H2.B ZENTRUM WASSERSTOFF. BAYERN

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Hydrogen
Energy carrier for Bavaria's future

Initiiert durch

Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie

V.2022-05

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Foreword by the Minister of State Hubert Aiwanger

With the foundation of the Center Hydrogen.Bavaria (H2.B), we have created a think tank and coordination center for hydrogen in Bavaria. Hydrogen will play a key role in managing the energy and mobility transition. H2.B brings together the key players for a successful ramp-up of the Bavarian hydrogen economy. This includes stakeholders from municipalities, economy, politics and science.

With the support of our partners in the Hydrogen Alliance of Bavaria, we want to promote the widespread practical use of hydrogen. We see great potential in the areas of logistics and storage, industrial use and mobility. In the field of local public transport in particular, much can be achieved in cooperation with municipalities, for example by using hydrogen buses to improve air quality in communities and cities. Together, we need to implement projects quickly. Bavaria now has the chance to take the lead in the hydrogen economy.

Hubert Aiwanger
Bavarian State Minister of Economic Affairs, Regional Development and Energy

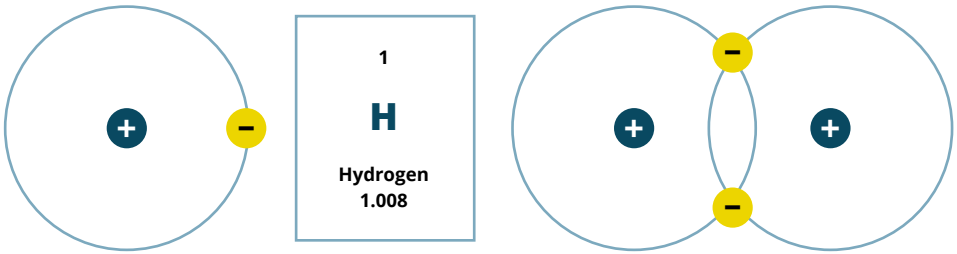
Bayerisches Staatsministerium für
Wirtschaft, Landesentwicklung und Energie

Hydrogen—Energy carrier for Bavaria's future

Hydrogen will play a significant role in a climate-neutral industrial society of the future. Due to its high energy density and good storage capacity, hydrogen is predestined to close the gap between renewably generated electricity and energy-intensive applications in the areas of heat supply, industry and mobility. The diverse applications hold great potential for the industrial production of key components of a future hydrogen economy in Germany and beyond. Bavaria has recognized this potential and created the basis for a sustainable hydrogen economy in research and industry. The Center Hydrogen.Bavaria (H2.B) brings together numerous Bavarian players from industry, science and politics and contributes to the large-scale application of hydrogen technologies, especially green hydrogen, as a central element of the cross-sector energy transition.

Hydrogen as an important component of the energy transition

Climate change and its consequences have an immediate effect on all of us. To achieve the climate goals stipulated in the Paris Agreement, global economies must significantly reduce their greenhouse gas emissions. Thereby, hydrogen is an indispensable component and offers attractive opportunities for its usage in various sectors.



Hydrogen is the lightest and most abundant element in our universe and has a very high energy density: One kilogram of hydrogen is about as energy-rich as three kilograms of gasoline or diesel. On earth, hydrogen is very rarely found in its elemental form, but is mostly chemically bound—primarily in water, but also in biomass or hydrocarbons such as crude oil or natural gas.

On the way to a sustainable and climate-neutral industrial society

The development of technologies for the generation of renewable energies from wind, sun, hydropower or geothermal energy has made enormous progress in recent years. Converting our energy system to renewable energy sources also requires dealing with the problem of intermittent availability of wind and solar energy (e.g. due to slack periods or cloud cover). The development of efficient storage technologies and the continuous supply of energy without the use of fossil fuels remain major challenges.

