition that appropriate budgetary resources are or will be allocated. The provision of resources is thus reserved for the budget legislature and is decided in the respective budget preparation procedures, taking into account the budgetary framework. The focus here should also be on electrolyzers and technologies for the production of green hydrogen.

In addition, the state government will create the conditions for efficient approval procedures if they do not yet exist and continue to strengthen them with guidelines and handouts if necessary.

Thematic and project-related cooperations with other federal states can support the hydrogen boom and the political positioning of Baden-Württemberg. For example, the Prime Ministers of Baden-Württemberg and Bavaria agreed on a hydrogen alliance in 2022.

3. Further development of the Hydrogen Roadmap

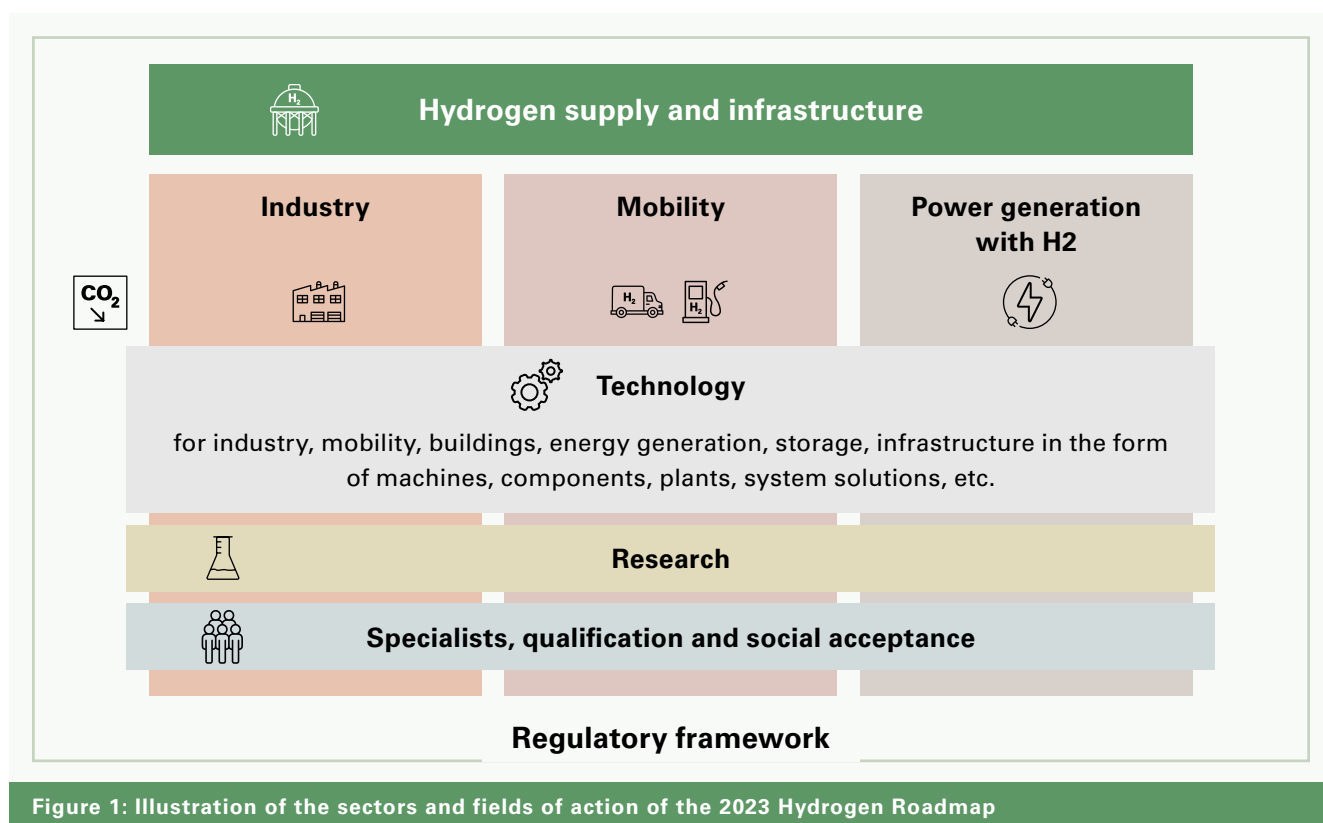
The further development of the Hydrogen Roadmap is based on relevant fields of action in various sectors – mobility, industry, electricity generation – and interdisciplinary fields such as technology, applied research, education and social acceptance. The medium- and long-term availability of green hydrogen (production and import) and the expansion of infrastructure are essential pillars of the future hydrogen economy.

3.1 Recommendations of the BW Hydrogen Advisory Board

In order to be able to further develop and implement the state’s Hydrogen Roadmap in a targeted manner, the state government is advised and supported by the BW Hydrogen Ad-

visory Board (formerly BW H2 Advisory Board), a committee of 25 experts from various sectors and industries. An important basis for this progress report is the position paper prepared by the BW Hydrogen Advisory Board on the roadmap update . This includes seven recommendations, each with four recommendations for action to the state government (see Figure 2), as to how the hydrogen market boom should now be accelerated and which activities should be prioritized. The recommendations of the Advisory Board are primarily aimed at substantially improving the structural conditions in Baden-Württemberg for the production and purchase of green hydrogen.

The Advisory Board also recommends reviewing the implementation of the Hydrogen Roadmap annually.



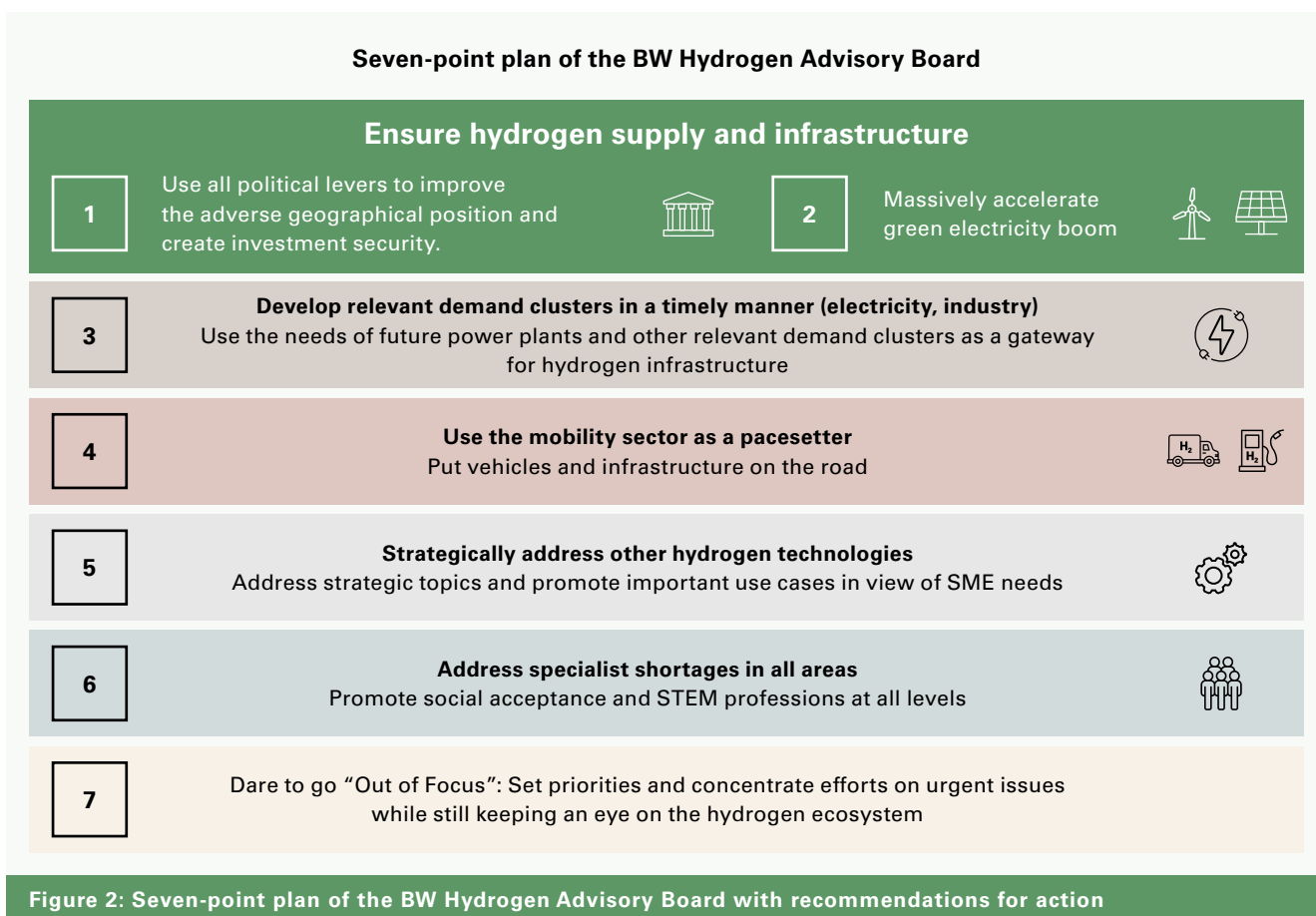
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Figure 1: Illustration of the sectors and fields of action of the 2023 Hydrogen Roadmap

The state government is taking up this recommendation, but will align the time interval of the review with current developments. The most urgent implementation steps recommended by the Advisory Board are the provision of hydrogen and the expansion of infrastructure (Chapter 3.3), as well as the determination of hydrogen demand clusters in electricity generation and industry (Chapter 3.4). In addition, the Advisory Board recommends that more fuel cell-powered vehicles be put on the road (as well as the associated infrastructure), so that the mobility sector can be used as an essential pacesetter for the market boom of hydrogen technologies (Chapter 3.5). In the area of technologies, further topics should be covered in order to strategically expand the technological skills that currently exist primarily in the field of fuel cells (Chapter 3.7), for example to electrolysis technologies. The overarching

recommendations, which do not in turn exclusively concern the area of hydrogen, should be regarded as countermeasures for the shortage of specialists and the social acceptance of hydrogen technologies (Chapter 3.9). The last recommendation advocates for a clear prioritization of measures and sectors for hydrogen use. Due to more efficient possibilities, the building sector is currently not considered a priority sector for hydrogen application (Chapter 3.6).

The recommendations of the Advisory Board will be implemented in the further course of updating the roadmap, and reference will be made to them. The Advisory Board's recommendations will be taken into account when measures are further developed.



3.2 H2BW platform

With the H2BW platform, the state government has created a central point of contact for hydrogen-related issues. The platform serves as a central intermediary and contact for the development of a hydrogen economy and supports the state government with the implementation of the BW Hydrogen Roadmap. The H2BW platform also coordinates the BW Hydrogen Advisory Board.

The focus of the H2BW platform is on the networking of various players in the business, science and research sectors. In doing so, the platform addresses both technologically adept and interested companies from Baden-Württemberg equally and creates a basis for common exchange. The H2BW platform initiates and provides support on various topics from research and development to industrialization, for example by providing information on funding opportunities through tenders, enabling exchange between players and strengthening networks. In order to further strengthen knowledge sharing, the platform publishes helpful summarized background knowledge in its own publications and studies. The platform also offers an overview of national activities in the field of hydrogen on the website www.platform-h2bw.de and thus increases the visibility of the diverse player landscape in the state. The H2BW platform thus offers a wide range of services in a wide variety of areas.