Hydrogen can make an ideal contribution to overcoming these challenges. It can be produced from water in a CO_2-neutral manner, has a high energy density, can be stored almost without any energy loss and can be transported over long distances. This makes hydrogen the decisive energy carrier in the context of global climate-neutral energy logistics. From today's point of view, hydrogen is the only reasonable option for seasonal electricity storage in a CO_2-neutral energy system and can prospectively serve as a backup during slack periods. The coupling of the electricity, mobility, heat and industry sectors will also largely be based on hydrogen technologies in the future.

Read our Hydrogen FAQs (in German)

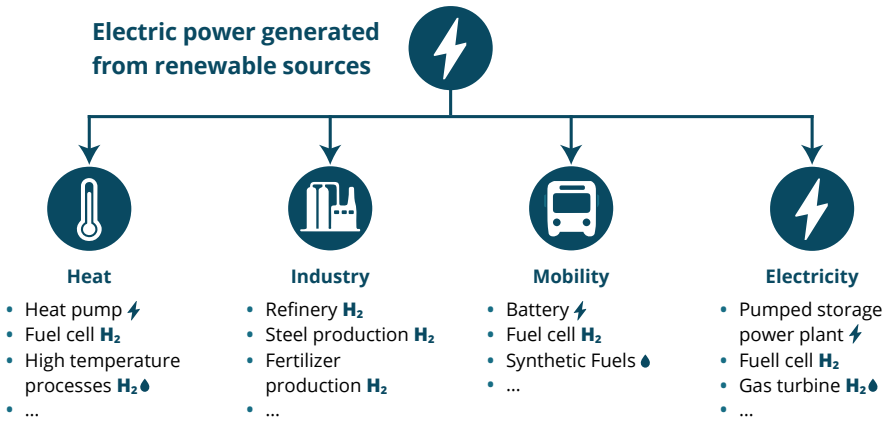
Did you know?

Hydrogen is not an energy source like oil, but an energy carrier, i.e., a transport medium for energy. The worldwide expansion of renewable energies, such as solar and wind power, is therefore a basic prerequisite for the success of the energy transition.

Sector coupling as a key to reducing net greenhouse gas emissions

The long-term goal of the energy transition is to decarbonize—or defossilize—all major sectors including energy industry, transport, buildings and agriculture, i.e., to reduce net greenhouse gas emissions to zero. Direct electrification, such as heating with heat pumps or battery-electric mobility, is not always technically possible or economically viable. In many applications, hydrogen can provide the crucial solution: It can be obtained from renewable sources in times of surplus energy or at locations with particularly favorable conditions and then stored directly or converted into synthetic fuels (synfuels). For example, it can be used directly in fuel cells, fed into the gas grid, used to refuel vehicles, or converted back into electricity or heat during slack periods. In addition, H_2 is also used as a base material in many processes, such as methanol or ammonia production.

Hydrogen also plays an important role in sustainable mobility. It is particularly interesting for powering heavy vehicles such as trucks, buses, construction machinery, trains, ships and airplanes. Hydrogen and hydrogen-based energy carriers represent a useful alternative to fossil fuels such as diesel, heavy oil or kerosene. Beyond the mobility sector, however, hydrogen is also of great importance for energy-intensive industrial applications, for example as a reducing agent in the metal industry, as a base material for chemical products, or even as fuel for high-temperature applications.



Examples of sector coupling:
Coupling via current H_2 Coupling via hydrogen Coupling via synthetic energy sources

Hydrogen technologies are not only highly attractive from an ecological point of view, they also offer enormous opportunities for a sustainable transformation of the industry. Bavarian plant engineers, automotive manufacturers and suppliers are among the technology leaders and have the best conditions for exporting new high-tech products “Made in Bavaria” all over the world.

In order to consolidate and expand the strong position of the Bavarian industry and science in the future field of the hydrogen economy, the Free State of Bavaria has founded the Center Hydrogen.Bavaria (H2.B). Thereby, Bavaria is pursuing the goal of bringing together key players from business, science and politics in order to advance the development of hydrogen technologies as quickly as possible and to achieve the widespread practical application of hydrogen.