The H2BW platform is coordinated and managed by the State Agency for New Mobility Solutions and Automotive, e-mobil BW GmbH, which contributes its many years of experience and expertise in the management of the Cluster Fuel Cell BW and can harness synergies in many projects in the mobility sector and beyond.

As an interface between research and development of new technologies and innovative business models, the H2BW platform with the Cluster Fuel Cell BW promotes important cross-sector exchange and thus provides the optimal framework for project initiation and an established forum for in-depth professional exchange. The Cluster Fuel Cell BW consists of more than 200 partners, bundles and structures the diverse activities and skills in the field of hydrogen and fuel cell technologies in Baden-Württemberg and thus strengthens the cooperation of players in the business, science, trade association and politics sectors in the state.

The close integration of the platform with the BW State Transformation Knowledge Pilot Office, which is also under the umbrella of e-mobil BW GmbH, also enables a special approach to small and medium-sized companies that particularly need support and information in the transfer process towards new energy and drive technologies.

3.3 Hydrogen availability and infrastructure construction and expansion

In addition to supporting the technological market boom of hydrogen, which has been intensively driven by numerous projects and funding programs in recent years, the hydrogen market boom must be supported specifically by constructing and expanding a future-proof hydrogen infrastructure. The rapid expansion of infrastructure is a central prerequisite for the hydrogen boom. The network expansion plans of the transmission system operators (TSOs) outline the first connection of Baden-Württemberg to a national and European hydrogen grid starting in approximately 2030. In addition to expanding the pipeline network, regional solutions for hydrogen production must be strengthened and the development of electrolysis capacities advanced at the same time. In order to ensure a large-scale supply of hydrogen at an early stage, the state is also increasingly committed to international partnerships for the import of hydrogen and hydrogen derivatives.

Considering future hydrogen demands

The draft update of the National Hydrogen Strategy assumes a total German hydrogen demand of 95 to 130 terawatt hours (TWh) for the year 2030. The federal government has increased the expansion target for generation capacity from the original 5 gigawatts to 10 gigawatts. The EU expects the total hydrogen demand to be 670 TWh for 2030 and 2250 TWh for 2050.

A recently published study by the National Hydrogen Council (NWR) suggests that the geopolitical upheavals and their influence on the energy markets result in a far greater demand for hydrogen for Germany – possibly even a doubling of the demand previously assumed by the NWR.

For the period after 2030, a significant increase in demand is to be expected, as more and more production and energy-related processes have to be converted by then. According to forecasts, the demand for hydrogen and its synthesis products throughout Germany is expected to reach 420–660 TWh by 2045. Against the backdrop of the new geopolitical situation and the resulting changes in energy supply, as well as the urgency of measures to protect the climate, it can be assumed that hydrogen will be needed earlier and in far greater quantities than expected to diversify the energy system.

The BW Hydrogen Advisory Board also expects a significantly higher demand for hydrogen and an earlier upsurge. According to the previous results of the research project “2030 Sector Goals and Climate-neutral Baden-Württemberg by 2040”, there will also be a significant increase in hydrogen demand in Baden-Württemberg from 2030 onwards, especially in the conversion sector (power generation, refineries) and in industry.

In the target scenario of the above study on the 2030 sector targets, a final energy consumption of 197 TWh for 2040 is assumed; hydrogen would account for around 15 percent of the final energy consumption in all sectors at around 30 TWh and PtLs (8 TWh) of around 4 percent. By 2030, due to the still limited availability, use will be limited to around 4 TWh of hydrogen and 5 TWh of PtLs.



In terms of their trends, the changes in hydrogen demand are in line with the results of the study commissioned by the H2BW platform “Analysis of the current situation of H2 demand and production potential in Baden-Württemberg” from January 2022, but which refer to the year 2035 (16.6 TWh). Due to the dynamics that must be observed, higher numbers may already be possible at present.

These dynamic developments in the field of hydrogen require that changes in hydrogen demands be regularly recorded and updated, in particular to be able to plan and dimension transport and storage infrastructures as well as production and import capacities. Requests for resources from industry, commerce and downstream network operators are of fundamental importance for the connection of regions to a hydrogen grid. These requests for resources must also have a certain degree of bindingness in order to be integrated in the network planning processes with transmission system operators at the federal level. A thorough survey is required to determine which applications require hydrogen, where and to what extent. The industrial sectors which green hydrogen is essential for must be able to access it quickly. With careful consideration and prioritization of where green hydrogen is used, poor investments and poor incentives can be avoided.

The state government will closely monitor and analyze the evolution of hydrogen demand. It will support grid operators in making hydrogen consumers aware of the importance of hydrogen demand reports for infrastructure planning and will enter into a joint initiative with grid operators, trade associations and chambers to this end. The planning of the hydrogen infrastructure should be part of a holistic concept at the federal level for energy supply that is geared towards the goal of climate neutrality.

In its recommendations, the BW Hydrogen Advisory Board states that the future hydrogen demands of SMEs and traders have only been recorded to a limited extent to date and should be precisely determined and critically examined within the next two years as part of the update of the Gas Grid Transformation Plan (GTP) by the gas distribution system operators. The state government will take this suggestion into account in the activities specified above.

Development of decentralized generation capacities

Until there is a large-scale supply via transmission and distribution networks, the rapid development of electrolyzers and promising generation capacities for climate-neutral hydrogen is necessary to meet the increasing demand for hydrogen. Since the hydrogen pipeline network only connects the various clusters and industrial centers gradually (based on the current status, as of 2028 at the earliest in the Freiburg area), the decentralized development of on-site electrolysis services also serves to ensure energy supply security. Electrolyzers will also be operated to a certain extent in Baden-Württemberg in the long term – at decentralized locations without direct pipeline access, for example, but also because the lifespan of electrolyzers is around twenty years. The construction of electrolyzers is therefore an important element of the state's hydrogen strategy. In the site selection and overall planning, it must be taken into account as a criterion for increasing overall economic efficiency and improving resource efficiency that the waste heat generated can be used in the surrounding area if possible by means of a heat grid.

Within the framework of the European Regional Development Fund (ERDF), the state government is funding two model regions in which, according to the current status, the development of electrolysis capacities totaling around 30 MWel is planned. In other funded electrolysis projects, capacities of at least 14 MWel are included.

The increasing demand is also reflected in an increasing number of initiatives and projects for the construction of electrolyzers, some with an output of 50 MW of electrolysis power per project and more. Project planning or preparations can be assumed to cover a total of several hundred MW of electrical power.

The state government supports the federal government's goal of achieving a nationwide electrolysis capacity of 10 GW by 2030. It intends to support other regions that serve as regional and initial hydrogen hubs and to fund the development of electrolyzers in the state depending on the budgetary situation, insofar as this is necessary beyond the announced federal funding programs.

The use of waste heat should be taken into account here.

It must be made possible to develop generation capacities near consumption clusters at decentralized locations in so-called clusters or isolated solutions. The development of a regional, decentralized hydrogen infrastructure with local pipeline systems, the installation of regional hydrogen hubs and the planning of interfaces for future connection to national or cross-border pipelines are conceivable here.

This can establish important hotbeds for hydrogen ecosystems at the municipal level. In this context, the BW Hydrogen Advisory Board emphasizes in particular the importance of regional solutions for regional demand clusters which can only be connected to an appropriate pipe-bound infrastructure at a late stage. In this context, identifying so-called favorable locations for the installation of electrolyzers is advantageous and strived for by the state government. Knowledge of favorable locations generates additional planning security for investors before major investments are made.

The state government will support potential investors by providing information on possible favorable locations for the construction of electrolyzers.

To this end, it is important that the necessary framework conditions that enable hydrogen production in all regions of Germany are established. In the draft update of the National Hydrogen Strategy known to date, special focus is placed on electrolysis hubs in northern Germany that supply the power grid. For appropriate network planning, the definition of funding conditions as well as legal framework conditions at the federal level, care must be taken to ensure that generation capacities can also be expanded in southern Germany. From the state government's perspective, in addition to the utility of the power grid, the utility of the system (diversification of supply, heat provision as a substitute for power plants that are shutting down, as well as the possibility of electrolysis waste heat utilization) of locations must also be taken into account.

The state government will continue to lobby the federal government to ensure that electrolysis hubs and associated network nodes are also taken into account in Baden-Württemberg. The federal government's framework conditions must enable the construction of electrolyzers in BW under realistic conditions. This also applies to the configuration of federal funding programs and tenders.

The Delegated Act pursuant to Art. 27 para. 3 of the Renewable Energy Directive II (RED II) must also be implemented promptly into national law and without additional intensification.

As part of the amendment of the European Industrial Emissions Directive, the state government is lobbying through the federal government to remove smaller electrolyzers for the production of hydrogen from the scope of Annex 1 of the Directive. This would allow the scope of the approval requirement under pollution control law to be adapted accordingly at the federal level.

The state government will continue to strengthen approval procedures that are as efficient as possible with supporting guidelines and recommendations for action.

Infrastructure expansion

The expansion of the hydrogen infrastructure must be advanced at full speed in order to be able to meet the massively increasing hydrogen demand of various sectors by 2030 at the latest, including through imports. The supply of hydrogen to Baden-Württemberg via pipelines depends primarily on the development of a national and European hydrogen grid. The activities to build such a network have increased sharply at the European, national and state level.

In view of the long planning and approval processes and high investment requirements, the appropriate framework conditions must be established very quickly.

The state government will continue to work with the federal government and the EU to ensure that suitable framework conditions are established as soon as possible in order to further accelerate the expansion of infrastructure for and in Baden-Württemberg. This applies in particular to the unbundling regulations at the European level as well as to the basic decision on network expansion at the national level and to investment incentives (see Section 2).

Plans by transmission system operators (TSOs) foresee that Baden-Württemberg will have its first pipeline connections to a hydrogen grid by 2030, possibly as early as 2028 in the Freiburg area. For example, the South German natural gas pipeline SEL, which is being built from the junction in Lampertheim in southern Hesse to Bissingen, is expected to be completed by 2027 and can be converted to hydrogen as quickly as possible.

As of 2030, it will be possible to supply Baden-Württemberg from the North Sea by landing ships via Dutch, Belgian or northern German ports or via pipeline deliveries from Scandinavia along the Rhine, for example to Lampertheim and further to Baden-Württemberg (Project H2ercules). Another supply route could be set up from the Baltic Sea via the East German federal states to this junction and then further via the SEL (Project Flow – making hydrogen happen). The announced H2Med pipeline from Spain, where a major focus can be placed on European production, with an underwater pipeline from Barcelona to Marseille and the extension to Germany, is also an important option. Branches to Baden-Württemberg are quite possible. The cross-border RHYNE Interco project is also being specifically planned in the Freiburg area, with a possible connection to Baden-Württemberg starting in 2028. In the long term, options for deliveries (e.g. from North Africa) via Italy and Switzerland or Austria/Bavaria and for deliveries from Eastern Europe via Bavaria are also possible. Baden-Württemberg thus essentially has the prospect of being able to be connected to all five main lines of the planned European Hydrogen Backbone Network.

However, the above-mentioned TSO project plans require appropriate framework conditions at the federal and EU level, especially planning security for the scope of a hydrogen start-up network and investment incentives.

It will be possible to feed hydrogen into a European backbone network within a few years. Everything must be done on the German and Baden-Württemberg ends now to ensure that this hydrogen can also reach Baden-Württemberg.

The state government is advocating for an early connection to a national and European hydrogen grid by implementing the projects planned by the transmission system operators.

It is supporting the realization of a connection point in the southwest as part of the pipeline connection from Marseille to Germany agreed between Germany and France (extension of the planned connection between Barcelona and Marseille). It is also committed to creating the necessary framework conditions at the EU and federal level as quickly as possible.

The gas distribution networks which many private customers, commercial enterprises and industrial companies are connected to must be taken into account when constructing the pipe-bound hydrogen infrastructure. The study on the decarbonization of the heat sector by the two Fraunhofer institutes ISE and IEE (on behalf of the National Hydrogen Council) correctly concludes that the plans for the expansion and conversion of the national and European hydrogen grids must be brought into alignment with the transformation of regional supply infrastructures. This requires a differentiated and decentralized approach and analyses of the different local and regional supply structures.

In order to be able to supply industries, power plants and mobility applications with hydrogen and its derivatives in a timely manner, other transport routes and storage options for climate-neutral hydrogen and its derivatives must be taken into account in addition to pipeline connections.

In December 2022, the state government discussed the current challenges in the area of hydrogen infrastructure with the members of the BW Hydrogen Advisory Board and the Corporate Energy Transition Dialogue as well as other players in a top-level meeting on hydrogen infrastructure conducted by Minister Thekla Walker MdL [State Parliament Member].

Continuing along these lines, three workshops will be held until the summer of 2023 as part of the Expert Dialogue on Hydrogen Infrastructure and as an active contribution to Mission IV in the Strategic Dialogue for the Automotive Sector in Baden-Württemberg. The aim of the workshops is to create a knowledge base on hydrogen infrastructure requirements – with regard to topics such as supply options, regulation, grid expansion, financing models, hydrogen demands and production of green hydrogen – in Baden-Württemberg in order to build on this with the stakeholders to develop a common picture and to enable a strategically coordinated approach to the development of hydrogen infrastructure. The results will be presented in a second top-level meeting.

With the Expert Dialogue on Hydrogen Infrastructure, the state government is initiating the groundwork for a strategically coordinated approach to the development of hydrogen infrastructure, which must be promoted together with all relevant stakeholders. The workshops are also part of Mission IV within the framework of the BW Strategic Dialogue for the Automotive Sector (SDA).

Energy partnerships and international networks

Even with an ambitious expansion of renewable energies in Baden-Württemberg, hydrogen demands in the state (as in Germany) cannot be met purely by self-generation. If hydrogen and synthetic fuels were produced exclusively in Baden-Württemberg, gross electricity consumption in 2040 would be more than twice as high as today and would require 57 TWh of renewable electricity.

Much of the hydrogen and its derivatives will therefore have to be imported in the medium and long term, which makes the broadest possible diversification of energy partnerships necessary in order to avoid technical and political dependencies. Supply security for green hydrogen, but also the export of hydrogen technologies, is supported by the establishment of stable and sustainable energy partnerships. This requires a broad network of partners in different regions of the world, which Baden-Württemberg has at its disposal or which is being further expanded. Partnership declarations on topics such as climate action and hydrogen were agreed with Scotland and Andalusia for this purpose in 2022. Mutual benefits and the joint development of local value chains are crucial for successful hydrogen partnerships. The task of the state government is to politically support and promote possible supply relationships between the players at an early stage. This can be done, for example, in the hydrogen market boom phase with supporting “matchmaking” offers between potential

players (producers and consumers of hydrogen, intermediaries). This is why the state closely monitors the activities of the federal government and, in addition to building up its own generation capacities, analyzes state-specific hydrogen priorities and supports them with policy measures.

The state government will continue to advocate for import options of hydrogen to Baden-Württemberg in the form of cross-border and international cooperation.

To this end, it will implement the new partnerships with Scotland and Andalusia in Europe, enter into further targeted partnerships and deepen the already existing cooperations, for example with Catalonia (partner of ‘Four Motors for Europe’) as well as with regions in neighboring countries such as France and Switzerland.

In addition, the partnership with the Netherlands should be strengthened, as the port of Rotterdam is an important import point for green hydrogen.

Beyond the aforementioned cooperations, other European countries can be identified as potential hydrogen supply countries in the short to medium term: In addition to other Spanish regions and Portugal, these are Scandinavian countries such as Norway and Denmark as well as (south)eastern European countries (e.g. Croatia).

In terms of political stability, the availability of renewable energies and the high level of technology, countries such as the USA, Canada or Australia also offer good prospects for cooperation.

Cooperation opportunities with other non-European countries and regions that have a high hydrogen production potential are currently seen in Latin America, particularly with regard to Brazil and Chile in Latin America, individual countries in North Africa and in Asia, such as India. When purchasing hydrogen in the future, care should be taken to ensure that this does not lead to unilateral dependence on regimes that are in opposition to our liberal democratic basic order. These priorities of the state, which must be adapted to current developments and analyses, also incorporate the federal government's advice and activities. The state is also generally guided by the international energy partnerships of the federal government.

Another important tool for the sustainable procurement of hydrogen is seen in H2Global's double auction model. In order for companies to benefit from hydrogen deliveries or its derivatives, purchase agreements can be concluded within the framework of H2Global. H2Global can also be extended as a tool to other regions, e.g. European countries. The regulatory framework necessary for this would have to be adapted accordingly.

The state government will increasingly make companies aware of the importance of H2Global for establishing a supply and logistics chain as well as the first hydrogen hubs, for example in the form of workshops.

International networks

In order for the diverse hydrogen projects and initiatives in Baden-Württemberg to have their greatest possible long-term impact, networks and alliances are also being expanded internationally. International exchange is particularly indispensable for three areas:

- Hydrogen supply and infrastructure
- Scaling of production processes
- Development of relevant sales markets with technology exports, for example

In addition to the possible import of hydrogen, hydrogen partnerships may also include offers for technology export and technological cooperation (production of components and sub-systems for the hydrogen economy), the scientific exchange of know-how, and the initiation of cooperation projects in which Baden-Württemberg is particularly strong.

The state government will also address and further intensify the topics of technology export and scientific cooperation in its relations with partner regions.

The focus is also on the expansion of regional and European networks, the reinforcement of cluster work and targeted knowledge sharing. Only in this way can the complex change to a climate-neutral hydrogen economy succeed and the goals of the Baden-Württemberg Hydrogen Roadmap be achieved.

European networks and platforms such as the European Hydrogen Valley Partnership (S3 EHVP), the regional pillar of the European hydrogen association Hydrogen Europe, and the hydrogen focus group of the EU Strategy for the Alpine Region are used in a targeted manner.

Hydrogen Europe

Hydrogen Europe is the umbrella organization for hydrogen in the EU based in Brussels. The members belong to industry, research and national hydrogen associations in the member states. The industry representatives are organized in Hydrogen Europe Industry, the research in Hydrogen Europe Research (HER). In turn, HER is part of the Public Private Partnership Clean Hydrogen Joint Undertaking, formerly Fuel Cells and Hydrogen Joint Undertaking (FCH JU). Baden-Württemberg is a member of a regional pillar (consisting of European regions) of Hydrogen Europe that was founded specifically for regional players.

European Hydrogen Valleys Partnership (EHVP)

The use of hydrogen in different regions in the EU is discussed within the framework of the S3 initiative EHVP (platform of the EU Commission for Interregional Cooperation). Baden-Württemberg is active in the initiative as a “participating region”. There are more than 30 regions from over 13 countries in the group in total.

Strategy for the Alpine Region (EUSALP)

EUSALP is the EU’s macro-regional strategy for the Alpine region and was endorsed by the Council of the European Union in November 2015. Within the framework of the EUSALP strategy, Baden-Württemberg is active, among other things, in the focus group on hydrogen. An important goal is improving the hydrogen infrastructure, as important transport routes run through the Alps. A total of seven states (five member states and two non-member states) and 48 regions are involved in EUSALP.

3.4 Industry and power generation

Industry

The Baden-Württemberg-based industry is made up of various industrial sectors that, firstly, use hydrogen materially and, secondly, use (previously gray) hydrogen energetically for high-temperature heat processes as an alternative to fossil fuels. The waste heat generated during electrolysis also represents an ecologically and economically practical use in industrial processes.

An essential criterion for the future energetic use of hydrogen is the temperature level required for process heating. Industries that require process temperatures $> 400^{\circ}\text{C}$ are therefore particularly suitable for the use of (green) hydrogen. The greatest (energetic) hydrogen demand in Baden-Württemberg is therefore seen primarily in the steel, paper, glass and sugar industries. In terms of materials, (green) hydrogen is mainly used in raw material and mineral oil processing. The total demand of the aforementioned industrial sectors is forecast to increase from a total of 3.1 TWh in 2020 to up to 7.7 TWh in 2035. Due to the energy and material requirements, the topic of hydrogen is of particular importance in industry. The industry transformation process to climate neutrality must be advanced quickly and needs special attention for the industrial and business hub to remain competitive.

The expansion of the hydrogen infrastructure to a large-scale supply of green hydrogen to Baden-Württemberg via large hydrogen pipelines is currently being planned and will be gradually developed and expanded. Until the pipe-bound hydrogen supply is expanded, it is important to consider the technology-neutral production of hydrogen in order to meet short-term increasing demand during the hydrogen rollout, to prioritize and prepare for the use of green hydrogen, and to electrify processes directly if technically feasible or to further

support the expansion of the circular economy and the use of biomass. This also includes considering local, decentralized production of green hydrogen and implementing it accordingly. In terms of the material use of green hydrogen, depending on the technical processes, alternatives such as green ammonia or methanol are also being investigated in the process directly and without prior conversion into hydrogen.

The state government supports the economy in the transformation process to a green industry, which has an increased demand for hydrogen and its derivatives, on the path toward achieving its climate targets.

For example, the state of Baden-Württemberg is already supporting this transformation process through projects such as H2Chemie 2050 (complete conversion of the previously essentially “gray” hydrogen economy in the chemical-pharmaceutical industry to “green” by 2050) and H2GreenForge (development of a decentralized hydrogen supply for use in open-die forging [steel industry]) in the funding programs “Hydrogen Future Program” and “Climate Action and Value Creation through Hydrogen” (details in Chapter 4). The state government will continue to support the various industrial sectors with demonstration projects based on the funds available in the budget.

At the end of 2022, the state government set up a series of expert dialogues with stakeholders in business with the aim of entering into an active exchange with the business community and working closely with it on a professional basis during the aforementioned transformation process.

The state government supports the transformation process in various industrial sectors through funding programs and demonstration projects and will continue and broaden its intensive dialogue with the industrial sector.

Electricity generation and district heating

The energy sector has the greatest demand for hydrogen in Baden-Württemberg, and every second kWh of hydrogen will be allocated to this sector in 2040.