Prof. Dr. Veronika Grimm, Member of the Board

Hydrogen technologies are a key to the comprehensive transformation of the energy system and of the Bavarian industry. In order to leverage the great potential for value creation, technological fields of action must be developed jointly and simultaneously by many players. In addition, the energy policy framework conditions must be appropriate. Demonstration and industrialization of the hydrogen production and its key components are central to further reducing costs. With the Center Hydrogen.Bavaria (H2.B), we want to coordinate and strategically strengthen these processes.

Green Hydrogen
Water (H_2O) is broken down into its components hydrogen (H_2) and oxygen (O_2) via electrolysis. Electrolysis is carried out using electricity from renewable energies and is thus CO_2-free.

Orange Hydrogen
Hydrogen is obtained from biomass by thermochemical or biological conversion processes.

Turquoise Hydrogen
Hydrogen is produced via thermal cracking (pyrolysis) of methane (CH_4). In contrast to the production of gray hydrogen (see below), the production process does not produce CO_2 but solid carbon, which can be stored or further processed.

Blue Hydrogen
Blue hydrogen is gray hydrogen (from fossil fuels—see below), where the CO_2 produced is either stored (carbon capture and storage, CCS) or reused (carbon capture and utilization, CCU).

Yellow Hydrogen
In contrast to green hydrogen, electrolysis is carried out using the general electricity mix (thus also in part produced from fossil energy sources).

Red/pink Hydrogen
In contrast to green hydrogen, electrolysis is powered by nuclear energy.

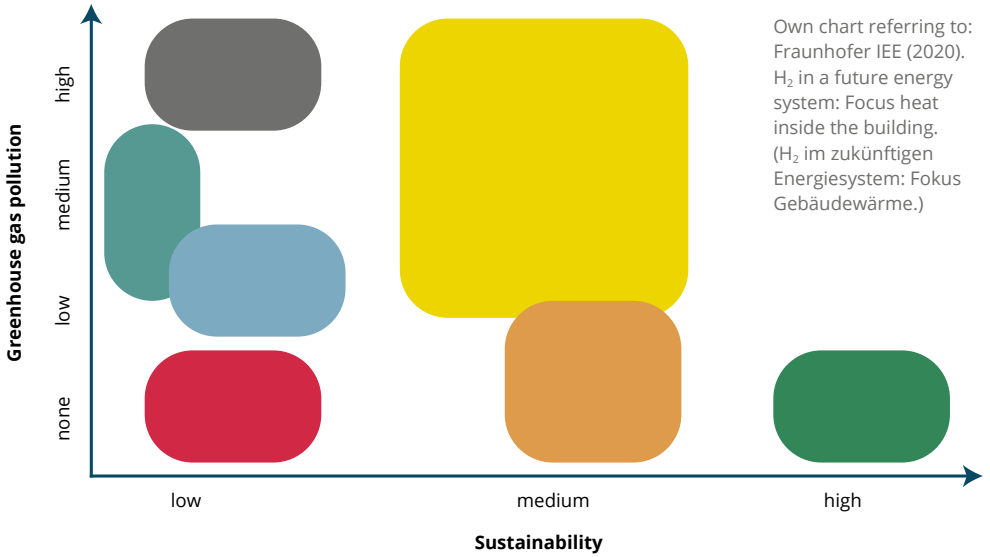
Gray Hydrogen—climate-damaging
Hydrogen obtained by steam reforming—or partial oxidation of fossil hydrocarbons (in Germany almost exclusively natural gas) —is referred to as "gray". From methane (CH_4) and water (H_2O), hydrogen and CO_2 are produced. In the process, about 10 t of CO_2 per ton of H_2 are released into the atmosphere.

Color theory—Production processes of hydrogen

Until now, hydrogen has been produced almost exclusively from fossil fuels such as coal and natural gas. CO_2 is released during the production of "gray" hydrogen. During the production of so-called "blue" hydrogen, the released CO_2 is captured and stored ("carbon capture"). This form of hydrogen is thus largely climate-neutral.