In detail, the study “2030 Sector Goals and Climate-neutral Baden-Württemberg by 2040” determined a hydrogen demand for electricity and heat generation of around 15 TWh by 2040. The new gas-fired power plants to be built or converted will become central bulk hydrogen consumers by 2040. While the output of coal and nuclear power plants (6.8 GW in total in 2020) will be completely eliminated in this scenario by 2030, the output of gas power plants will increase to 4.6 GW, almost double today’s output. The latest generation of gas and steam turbine power plants are either already hydrogen-ready or can be converted accordingly and operated with hydrogen at any time if there is a sufficient supply of it. The authors of the study “2030 Sector Goals and Climate-neutral Baden-Württemberg by 2040” assume that 11 percent of hydrogen consumption will already be allocated to electricity and heat generation in 2030. By 2040 at the latest, the complete transition (fuel switch to hydrogen) must be completed in order to ensure climate neutrality in Baden-Würt-

temberg. According to this study, electricity generation from hydrogen will amount to around 7.5 TWh in 2040, which is then 8 percent of total gross electricity generation (including fluctuating renewable energies). However, at around 70 percent of the guaranteed output, gas power plants will make a significant contribution to supply security in the transformed, climate-neutral electricity system in 2040. Hydrogen is a backup option in the power supply that is needed in times of high residual load (i.e. power consumption that is not covered by renewable energies).

As of 2030, hydrogen will also be increasingly used to generate district heating, among other technologies. Hydrogen also functions as a backup option in situations with a limited alternative supply of renewable heat. Since situations of high (electrical) residual load and high heat demand often occur simultaneously, sufficient capacities of the most flexible CHP plants possible must be planned to increase the efficiency of hydrogen use. For supply security and grid stability, the BW Hydrogen Advisory Board is in favor of connecting the major power plants in Heilbronn, Stuttgart and Altbach/Deizisau to a hydrogen pipeline at an early stage. There are also other decentralized industrial power plants in the state that will continue to be operated in the future.

The aim is to connect the major power plants in Heilbronn, Stuttgart and Altbach/Deizisau to a hydrogen pipeline at an early stage. The state is conducting a dialogue with power plant operators to ensure a timely switch to hydrogen.

3.5 Mobility

Green hydrogen is a possible field of application in the transport sector. Particularly where battery-electric drives reach their limits, the use of hydrogen can make sense. Further technical developments will be closely monitored to ensure that green hydrogen is available for the applications that rely on green hydrogen. Commercial vehicles currently generate approximately one third of CO₂ emissions in the transport sector. Their decarbonization is thus a primary key to effectively implementing climate action in transport. The first demonstration projects with commercial vehicles have been started in Baden-Württemberg. The most prominent projects are H2Rivers and H2Rhein-Neckar, where, in addition to passenger cars and light commercial vehicles, 62 buses, three waste collection vehicles, two road service vehicles and ten fuel cell-powered forklifts will be put into operation. Other model projects are in the development phase – in the ERDF funding program “Green Hydrogen Model Region”, for example, fuel cell-powered heavy-duty commercial vehicles are being used in the logistics industry. There are other vehicles in use in the state that are powered by hydrogen and fuel cell technologies and are supported, for example, by federal funding.

In addition, there are several demonstration projects in Germany for rail-based public transport, for each of which a central hydrogen refueling system has been set up. In Baden-Württemberg, the federally funded “H2goesRail” project is currently planned on the route between Tübingen and Pforzheim. The use of hydrogen to propel ships will also be an area of application in the future.



The state government will continue to advocate intensively for the application of hydrogen in the mobility sector. It contributes to the design of the framework conditions, coordinates them with the stakeholders, and funds other demonstration projects based on the budgetary situation.

In the development of fuel cell systems, which are also used in the mobility sector, companies and research institutions in Baden-Württemberg are leading the European and German field. This is clear in innovative projects such as the “HyFaB” research factory and the Baden-Württemberg IPCEI projects, which focus, for example, on the development and production of fuel cell components and systems. This technology offers enormous opportunities for the domestic industrial and research landscape in Baden-Württemberg (see also technology subchapter).

In terms of maximizing efficiency, the intensity of use as well as the output and range requirements in particular play a central role in the mobility sector. The state of Baden-Württemberg therefore presented a BW reFuels Roadmap in July 2022, which sets out the necessary steps to realize value creation potential and achieve the state’s climate targets with synthetic fuels. The measures in the BW reFuels Roadmap will be implemented and updated at certain intervals due to changing framework conditions. Both the measures and the means must be adapted for targets beyond this that are derived from the sector targets.

In addition to the use of reFuels, the hydrogen combustion engine can also be used, especially in the heavy-duty commercial vehicle segment.

Expansion of hydrogen tank infrastructure

The infrastructure for the road transport sector must be conceived in a pan-European way. We are therefore closely monitoring the development and focusing on a pan-European infrastructure. In addition to expanding pipelines and other hydrogen transport options, it is important to further accelerate the expansion of a reliable and efficient network of hydrogen filling stations, especially for commercial vehicles of all classes. In order to develop a branched tank infrastructure network and be able to connect these across national borders, alliances and partnerships in the European area are necessary.

The development of the hydrogen tank infrastructure also gives Baden-Württemberg companies in the automotive and mechanical engineering sectors, for example, the opportunity to place their products on the market.

To date, 15 hydrogen filling stations (of currently 93 active filling stations in Germany, 02/04/2023) have been built in BW through federal funding as part of the National Innovation Program for Hydrogen and Fuel Cell Technology (NIP). A large portion of these refueling systems are currently operated at the standardized hydrogen pressure level of 700 bar for passenger cars. For the first expected commercial application of commercial vehicles, there are currently still insufficient refueling options and uniform standards. Other refueling concepts, such as liquid refueling, are currently in development.

The “Alternative Fuels Infrastructure Regulation”, AFIR, is currently in trilogue negotiations at the EU level and is intended to establish guidelines for the future infrastructure for hydrogen refueling and standardization. There is currently no planning security for manufacturers and users due to the pending decisions. Should the more ambitious proposal by the Parliament prevail in the negotiations and be transferred to Baden-Württemberg, about 30 hydrogen filling station installations would need to be put into operation in the state by 2027.

There must be open technical coordination in and with the vehicle industry and other stakeholders as soon as possible. The state government will continue to support the process of developing uniform standards, such as for the so-called refueling protocol for commercial vehicles, refueling couplings and filling nozzles, and will also work together with relevant stakeholders in the industry and research sectors on the conditions for the market boom and filling station infrastructure, especially for heavy-duty commercial vehicles, and will proceed in a results-oriented and technology-neutral manner – particularly within the framework of the automotive industry strategy dialogue.

A study on hydrogen infrastructure for commercial vehicles in long-distance transport, which was commissioned by the H2BW platform, investigates the above-mentioned aspects of the refueling and refueling infrastructure of different fuel options for Baden-Württemberg. The study confirms the importance of completing various international standardizations, but also of creating sufficient capacities for the production, conditioning, transport and distribution of hydrogen and initiating demonstration projects to test different fuel options and their infrastructure requirements.

As part of the Strategic Dialogue for the Automotive Sector (SDA), valuable results are achieved with stakeholders on, for example, the hydrogen supply (Mission IV) and the development of the hydrogen filling station infrastructure (Mission V) in Baden-Württemberg. The project “BW Truck Pilot Charging and Hydrogen Filling Station” (PiLaTes) was jointly agreed in a letter of intent between the state government and stakeholders as part of the SDA with the goal of planning, constructing and operating the first combined pilot filling station for fast high-performance charging, as well as for gaseous and liquid hydrogen refueling for battery-powered and fuel cell trucks.

In order to support the further expansion of the hydrogen refueling infrastructure, the state government will fund the construction of a pilot charging and hydrogen filling station for trucks and issue a tender for it in 2023.

As part of IPCEI Hydrogen, three truck filling station projects were also generated that are located throughout German and affect Baden-Württemberg proportionally. The state has proposed funding for these projects.

Further funding opportunities for hydrogen filling stations along strategic transport hubs, in particular for heavy-duty commercial vehicles, are being reviewed.

3.6 Buildings

The BW Hydrogen Advisory Board is of the opinion that efficient and technically sophisticated solutions should preferably be installed for the decentralized supply of heat to buildings. The primary reason is the delayed availability of hydrogen in the area. In the long term, however, portions of the heat supply could be generated by gases and thus by hydrogen (in particular combined heat and power plants). Hydrogen for the heating market should therefore not be categorically excluded in future considerations and developments.

The Advisory Board refers here to a bottom-up study commissioned by the National Hydrogen Council (NWR) on path options for an efficient and socially acceptable decarbonization of the heating sector. This study arrives at the conclusion that, for a climate-neutral energy supply in Germany by 2045, all potential climate-neutral energy sources - electricity, district heating, renewable energies and hydrogen - are needed in the heat supply. In the scenarios considered, the proportions of the respective energy sources are largely determined by the cost difference between the energy sources and their availability. The 2030 route is characterized by a strong ramp-up in PV and heat pump capacities.

Hydrogen in particular is seen as a component of an industrial application (process heating) and a central heat supply as of 2030. A one-size-fits-all solution does not exist for the heating market. It is recommended that preparations be made in the phase up to 2030 to decide which distribution network infrastructures will supply the areas. Municipal heat planning is seen as a central tool here. Integrated supply infrastructures would have to be further developed, and a powerful H2 backbone with downstream hydrogen infrastructures would have to be built for the relevant applications. The partial report on the research project “2030 Sector Goals and Climate-neutral Baden-Württemberg by 2040” concludes that hydrogen will

be used after 2030 to gradually replace the remaining natural gas demand in larger CHP plants. In 2040, 14 percent of district heating demand will be met by hydrogen. Hydrogen thus primarily takes on a backup function in the central heat supply to supplement renewable energies during peak load periods.

The state government generally shares these assessments and gives priority to the use of hydrogen for generating district heating and industrial applications (see also the power supply and district heating subsection).

An important aspect in the context of heat supply is the use of waste heat from electrolyzers that is fed into heating networks. Waste heat utilization is an important indirect area of use for hydrogen where possible and sensible which simultaneously contributes to increasing the economic efficiency of electrolyzers.

The state gives priority to efficient solutions in the decentralized supply of heat to buildings. If hydrogen is used for heat generation, it should be used primarily for the generation of district heating and industrial process heating. We also support the goal of using heat generated in the production of hydrogen by electrolysis. This can significantly increase overall efficiency.

The use of stationary fuel cell systems, especially in buildings, to support electricity-powered, high-efficiency combined heat and power applications in hospitals, data centers and similar facilities can be supported as part of demonstration projects. For example, the development and operation of highly efficient, stationary fuel cell systems by the state for use in industrial parks, hospitals, data centers and similar facilities as well as modern urban districts is supported by the federal and state governments due to the great future potential as part of the current IPCEI project “BoschPowerUnits” (more information in Chapter 4). The state government also sees the development of know-how in this area, especially among local companies, as an important step in strengthening Baden-Württemberg as a technology hub and its long-term competitiveness.

3.7 Technology

As a strong European industrial region, it is important for Baden-Württemberg to achieve its own climate targets and simultaneously keep the business location efficient in the national and international field and to transform it toward complementary, sustainable technologies. International markets offer companies in Baden-Württemberg enormous export potential for hydrogen and fuel cell technologies.