An alternative is the production of "orange" hydrogen from biomass. Although CO_2 is released during this type of process as well, the material cycles are much shorter than for coal, oil or gas: During the production of orange hydrogen, only the carbon dioxide that the plant absorbed during growth is emitted.

By far the greatest potential for a sustainable energy system is "green" hydrogen, which is obtained from the electrolysis of water. In this process, water is broken down into its two components: hydrogen and oxygen. Since electrolysis requires electrical energy, this process is only climate-neutral if the electricity originates from renewable sources.



Own chart referring to: Fraunhofer IEE (2020). H_2 in a future energy system: Focus heat inside the building. (H_2 im zukünftigen Energiesystem: Fokus Gebäudewärme.)

Hydrogen—A vector of global energy logistics

The climate-neutral energy system of the future will be driven primarily by wind power and solar energy. If the future mobility sector, heating sector and industry are also to be decarbonized largely through coupling with the power sector, the global demand for electricity will increase. The German government has set the goal of achieving a 65 percent share of renewable energies in electricity consumption by 2030. However, even a drastic increase in the installed capacity of renewable energy will probably not be sufficient to cover the future electricity demand in Germany. The regional and seasonal potentials for the use of wind and sun are limited, especially in Bavaria. Thus, even in a climate-neutral world, Germany and Bavaria will remain energy importers.

Are green sources even sufficient for a reliable energy supply? Looking at other regions in Europe and the world reveals that there is a high potential for renewable energy. Even covering a relatively small part of the Sahara with photovoltaics could supply the entire world with electricity. Offshore wind farms —in the North Sea, for example—are much more productive than comparable inland facilities. Iceland has far more geothermal energy than it can consume. At the same time, the prices of renewable energies are falling with increasing expansion: In particularly sunny regions, the levelized costs of solar power are already less than two cents per kilowatt hour.

The areas with very favorable conditions for the use of wind, solar, hydropower or geothermal energy are usually not located in regions where energy demand is high. If we want to achieve a climate-neutral society, we need to leverage this potential and start tapping it today together with international partners. A global trade of renewable energy can be realized in the future through new forms of energy logistics in which electricity or energy equivalents are transported from the producing regions to the centers of consumption.