The Baden-Württemberg player landscape in the field of hydrogen and fuel cells has many years of experience in research and development and a high level of technological skill and innovative power at its disposal. The state's traditional strengths lie in the field of complex system solutions and innovative and knowledge-intensive fields of application – particularly in mechanical and plant engineering as well as in the automotive sector. In 2021, Allianz Wasserstoffmotor (Allianz Hydrogen Engine) e.V. was founded as a network of automotive companies, suppliers, engineers with various specializations and research institutes. Baden-Württemberg is one of the leading hubs in the development and production of fuel cell components and systems and has also started important activities for the development and production of electrolyzers and their components.

A study by Roland Berger forecasts a possible gross added value of up to 2.3 billion euros and a sales potential of up to 9 billion euros for the hydrogen and fuel cell industry in Baden-Württemberg by 2030. Approximately 16,500 additional jobs could be created by 2030. Industrial market participants in Baden-Württemberg can already boast an export share of more than 50 percent in the field of hydrogen and fuel cell technologies. Baden-Württemberg has the potential to build a hydrogen industry across the entire value chain, from green hydrogen production by electrolysis and the necessary infrastructure development to a large number of fuel cell applications.

However, the sales potential can only be realized if Baden-Württemberg's hydrogen and fuel cell technologies can be exported to relevant target markets and international market shares can be achieved in an increasingly competitive environment. With its proposal for the Green Industrial Plan, the European Union has developed a concept for continuing to operate competitively in the global market.

In addition to potential and market analyses, the state will make intensive use of available tools in the field of foreign trade and location marketing in order to further support the technology export of products 'made in BW'.

Further steps toward broad industrial and, in particular, economic scaling are needed. The state government therefore supports leading international companies in Baden-Württemberg through funding as part of the so-called Important Projects of Common European Interest (IPCEI). This is intended, among other things, to help build next-generation production plants for fuel cell and electrolysis stacks or for components on an industrial scale and optimized fuel cell or electrolysis technology (details on IPCEI funding in Chapter 4).

In addition to the technological importance of fuel cell technologies for Baden-Württemberg, increasingly more electrolyzers will be needed globally to produce green hydrogen. There is therefore economic potential for Baden-Württemberg companies in the field of manufacturing electrolysis technologies. Their industrial production, however, must still be supported and funded in the future. The BW Hydrogen Advisory Board proposes to support the industrialization of electrolysis production by creating favorable framework conditions and by promoting test options. As part of state-supported projects, such as “Electrolysis made in BW”, for example, an electrolysis plant could be built, the development and production of which around 40 companies from Baden-Württemberg have contributed components, technologies and know-how to.

Industrial production processes and scaling projects must be further supported and funded in the future so that Baden-Württemberg can further establish and expand its market position in the field of hydrogen and fuel cell technologies. The state government will therefore continue to advocate for serial production of electrolysis technologies and systems and support them with subsidies where possible.

The diversity and highly developed know-how of the medium-sized industry in BW offers a very strong basis for realizing the technological opportunities of the hydrogen economy. The BW Hydrogen Advisory Board recommends harnessing the potential of medium-sized companies and increasing the involvement of SMEs, but also start-ups, in the innovation and transformation process in particular.

This can be done, for example, by further strengthening the already well-developed cluster and networking activities to support the construction of smart ecosystems for technology development. For example, the statewide BW Fuel Cell Cluster Network has more than 200 partners and thereby strengthens the cooperation of players from industrial, scientific, trade association and political sectors in the state.



3.8 Applied research

In addition to important research institutions where many years of research expertise has been built up, innovative companies now have numerous skills and expertise in the field of hydrogen and fuel cell technologies.

The focus of previous funding programs and project funding has primarily been on supporting innovations, which enable steps to be taken toward scaling technologies in order to open up export markets and secure and expand market shares in international competition.

With the participation of companies and research institutions, the state government is funding an open industry platform with the Research Factory for Hydrogen and Fuel Cells (HyFaB) to research automated production and quality assurance procedures, factory approval tests and the commissioning of fuel cell stacks. In addition, specialists must be qualified and industry knowledge generated. With the “Electrolysis made in Baden-Württemberg” project and the funding of other projects, the “made in BW” scaling and production of electrolyzers is supported by the state government (see also Chapter 4 for detailed project descriptions).

Despite the good results, there is still a need for further research and development in order to be able to leverage the potential of hydrogen for the Baden-Württemberg site as comprehensively as possible and convert it to value creation. The industrialization of electrolysis and the development of large-scale fuel cell production will continue to play a key role in the future. Among other things, it is important to respond to the sharply increased industry interest in test capacities.

The industrial transformation process can be further accelerated by the market boom of the hydrogen economy.

The state government therefore intends to continue to support applied and business-related research at universities and non-university research institutions with the help of a hydrogen funding guideline. Funds that support the generation and use of hydrogen should be allocated to projects that generate or use green hydrogen.

The generation of funding to support the ongoing boom in the hydrogen economy is supported by a variety of funding programs. The H2BW platform, which is funded by the state government, offers interested stakeholders initial consultations and informational events on various funding calls at the state, federal and EU level.

The H2BW platform, as a central point of contact for the state’s diverse skills and hydrogen activities, will provide information on the various funding opportunities in the hydrogen and fuel cell sector, serve as a central contact for companies, communities, etc., and continue to offer informational events on funding opportunities.



3.9 Education and social acceptance

Topics such as the early qualification of specialists as part of educational and vocational continuing and advanced training, as well as raising public awareness are important success factors that enable Baden-Württemberg to maintain its position as a technology hub and secure industrial value creation in the state. The state supports the qualification and skills development of specialists with various initiatives and focuses in particular on the involvement of social players as part of funding programs, such as the ERDF funding program Green Hydrogen Model Region.

Qualification of specialists

The transformation to a hydrogen-based industry and society requires skills from specialists, some of which must first be developed and trained. It is therefore urgently necessary to expand and accelerate the qualification of needed specialists. Technology changes and infrastructure expansion are generating employment growth in multiple sectors. Qualified specialists are therefore needed along the entire value chain, in all sectors - generation, infrastructure, technology (system and component development), industry, mobility, logistics and heat supply. The future-oriented topic of hydrogen is also relevant for the recruitment of students in STEM subjects, as this is where academic specialists also needed in the field of hydrogen are trained.

In a policy paper, the National Hydrogen Council (NWR) proposes various measures at the federal and state level along the entire education chain, as requirements for research and development activities in the hydrogen economy field stipulate that specialists must have appropriate skills. Existing vocational and advanced training systems must be strengthened, but also more heavily promoted in terms of the potential of the hydrogen economy. This requires the teaching of appro-



appropriate skills to today's apprentices and specialists. Advanced training also plays a crucial role in broadly and sustainably disseminating knowledge of these key technologies. The BW Hydrogen Advisory Board reiterates these important conditions as key success factors in its position paper.

The various and extensive measures taken by the state government to secure specialists are fundamentally aligned across sectors and occupations. The hydrogen economy benefits from this to a particular extent, as do other professional fields with a high demand in the labor market. An example of the cross-sector and cross-occupational measures is the Apprenticeship Ambassador Initiative, in which apprentices at general education schools present their professions and explain the opportunities for vocational training.

Around 1,000 training ambassadors are currently active in professions in the context of STEM in Baden-Württemberg. Measures to increase transparency regarding programs in the training market, which responds quickly and flexibly to changes in demand, are also important. The network for vocational continuing training in Baden-Württemberg, including the regional offices for vocational continuing training, and the advanced training platform www.fortbildung-bw.de in particular contribute to transparency regarding advanced training programs in the state. The latter offers information on currently more than 50,000 reservable advanced training programs in Baden-Württemberg, including advanced training in the hydrogen economy field.

Furthermore, within the framework of the Baden-Württemberg Specialists Alliance, a focus is on actively monitoring the effects of technology-related structural change, leveraging its positive potential and mitigating negative effects through proactive action – this includes the increased use of hydrogen and fuel cell technologies in Baden-Württemberg.

In the field of vocational education and training, the state government is funding the “Hylab‘ Learning Workshop for Future Hydrogen and Fuel Cell Technology” project at the Backnang Commercial School. The aim of the project is to address training for relevant job profiles – such as automotive mechanics – on future hydrogen and fuel cell technologies and to speak to the public with a showroom. In the field of scientific advanced training, the [Hochschulweiterbildung@BW](#) (UniversityHigherEducation@BW) platform is available online and can also serve as a platform for hydrogen-related advanced training at universities.

It should also be noted that the initiative to modernize existing and create new apprenticeships comes from social partners at the federal level. The training regulations and corresponding framework curricula for vocational schools are formulated in a technologically neutral way and thus offer the opportunity for new developments to be directly incorporated into the training.

In order to teach skills in the field of hydrogen to apprentices and specialists in Baden-Württemberg, it is necessary to provide comprehensive programs for acquiring the necessary knowledge at educational institutions. Through formats such as “interactive courses” or “showrooms”, these technologies can be made directly accessible.

With the market boom and the implementation of hydrogen technologies in a wide variety of industries, requirements for the knowledge and skills of respective employees are changing. The educational curricula for both apprentices and students must be adapted accordingly. At the same time, it is important to provide adequate training opportunities for the employees in question and to approve them.

As part of the interdepartmental training initiative [WEITER.mit.BILDUNG@BW](#) (FORWARD.with.EDUCATION@BW), the state is planning to carry out an information and advertising campaign for continuing vocational training which can also benefit the hydrogen industry.