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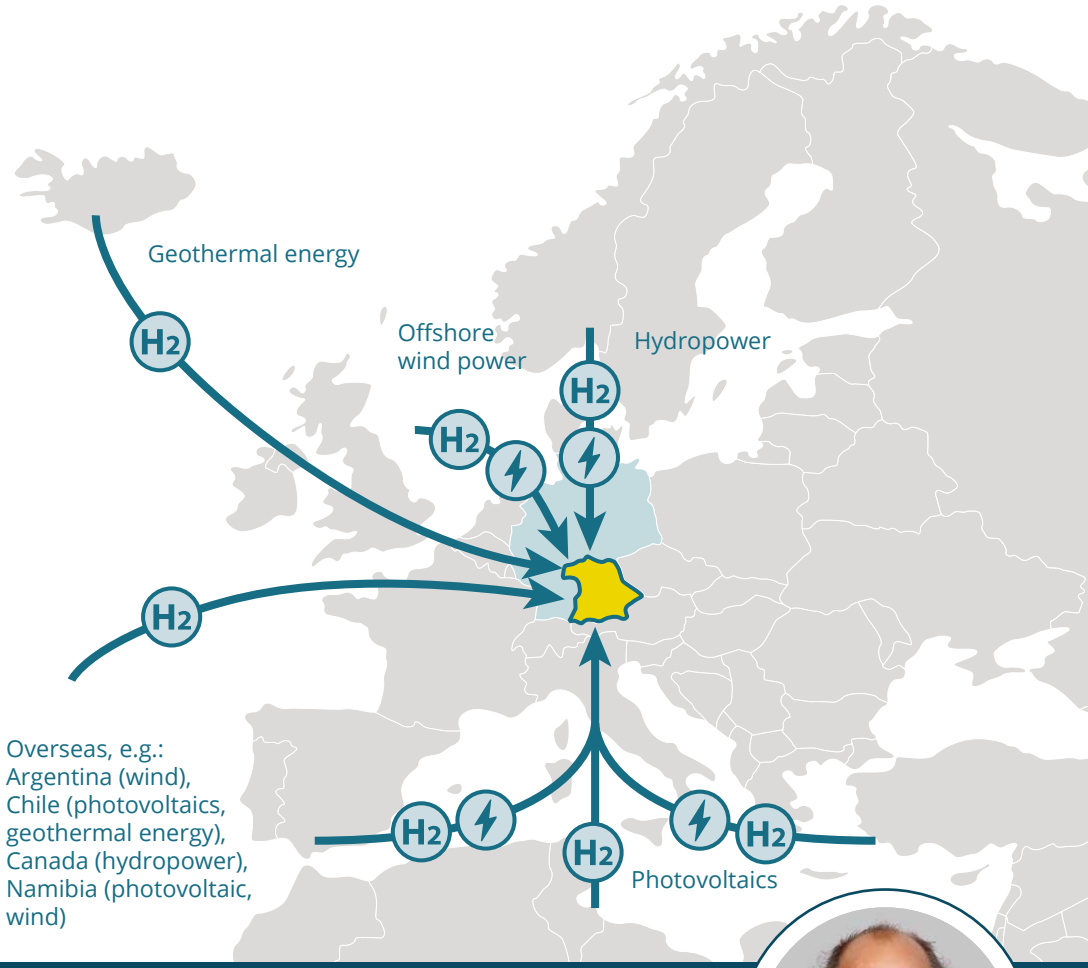

Prof. Dr. Peter Wasserscheid, Member of the Board

The hydrogen economy of the future will consist of green and inexpensive hydrogen sources, which will be linked to high-quality applications in the mobility or industrial sectors via efficient logistics paths. Research and framework conditions have developed dynamically in recent years—the task now is to drive technological development forward and accelerate its transfer into practical applications.

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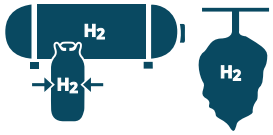
The transport of energy via electricity grids is often ruled out due to long distances or geopolitical conditions. Hydrogen can be stored and transported, on the one hand, at high pressure or very low temperatures or, on the other hand, chemically bound (as in ammonia, methanol or LOHC). In the future, hydrogen will thus make it possible to transport energy equivalents from sun- and wind-rich regions to meet demands in Bavaria and to use them in mobility, industry or to compensate for the seasonal fluctuations of renewable energies.

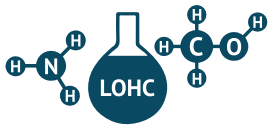
Modern technologies enable both the almost loss-free transport and the regional distribution of hydrogen via existing infrastructures. If hydrogen is produced at minimal cost in electricity surplus regions, efficiency losses of the conversion steps as well as transport costs become far less important.

Hydrogen storage technologies:

Liquid hydrogen (LH_2)
H_2 is deep-frozen and stored at -253 °C, which enables transport over long distances.



Gaseous hydrogen (GH_2)
H_2 is compressed under high pressure (20–1000 bar) and stored in caverns or tanks made of steel or compound materials. GH_2 is used, for example, in passenger cars (700 bar) or commercial vehicles (350 bar).



Chemically bound hydrogen
H_2 is bound in carrier fluids (LOHC) or used to produce synthetic fuels (such as methanol, ammonia or diesel).

Metal hydrides
H_2 is stored in solids made of metal, which can absorb the gas like sponges.