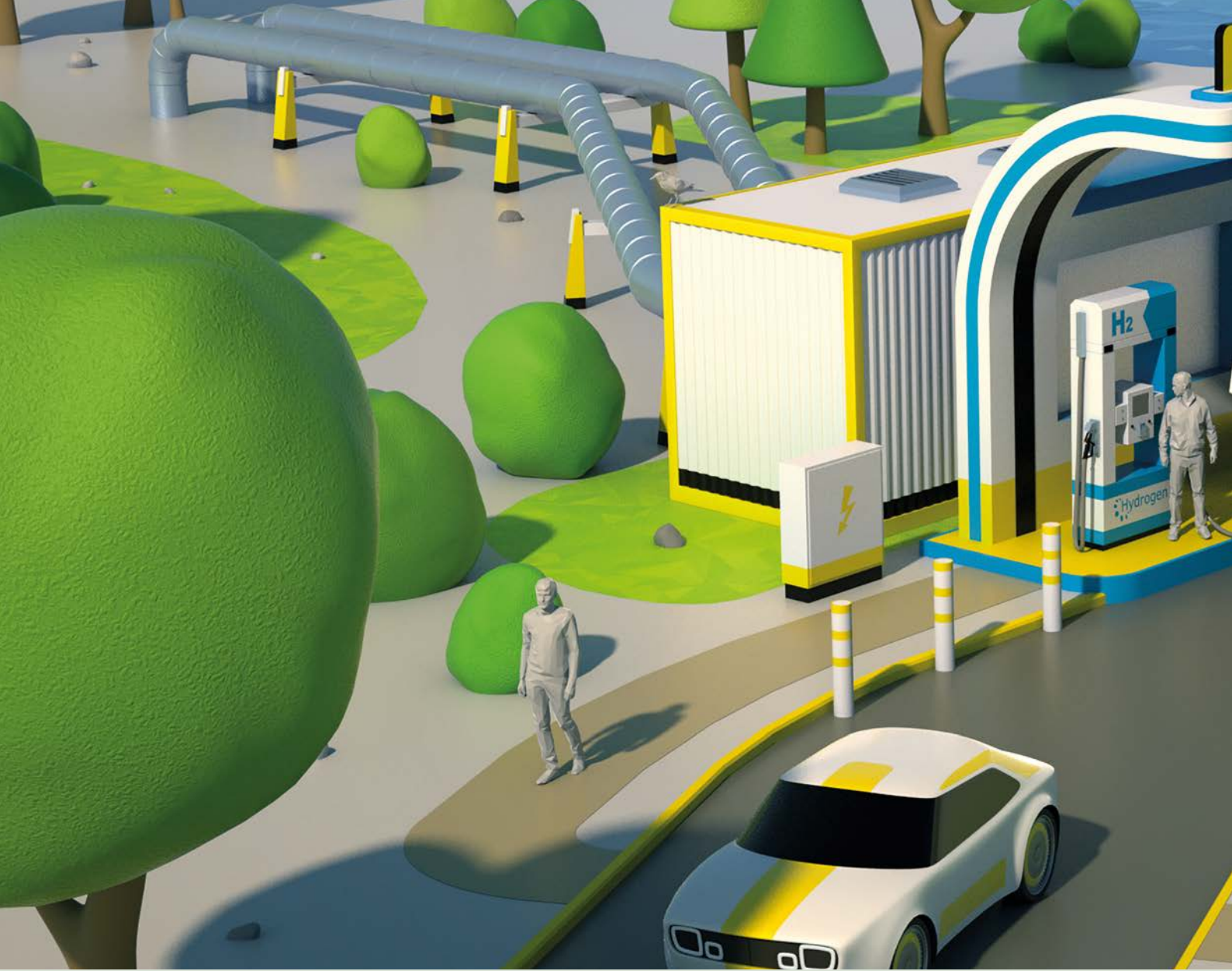
Social acceptance

The early involvement and awareness of citizens plays an important role in the establishment of new technologies and fundamental economic transformation processes. The implementation of the energy transition has shown that early involvement of relevant stakeholders and transparency in important decision-making processes can significantly contribute to social acceptance and “awareness building”.

The BW Hydrogen Advisory Board proposes supporting the hydrogen economy boom with an acceptance strategy that involves the general population and various government agencies at the same time.

Transparency and enthusiasm for the topic of hydrogen can also be facilitated by more actively involving the population in ongoing demonstration projects, the building of infrastructure and informational events. The hydrogen projects funded by the state government already make provisions for the involvement of the population through various public relations formats and should be intensified. For example, in the ERDF funding program Green Hydrogen Model Region, an important focus is on the active involvement of social players and their awareness of the topic of hydrogen.

Formats such as ‘Hydrogen Week’ and hands-on demonstration projects can help minimize barriers to acceptance and information. The state government will continue to work to ensure that the hydrogen economy is supported with the help of acceptance-promoting measures and made accessible to the general public.





PART II: IMPLEMENTATION OF MEASURES FOR BW HYDROGEN ROADMAP

4. Two-year BW Hydrogen Roadmap – 500 million euros in funding already active in projects

With the implementation of the Hydrogen Roadmap, Baden-Württemberg is specifically focusing on the initiation and implementation of local and cross-regional projects for demonstration and technology development.

Around 500 million euros in state funds are currently active or anticipated in numerous funding projects along the entire hydrogen value chain in order to support and promote the transformation process in the industry, research and development sectors. Funding rates are on average 40 to 60 percent; initiated investments of the same magnitude can therefore be assumed. There are also further investment and synergy effects along the entire value chain.

In terms of the level of innovation (technology projects), the broad impact (model regions), the supportive effect on the transformation of the Baden-Württemberg economy and the financial scope of funding, Baden-Württemberg is one of the leading hydrogen technology regions in Germany. The following projects promote the criteria mentioned above and therefore represent a selection of innovative hydrogen projects in Baden-Württemberg.

Large model and demonstration projects in the state show how hydrogen can be used for everything from generation, transport and logistics to various applications in mobility, heat generation for districts or in industry. These real laboratories are not only used for technology development, but are also intended to function as showcases for hydrogen applications and make hydrogen accessible. In doing so, they examine different perspectives of the application of hydrogen in the overall ecosystem – from economic efficiency and ecology to social aspects. The model and demonstration projects pave

the way for the start-up of a functioning hydrogen economy and the defossilization of the energy system.

ERDF funding program “Green Hydrogen Model Region”

The Ministry of the Environment, Climate Protection and Energy Sector Baden-Württemberg supports the development of economically and structurally networked regions that exclusively use hydrogen as an energy source and thus represent as complete an ecosystem as possible for green hydrogen (climate-neutral production) with the “Green Hydrogen Model Region” funding program as part of the Baden-Württemberg program for the ERDF. In total, around 48 million euros are available in the program from EU and state funds.

4.1 ERDF Green Hydrogen Model Region Central Alb-Donau (formerly HyFIVE)

The project consists of four lighthouse projects that simulate different use cases for hydrogen relevant to the region, both in rural and urban areas.

The H2 Factory subproject in Ulm aims to commission an electrolyzer powered by hydroelectric power. The hydrogen generated is to be integrated into existing consumption infrastructures, in particular at the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW). An overall electrolysis capacity of around 12 MW is to be installed in this subproject.

The second subproject H2-ToGo demonstrates the use of hydrogen in logistics, in municipal vehicles and in public transport. A 40-ton fuel cell-powered truck will be available in 2024. A refueling infrastructure will also be developed for this purpose.

H2 Aspen addresses the production, application and distribution of hydrogen in an industrial park. In 2023, a 10 MW PEM electrolyzer is to be put into operation here, which will enable a local hydrogen infrastructure with national pipeline connections in the future.

The fourth subproject, H2 Grid, demonstrates the networking of decentralized hydrogen production and storage with users of hydrogen, for example in homes, communities, districts or industry. An overall electrolysis capacity of 1.5 MW is to be created here by 2023. The entire model region will receive funding of around 32 million euros, and the consortium will be managed by a project association initiated by the city of Ulm. The funds come from the ERDF and the state of Baden-Württemberg.

4.2 ERDF Green Hydrogen Model Region “H2GeNeSiS” – Stuttgart Region

In addition to the production of green hydrogen (electrolysis capacity of around 5 MW), an extensive distribution network for hydrogen is to be built along the Neckar in the Stuttgart region. A hydrogen pipeline along the Neckar is at the heart of the project.

Through the pipeline, local hydrogen producers and users in the industry or mobility sector can directly access the green hydrogen produced. All activities will be networked via an “H2 marketplace”, which is designed to simplify the use of green hydrogen for other players. A wide range of applications are being tested at the same time. The waste heat generated during hydrogen production can be used, for example, to supply heat to districts.

The H2Ge-NeSiS project, which is funded with around 11 million euros, is coordinated by the Stuttgart Region Economic Development Corporation. The funds come from the ERDF and the state of Baden-Württemberg.

The two model regions are also scientifically supported. The aim of the H2 Companion consortium is to make the results and findings obtained usable for other regions as well. In addition to supporting technological processes and business model development, accompanying research also focuses on the development of concepts for citizen participation and public relations.

4.3 Project “HyFaB-BW” – Industrialization of fuel cell production

The supplier industry is essential for a successful hydrogen economy boom. The focus here is on local state technological development and production in particular. In Baden-Württemberg, the technological know-how for fuel cell production is available in the research and industry sectors, but small-scale production is often predominant.

With the “HyFaB BW” research factory, the ZSW and the Fraunhofer Institute for Solar Energy Systems (FhG-ISE) are establishing an open industrial platform for research and testing of automated production and quality assurance procedures, factory acceptance tests and commissioning of fuel cell stacks. The aim of the project is to research the production processes for the industrialization of fuel cell production. The series production of fuel cells on a large scale is the focus of the project. In addition, specialists must also be qualified and industry knowledge generated. With “HyFaB”, the high technological skill of Baden-Württemberg companies and research institutions is further strengthened, and an essential element for fuel cells “made in Baden-Württemberg” is created. For the implementation of “HyFaB”, the Ministries of the Environment, Climate Protection and Energy Sector as well as Economy, Labor and Tourism of Baden-Württemberg provided a total of 18.5 million euros in state funds for the years 2019 to 2023. In addition, the federal government funds joint projects with industrial companies with up to 30 million euros. On February 23, 2022, the groundbreaking ceremony for a second factory building with an area of 3,000 square meters – the “HyFaB 2” – was held. The Ministry of Economic Affairs, Labor and Tourism of Baden-Württemberg supports “HyFaB 2” with a further 7.75 million euros in funding and funds the expansion of equipment infrastructure for fuel cell research at the ZSW with 2.9 million euros (HyFaB Equipment).

By purposefully maintaining this, the development of industrial mass production can be further expanded, and mass-produced and cost-effective fuel cell production in Baden-Württemberg can be significantly advanced. An additional 7.3 million euros will be made available for this purpose for the years 2023 to 2026. This creates a unique fuel cell development platform for companies that provides programs for joint projects from production and testing to training.

4.4 “IPCEI Hydrogen”– Important Projects of Common European Interest

In order to support the market boom for hydrogen technologies in Baden-Württemberg, Baden-Württemberg is using the opportunities to fund investments as part of the “Important Projects of Common European Interest” (IPCEI). For an IPCEI, the European Commission grants an exception to the intra-European aid ban for economic projects of particular pan-European interest. The funding comes entirely from the member states and not from EU funds. Federal funding amounts to 70 percent of the total funding, with a further 30 percent co-financed by the states. The financial contribution from the state of Baden-Württemberg is currently up to 265 million euros.

Twenty-three European countries participate in the IPCEI Hydrogen. The five selected projects for Baden-Württemberg companies concern the development of fuel cell components up to the finished fuel cell system and its application in heavy-duty transport, as well as the production of fuel cell systems for stationary applications.

Three other truck filling station projects generated by IPCEI are planned nationwide and concern Baden-Württemberg proportionally; they are currently in the process of being assigned to a suitable funding policy groundwork. Of 62 selected projects, five plus three are in Baden-Württemberg (or have a state share). This means that the state has a structurally important share in IPCEI funding.

In July 2022, the European Commission gave the green light for the first state aid approvals for projects as part of the IPCEI Hy2Tech technology wave in Germany. The focus of three of these projects is in Baden-Württemberg:

- The “BoschPowerUnits” project of Robert Bosch GmbH focuses on the field of fuel cell systems for stationary applications. The goal is the initial industrialization of solid oxide-based systems. The project is to be implemented at the locations in Baden-Württemberg, Bavaria and Saarland.
- The project “NextGen HD-Stack” of EKPO Fuel Cell Technologies (a joint venture of ElringKlinger and Plastic Omnium) in Dettingen/Erms focuses on the field of hydrogen mobility. In addition to the development of high-performance fuel cell stack modules for commercial vehicles, buses or ship and rail applications, the focus of the project is also on scaling the technology. Two main points are addressed: cost optimization (design to cost) and mass producibility (design for manufacturing), which includes a reduction in the carbon footprint of production.
- The “Pegasus” project of Daimler Truck AG is partially located in Baden-Württemberg. The aim of the project is the development and production of 100 fuel cell trucks and a four-year test operation of the trucks with the participation of 10-20 logistics companies, as well as the development, production and operation of up to 10 innovative truck hydrogen filling stations.