The Center Hydrogen.Bavaria and the Hydrogen Alliance Bavaria

The Center Hydrogen.Bavaria (H2.B)

The Free State of Bavaria has founded the Center Hydrogen.Bavaria (H2.B) to consolidate and expand the strong position of the Bavarian industry in the important future field of hydrogen. In this way, Bavaria is pursuing the goal of bringing together key players in industry, science and politics in order to advance the topic of the “hydrogen economy”. It is a particular goal to promote hydrogen in the Bavarian mobility sector as quickly as possible and to achieve the use of hydrogen in broad practical application areas.

The Center’s numerous activities are divided into four areas (see on the right) and are intended, among other things, to contribute to strengthening networking activities among Bavarian hydrogen players (in the Hydrogen Alliance of Bavaria), as well as with other national and international players. In 2020, H2.B and its partners in the Hydrogen Alliance Bavaria developed a Position Paper on the Bavarian hydrogen economy as a first step towards a Bavarian Hydrogen Strategy (see page 16). In April 2022, H2.B published the Hydrogen Roadmap Bavaria jointly with the Bavarian Ministry of Economic Affairs, Regional Development and Energy.

In addition, H2.B coordinates the activities and maintains the network in the Hydrogen Alliance Bavaria (see page 18).

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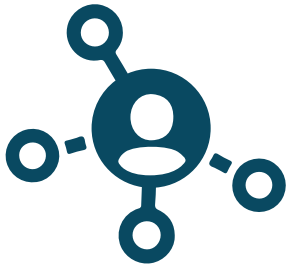
Strategy

- Development of a Hydrogen Strategy for Bavaria in cooperation with the central players from politics, economy and science
- Monitoring of other national and international hydrogen strategies
- Development of a hydrogen roadmap for Bavaria

Technology & Innovation

- Technological matchmaking with the goal of bringing together hydrogen players and their expertise, to leverage synergy effects
- Initial funding & project consulting
- Impetus to demonstration projects
- Market and technology analyses for the further development and large-scale implementation of the hydrogen economy in Bavaria



Public Relations

- Event management for Bavarian, national and international workshops, seminars and trade fairs
- Press and public relations work to increase the general awareness of hydrogen technologies and their prospects
- Networking activities and cooperation with other regional and national actors
- Fostering political relations

International Affairs

- Internationalization of the Hydrogen Strategy
- International matchmaking
- Cooperation with international players

The pathway to a Hydrogen Strategy and a Hydrogen Roadmap for Bavaria

With the Bavarian Hydrogen Strategy, the State of Bavaria aims to bring innovative hydrogen technologies into practical use quickly and thus promote the phase-out of fossil fuels. The Hydrogen Strategy creates an initial framework for the future production, transport and application of hydrogen.

The Center Hydrogen.Bavaria (H2.B) was charged with developing a Hydrogen Strategy for Bavaria and began the strategy process immediately after its establishment in 2019.

The Position Paper of the Hydrogen Alliance Bavaria was a first milestone on the pathway of developing a Bavarian Hydrogen Strategy. The Position Paper was prepared in an extensive consultation process coordinated by H2.B with the 36 companies, associations and research institutions represented in the Hydrogen Alliance Bavaria at the time. In addition, other associated companies, institutions and private individuals had the opportunity to discuss the topics from the network meetings and to make constructive contributions at a stakeholder dialogue.

Download Position Paper, Hydrogen Strategy and Hydrogen Roadmap Bavaria

The Position Paper and the Bavarian Hydrogen Strategy were presented at a press conference on May 29, 2020. Along the hydrogen value chain, the Position Paper identifies the needs for action, the course to be set and the central elements of a ramp-up of the Bavarian hydrogen economy.

The Bavarian Hydrogen Strategy aims to enter new markets with hydrogen and Bavarian innovations, to secure prosperity and, at the same time, to accelerate the phase-out of fossil fuels.

The strategic goals are divided into three areas:

- Promoting innovation and achieving technology leadership
- Accelerating industrial scaling and economic viability
- Achieving widespread practical use of hydrogen as quickly as possible

In April 2022, H2.B published the Hydrogen Roadmap Bavaria jointly with the Bavarian Ministry of Economic Affairs, Regional Development and Energy. The Roadmap is intended to highlight perspectives and concrete needs for action and to help accelerate the ramp-up of the Bavarian hydrogen economy.