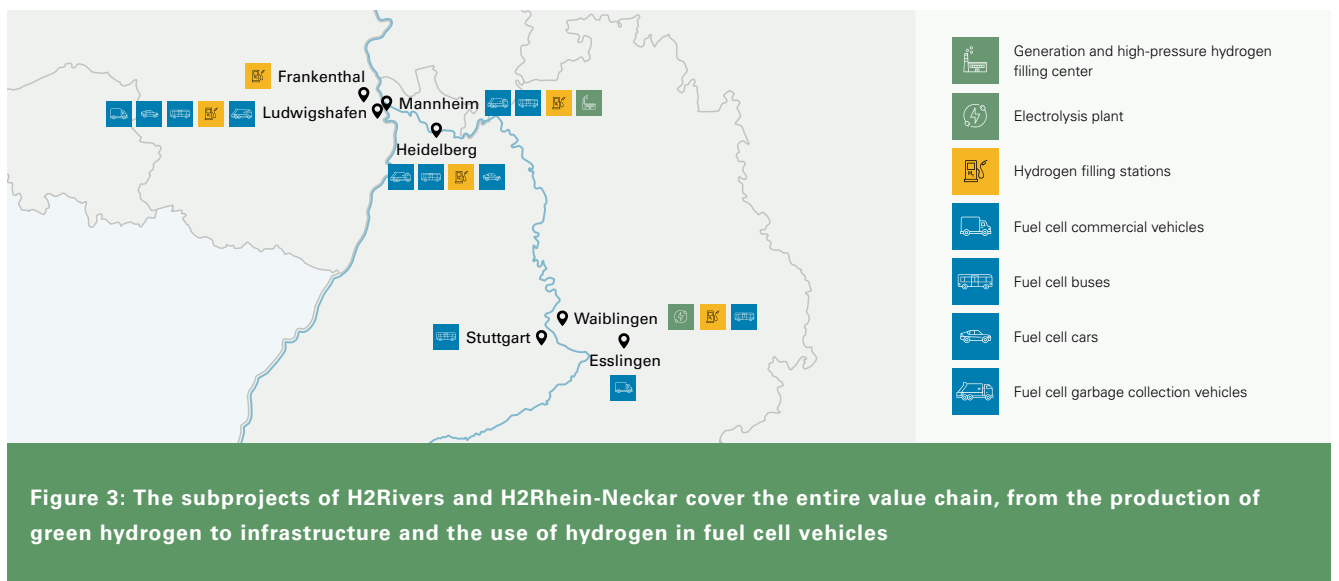
The following two projects in Baden-Württemberg are still awaiting notification by the European Commission as part of the Hy2Move mobility wave:

- With its “KLIMA|Werk project”, cellcentric GmbH & Co. KG aims to develop an innovative mass-production fuel cell system called “BZA150”. This fuel cell system is intended for use in hydrogen-powered heavy-duty transporters and is designed for the special requirements of this type of application. The aim is also to test possible industrial production of this system for the first time.
- The “NextGadila” project of Freudenberg Performance Materials in Weinheim studies gas diffusion layers to optimize fuel cells. Freudenberg specializes in the development and production of gas diffusion layers (GDLs) and porous transport layers (PTLs), which are considered key components for PEM fuel cells (GDLs) and PEM electrolysis plants (PTLs). With the IPCEI, Freudenberg Performance Materials intends to build out and expand the existing pilot line in a first step and to industrialize the production of GDL and PTL in a climate-friendly manner in a second step, taking into account high environmental requirements, with the aim of increasing production capacities tenfold and thus successfully positioning itself in the future market.

4.5 Lighthouse projects “H2Rivers” and “H2Rhein-Neckar”

The complementary “H2Rivers” & “H2Rhein-Neckar” projects show how the realization of emission-free mobility with hydrogen can be implemented economically. In the largest demonstration project in the southwest, various subprojects cover the entire value chain, from the production of green hydrogen to infrastructure and vehicle applications.

“H2Rivers” is funded by the Federal Ministry for Digital and Transport as part of the HyLand funding program and “H2Rhein-Neckar” by the Ministry of the Environment, Climate Protection and Energy Sector Baden-Württemberg. Together, the two projects have a funding volume of around 37 million euros.



In the “H2Rhein-Neckar” project, fuel cell technology will be used extensively for public transport in the future: By 2024, 40 fuel cell range extender buses are expected to replace the regular diesel fleet in Mannheim and Heidelberg. Important data is collected in real operation, from which accompanying research gathers new insights for the depots and energy requirements of new buses. There has been little experience to date in converting an entire bus fleet to fuel cell range extender buses in public transport, as only individual vehicles are often used. In this project, the project-specific accompanying research analyses both technological and business management issues in order to support future implementations in public transport. Regional synergies are important to the four project partners for making fuel cell mobility competitive. The state agency e-mobil BW GmbH has taken over management of the consortium for the project, which is funded by the Ministry of the Environment, Climate Protection and Energy Sector.

The parallel HyPerformer “H2Rivers” project also demonstrates the suitability of hydrogen as an energy source in the transport sector: A regional, fully integrated value chain for hydrogen that is unique in Germany is being created in the metropolitan Rhine-Neckar region and the adjacent central Neckar region. A total of ten partners are involved in the project. There are also important synergy effects here for the “H2Rhein-Neckar” project. This enables the provision of green hydrogen and the refueling of new fuel cell vehicles to be coordinated together. Green hydrogen will be generated as part of “H2Rivers” in the hy.waiblingen subproject, in which a 2 MW electrolyzer will be put into operation. Partners in the chemical industry are also involved as hydrogen suppliers. The renewably produced hydrogen is used by industrial customers and in the transport sector, including in waste collection vehicles, forklifts and buses in the Rhine-Neckar region. The metropolitan Rhine-Neckar region has taken over management of the consortium for the federally funded project.

HyLand – Funding Program for Hydrogen Regions in Germany

HyLand is part of the national Hydrogen II innovation program and a community competition launched by the Federal Ministry for Digital and Transport (BMDV) that motivates players in all regions in Germany to initiate, plan and implement hydrogen-related concepts. Based on the project and funding priorities, as well as previous areas of common activity with hydrogen, regional concepts are divided into the three categories HyStarter, HyExperts and HyPerformer. Baden-Württemberg communities were able to submit successful applications in all categories.

4.6 Funding program “Hydrogen Future Program” – ZPH2

In March 2021, the state government issued the call for funding for the BW Hydrogen Future Program (ZPH2). The aim of ZPH2 is to support companies in developing a sustainable hydrogen economy in Baden-Württemberg. The industrialization of hydrogen and fuel cell technologies as well as their applications preserves and creates jobs in the state. In total, the Ministry of the Environment, Climate Protection and Energy Sector Baden-Württemberg provides around 26 million euros for project funding. Twenty projects in four technology sectors were selected: fuel cell test stations; the production, storage and transport of hydrogen; component and sensor development; and networks and power supply systems in the field of hydrogen and fuel cell technologies. In addition, the state has sponsored four feasibility studies. The program focuses on the following projects:

Table 1: Overview of projects in ZPH2

Project topics	Project name - acronym	Funding amount
Component/sensor development	<ul style="list-style-type: none"> ■ H2Sensor4Quality – Development of an optical hydrogen sensor for preventive quality assurance of the fuel cell energy system ■ <i>ROAD Deutschland GmbH & Reutlingen University, Faculty of Applied Chemistry</i> 	5.6 million euros
	<ul style="list-style-type: none"> ■ MiKaBrezEI – Microwave drying of catalyst layers for fuel cells and electrolyzers ■ <i>Kiener Maschinenbau GmbH & Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW)</i> 	
	<ul style="list-style-type: none"> ■ WALD – Hydrogen sensors for leak detection ■ <i>Fraunhofer Institute for Physical Measurement Techniques IPM & University of Stuttgart, Institute of Space Systems</i> 	
	<ul style="list-style-type: none"> ■ HyFlex – Production plants for the flexible production of hydrogen membrane components ■ <i>OPTIMA life science GmbH & Business Excellence Solutions GmbH</i> 	
Generation, storage and transport of hydrogen	<ul style="list-style-type: none"> ■ EcoLyzerBW – Industrialization and preparation of series production of electrolysis system technology in BW ■ <i>Ecoclean GmbH & ZSW</i> 	6.63 million euros
	<ul style="list-style-type: none"> ■ ModularerGaserzeuger (Modular Gas Generator) – Development, validation and industrialization of a modular gas generator for stationary fuel cells ■ <i>Smk systeme metall kunststoff (systems metal plastic) GmbH & Co. KG</i> 	
	<ul style="list-style-type: none"> ■ H2Compress – Modular, highly integrated hydrogen compression solution for efficient transport via transmission networks ■ <i>J.M. Voith SE & Co. KG</i> 	
	<ul style="list-style-type: none"> ■ WaGuPa – Development of a hydrogen storage system in the TRTM process based on cast polyamide ■ <i>Albert Handtmann Elteka GmbH & Co. KG & Faserinstitut Bremen (Bremen Fiber Institute) e.V. & Institut für Polymer- und Produktionstechnologien (Institute of Polymer and Production Technologies) e.V.</i> 	
Grids and power supply systems	<ul style="list-style-type: none"> ■ H2REB – Development of large-scale options for the use of green hydrogen based on the grid booster concept to increase grid stability ■ <i>TransnetBW GmbH & KIT, Institute for Automation and Applied Informatics IAI & Ulm College of Applied Sciences, Institute of Energy and Drive Technologies & ZSW</i> 	3.97 million euros
	<ul style="list-style-type: none"> ■ RetrofitH2 – Retrofit concept for existing power plants as an introduction to hydrogen use ■ <i>DLR, Institut für Verbrennungstechnik (Institute of Combustion Technology) & Power Service Consulting GmbH</i> 	
	<ul style="list-style-type: none"> ■ BasicBZ – Development of a portable fuel cell generator for small commercial and private applications ■ <i>Industriegase Technik GmbH & ZSW</i> 	

Table 1: Overview of projects in ZPH2

Project topics	Project name - acronym	Funding amount
Fuel cell test stations	<ul style="list-style-type: none"> ■ ModuSkaBZ – Development of a modular and scalable test system for fuel cell stacks ■ JW Froehlich Maschinenfabrik (Machine Factory) GmbH & ZSW 	7.59 million euros
	<ul style="list-style-type: none"> ■ H2TwinTest – Multi-function test rigs for hydrogen applications with digital twin ■ IAVF Antriebstechnik (Drive Technology) GmbH & Fraunhofer Institute for Chemical Technology ICT 	
	<ul style="list-style-type: none"> ■ FullStackTS – Development of a fuel cell full stack test rig for heavy-duty and aerospace applications ■ MS2 Engineering und Anlagenbau (Engineering and Plant Construction) GmbH & Fraunhofer Institute for Solar Energy Systems ISE & Smart Testsolutions GmbH 	
Future strategies	<ul style="list-style-type: none"> ■ Fit4H2 – Fuel cell production training factory ■ Karlsruhe Institute of Technology (KIT), wbk Institute of Production Science 	1.41 million euros
	<ul style="list-style-type: none"> ■ H2Chemie2050 – Direct path to green hydrogen in chemical-pharmaceutical production by 2050 ■ Evonik Operations GmbH & Pforzheim University, Institute for Industrial Ecology (INEC) 	
Feasibility studies	<ul style="list-style-type: none"> ■ H2 Preform – Production of a hydrogen pressure tank with preforms ■ ACE Advanced Composite Engineering GmbH 	0.19 million euros
	<ul style="list-style-type: none"> ■ H2MaTe – Systems for the production of hydrogen storage systems with preforms ■ TBT Tiefbohrtechnik (Deep Drilling Technology) GmbH 	
	<ul style="list-style-type: none"> ■ Hydra – Production of “green hydrogen” by hydrothermal gasification of plastic-contaminated biomass ■ HAGO Druck & Medien (Printing and Media) GmbH 	
	<ul style="list-style-type: none"> ■ HyFly – Development and testing of a VTOL drone with fuel cell for transporting medical laboratory samples ■ German-Composite GmbH & Co.KG 	
Total funding 25.4 million euros		