The Hydrogen Roadmap Bavaria is intended to

- illustrate the potential as well as current and future needs for hydrogen and hydrogen technologies in Bavaria.
- define concrete measures and breakpoints to comprehensively reduce the use of fossil fuels in the various sectors and thus lower greenhouse gas (GHG) emissions.
- support the development and expansion of the Bavarian hydrogen economy in order to consolidate and expand Bavaria's strong national and international position in the field of innovative hydrogen technologies.

www.h2.bayern/en/bavarian-hydrogen-strategy

The Hydrogen Alliance Bavaria

The Hydrogen Alliance Bavaria is a joint networking, knowledge and interest platform of hydrogen players from industry, science and politics based in Bavaria. The Alliance serves as a contact point for hydrogen actors and aims at strengthening the Bavarian hydrogen economy and research landscape through networking, exchange of experience and information. The Alliance is coordinated by the Center Hydrogen.Bavaria (H2.B).

At the founding event of H2.B on September 5, 2019, the first key players from business, science and politics of a future Bavarian hydrogen economy signed the declaration of intent for the Hydrogen Alliance Bavaria. All partners of the Alliance declare that they will contribute to strengthening and expanding Bavaria's technological competence in the field of innovative hydrogen technologies and support the activities of H2.B.

Activities within the Hydrogen Alliance Bavaria:

- Internal workshops and seminars for networking, for exchange of both experience and information (e.g. via speed pitchings)
- Public events, partly with presentation opportunities for individual Alliance partners
- Internal, weekly newsletter for information ("infoletter")
- Regional, national and international networking and matchmaking (finding suitable technology partners, bringing together producers and users of hydrogen)
- Collaboration in Strategy and Roadmap development

Goals of the Hydrogen Alliance Bavaria:

- Bavaria is to become the leading location for the industrial production of key hydrogen components.
- Bavaria is to be established as a technology leader in the field of hydrogen storage and logistics.
- The establishment and expansion of the filling station infrastructure is to be accelerated.

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Founding partners in September 2019:

In addition to the founding partners, more than 200 companies, research institutions and associations have already joined (see next page). The Alliance is open to further partners. For more information, please visit:

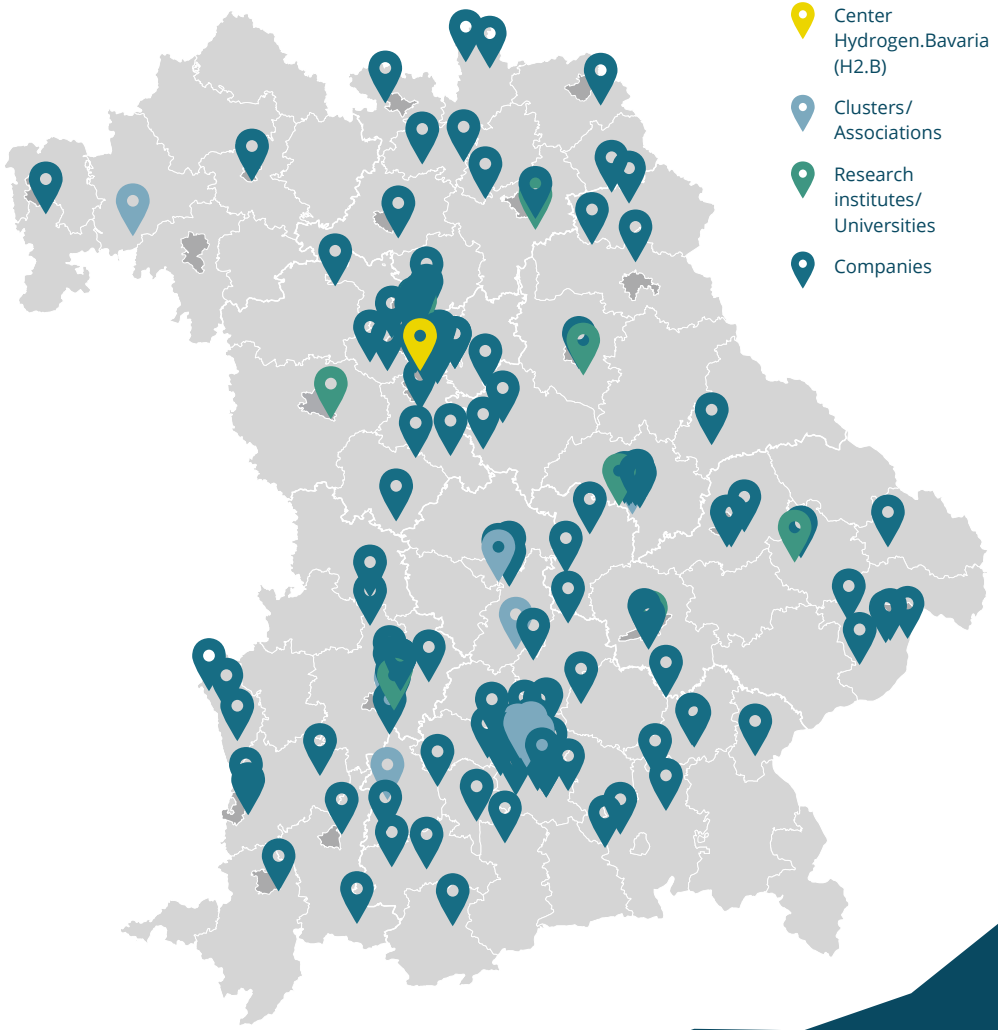
www.h2.bayern/en/hydrogen-alliance-bavaria

Get your information now

Information on how to join

Would you like your institution to join the Hydrogen Alliance Bavaria? The Alliance partnership is open to all players from industry, science and politics with a registered office in Bavaria. Here you can find more information on how to join: https://h2.bayern/en/hydrogen-alliance-bavaria

Partners and competencies within the Hydrogen Alliance Bavaria



Structure of the Hydrogen Alliance Bavaria*:

- Power engineering
- Engineering

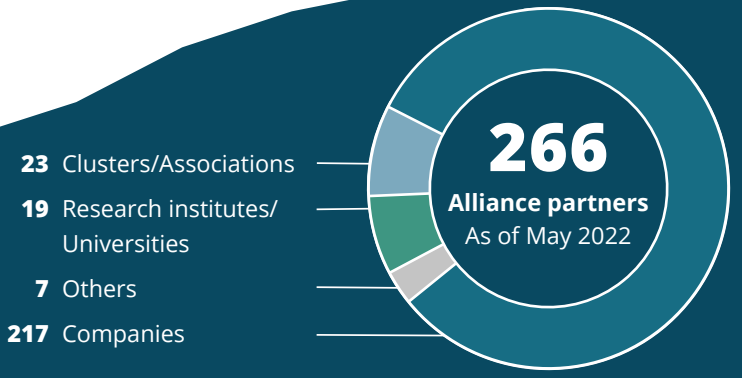
- Drive technology
- Automotive engineering
- Research & Development

- Fuel cell technology
- Gas logistics
- Grid operators
- Supply

- Investment & Financing
- Project management
- Project development
- Connection technology

- Chemical engineering
- Gas installation
- Plastics technology
- Sensor technology
- Vacuum technology

*Due to intersections, the shares do not add up to 100%.



23 Clusters/Associations
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7 Others
217 Companies

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Imprint

Publisher:
Center Hydrogen.Bavaria (H2.B) /
Zentrum Wasserstoff.Bayern (H2.B)

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Layout: zur.gestaltung, Nuremberg

Photos/Images: H2.B, Giulia Iannicelli,
Bavarian Ministry of Economic Affairs,
Regional Development and Energy

Graphics: Center Hydrogen.Bavaria (H2.B)

Version: 05/2022

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