4.7 Funding program “Climate Action and Value Creation through Hydrogen – KWH2”

The knowledge gained in research and development for a sustainable and resilient hydrogen economy should now be used for the further development of innovations. This will lay the foundation for market-ready technologies that secure essential market shares in the international hydrogen economy for Baden-Württemberg. The Climate Action and Value Creation through Hydrogen (KWH2) funding call supports companies in implementing pilot projects for the application and use of green hydrogen. Market-related investment measures for the use of green hydrogen are funded as well. The funding call is divided into the two funding modules Research & Development and Investment Projects. With the eight projects, pilot and demonstration projects are initiated that, in a general sense, link the hydrogen production, storage and transport value chain as well as the use of green hydrogen in so-called isolated solutions, such as in the industry sector. As of January 1, 2023, the projects will be funded by the Ministry of the Environment, Climate Protection and Energy Sector with a total funding volume of 17 million euros.

4.8 Climate-neutral city district “New West Town Esslingen”

A climate-neutral urban district is being built in Esslingen am Neckar based on power-to-gas technology. Approximately 480 apartments, office and commercial spaces as well as a new building at Esslingen University will be built on the former site of a freight yard. Green hydrogen is produced on site and prepared for use in the city district and in the mobility and industry sectors. The New West Town is one of six urban planning lighthouse projects funded by the Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Ministry of Education and Research (BMBF) with around 12 million euros.

4.9 Lighthouse project “Power-to-Gas Baden-Württemberg” and real laboratory in the “H2 Wyhlen” energy transition

The approach of further researching electrolysis technology as well as applying it in the High Rhine region also determined the design of the lighthouse project “Power-to-Gas Baden-Württemberg” (PtG-BW), which has already been successfully completed. In Grenzach-Wyhlen, a local electrolysis plant with a production capacity of 500 kg of hydrogen per day was built at the local hydropower plant. The aim was to make hydrogen production economically viable. The construction of the plant was supported by the Ministry of Economic Affairs, Labor and Tourism of Baden-Württemberg with funding of 4.5 million euros. Additional optimized electrolyzers were tested under real conditions in an adjacent ZSW research platform. In 2020, the PtG plant also won the idea competition “Real Laboratories in the Energy Transition” of the Federal Ministry for Economic Affairs and Climate Action. Since then, the project has been supported and expanded with federal funding. In the “H2Wyhlen” real laboratory, the capacity of the electrolysis plant in Grenzach-Wyhlen is increased to six megawatts of electrical power and tested under real conditions. The application of byproducts from hydrogen production is also being researched and tested, so that the waste heat generated during hydrogen production is used to heat neighboring residential areas.

4.10 Research initiative “reFuels – Rethinking Fuels”

The aim of the “reFuels - Rethinking Fuels” project is the efficient production and use of renewably produced fuels (reFuels). In addition to gaining insights into application properties and practical demonstration, the project is also focused on creating social awareness and acceptance of the technology. The “reFuels - Rethinking Fuels” project was created as part of the state’s Strategic Dialogue for the Automotive Sector (SDA). The Baden-Württemberg Ministry of Transport is funding the project with 5.0 million euros.

In 2021, the “reFuels Project Group” was created, which supports and coordinates the growing number of activities and projects in the field of reFuels in the state.

Baden-Württemberg has taken a pioneering role in reFuels research and development in Germany and, based on initial findings, approved a BW roadmap for reFuels in July 2022. One of the most important measures is supporting the Upper Rhine Mineral Oil Refinery MiRO in Karlsruhe in the transformation to a green refinery and the realization of an industrial (demonstration) plant. The measures are divided into measures to increase supply, measures to increase demand in the state and measures to shape the policy framework.

The reFuels program also funds various other projects, all of which aim to support the ramp-up and use of renewable fuels and the transformation of the refinery sector. Another approximately 15 million euros are available for this purpose.

4.11 Production of green hydrogen – “Electrolysis made in Baden-Württemberg”

Green hydrogen is becoming increasingly important in the energy transition and opens up great opportunities for the business and industry sectors. This requires a massive expansion of electrolysis capacities. According to a study, a required electrolysis capacity of about 9 gigawatts is forecast for Baden-Württemberg by 2035 if the calculated hydrogen demand of 16.6 TWh is to be met in the same period.

The “Electrolysis made in Baden-Württemberg” project focuses on industrializing electrolysis technology and ensuring international competitiveness for medium-sized companies in Baden-Württemberg. The aim of the project is the design and construction of an electrolysis demonstrator at the ZSW. The Ministry of Economic Affairs, Labor and Tourism of Baden-Württemberg is providing 5 million euros in funding for this purpose.

The electrolysis demonstrator with an electrical output of around one MW, built with expertise and components from Baden-Württemberg, is intended to accelerate the industrialization of hydrogen technology and series production at the state level. The system has a modular design so that, based on this smallest unit, the technology can be easily scaled into larger output classes in the future.

4.12 “Zero Emission” and RegioWIN lighthouse project “Hydrogenium”

The “Zero Emission” project is intended to help improve the cost-effectiveness and thus the marketability of hydrogen technologies. The focus is on technology development. The aim is to make the upstream and downstream processes more efficient. This includes all essential components of hydrogen technology – from generation and storage to use at the DLR

and ESA test rigs for rocket engines at the Lampoldshausen DLR site. Since 2020, the Ministry of Economic Affairs, Labor and Tourism has been funding the “Zero Emission” research project at the German Aerospace Center in Lampoldshausen with around 16 million euros.

The “Zero Emission” research project is divided into three subprojects:

- Subproject 1 “Green Aerospace”: The aim is to expand production capacities for green hydrogen, which is primarily intended to be used at the rocket test rigs. A hydrogen liquefier also produces cryogenic liquid hydrogen on site. It is being investigated to what extent hydrogen losses in supply systems can be recovered and practically processed through reliquefaction.
- Subproject 2: “CO₂-neutral site”: An optimized energy system is designed and implemented at the site. In doing so, machine learning methods are investigated in order to enable optimized operating management of components. In addition, the procurement of multiple fuel cell vehicles also addresses research and development topics in the field of H₂ mobility.
- Subproject 3: “H₂ Testing Facility”: In the “H₂ Testing Facility” subproject, a modular and flexible test environment for hydrogen technologies is being set up. With the cooperation of partners in the industry and research sectors, the entire value chain will be considered, from the production of green hydrogen in the electrolyzer to its application, for example in fuel cells.

The “Hydrogenium” lighthouse project, which won an award during the RegioWIN 2030 competition led by the Ministry of Economic Affairs, Labor and Tourism, enables the creation of a test and application center at the DLR site in Lampoldshausen that supports companies in the development and testing of hydrogen technologies. The test field will offer the industry, research and development sectors the opportunity to test and further develop liquid hydrogen-based systems and components and to carry out licensing-related testing. In addition, “Hydrogenium” also offers consulting and training opportunities for companies, communities, scientific institutions and other organizations striving to contribute to the energy transition with hydrogen applications. The project is considered to be of strategic importance within the framework of the Baden-Württemberg ERDF program in the 2021-27 funding period and has a project volume of 11.65 million euros, of which 4.66 million euros are from ERDF funds and 2.33 million euros are supplementary state funds from the Ministry of Economic Affairs, Labor and Tourism.

4.13 Projects in the “Hydrogen – NIP National Innovation Program”

In furtherance of the National Innovation Program, hydrogen and fuel cell technology (NIP 2) of the Federal Ministry of Digital Affairs and Transport was able to raise more than 62.4 million euros in funding from players in Baden-Württemberg. The ten federal-funded projects in the state focus on sustainable mobility and are geared toward bringing innovative technologies to the market.

4.14 Strong research universities and research institutions as a basis for innovation

The new research building for the Competence and Innovation Centre for Hydrogen Technologies and Cognitive Energy Systems – HYKOS – at the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg will further expand the state’s research infrastructure in the field of hydrogen technologies and also strengthen business-related energy research. The project will thereby offer the opportunity to secure and expand the industry’s technological advancement. The federal government and the Ministry of Economic Affairs, Labor and Tourism each provide 50 percent of the total financing for the new building in the amount of 42 million euros.

The Fraunhofer Society is seeking to spin off an H2T Fraunhofer Institute with a focus on “hydrogen” and “sustainable synthetic fuels” from the Fraunhofer ISE in Freiburg. A new Fraunhofer Institute would strengthen Baden-Württemberg as an economic and scientific hub and serve to implement the Hydrogen Roadmap as well as transform the industry. With the spin-off, Baden-Württemberg would have an excellent opportunity to create an international lighthouse and bring Baden-Württemberg to the forefront of hydrogen research.

Around 90 hydrogen projects are currently underway at universities in the state. These projects are funded with 78.2 million euros in total. The largest funding providers are the federal government with approx. 49.6 million euros and the German Research Foundation (DFG) with approx. 14.3 million euros. EU funding amounts to 6.7 million euros, and the state of Baden-Württemberg funds projects at a scope of 4.3 million euros. Industries, foundations and other sectors provide 3.2 million euros in funding. The three strongest research locations in this area are KIT and the Universities of Ulm and Freiburg. The two largest projects at KIT are the “TransHyDE” project for the transport and application of li-

quid hydrogen (funding amount 11.8 million euros) and the CataLight Collaborative Research Center at the University of Ulm (funding volume 10 million euros).

Research infrastructures at business-related research institutions

A “Research Testing Facility for Renewable Energies and Material Research” is currently being built at the ZSW in Stuttgart. The whole project is funded by the REACT-EU program in the amount of 2.5 million euros. The sub-area of electrolysis covered by the project relates to research work in the field of hydrogen and electricity-based fuels. The construction project enables, for example, the construction of an electrolysis test stand for testing electrolysis components during pre-testing for industrial implementation in large-scale plants as well as the development of technologies for producing CO₂ from air.

The “HyGenLab” (Hydrogen Generation Laboratory) project has also been funded with 4 million euros since February 2022 with funds from REACT-EU. With this, the ZSW’s research infrastructure in the field of hydrogen production and eFuels will be expanded in a targeted manner in order to research, among other things, scaling concepts for the market boom and large-scale application of hydrogen technologies. In addition to various electrolysis test rigs from the kilowatt to the megawatt scale, the expansion also includes measurement technology and analysis equipment for the quality assurance of parts and components for electrolyzers.

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