Hydrogen
as an essential component of the energy transition

Germany and the European Union aim to be climate-neutral at the latest by 2050. This should be achieved while ensuring that the population has a reliable energy supply and that industry remains competitive. To ensure Germany achieves its energy transition goal, technologies for producing, storing, distributing, and using hydrogen (H_2) need to be developed and made commercially available on a large scale. The reasons for this are as follows:

- Hydrogen technologies can close the gap between the fluctuating generation of energy from renewable energy sources and actual demand. This applies to gaps that would otherwise open up for hours, days, weeks, or even months. Hydrogen technologies can thus ensure that consumers are supplied with energy as required all year round.
- Hydrogen technologies enable the coupling and comprehensive optimization of energy sectors (electricity, heating), industry, and transport, which are often considered separately. For example, if there is a surplus of renewably generated electricity, industry can use this electricity to produce hydrogen, which can in turn be used to power fuel cell vehicles.
- Hydrogen is essential if industrial processes are to manage without the use of carbon energy carriers, for example to produce steel or base chemicals.
- For production processes in which the formation of carbon dioxide (CO_2) is unavoidable, industry can capture these emissions and use hydrogen to convert them into usable substances such as synthetic fuels or chemicals.

Helmholtz Association
Expertise and Infrastructure

The energy transition is one of the grand challenges facing society and one for which Helmholtz is working on developing solutions as part of a long-term, holistic approach. Around 600 employees across ten centers are researching hydrogen technologies. This research covers the whole spectrum, from basic research to application, and also spans the entire value chain. Helmholtz scientists not only conduct technical research, however, they also perform systems analysis and socioeconomic studies as they seek to optimize the energy system with a focus on technology and all societal, economic, and political aspects.

The Helmholtz centers also develop new process and value chains for hydrogen, including the resulting chemical energy carriers. They are thus able to create sustainable alternatives to production pathways and transport concepts that are currently based on fossil fuels. The centers also research the intelligent interlinking of various technologies and components to help shape an energy system that uses resources efficiently and is resistant to disruptions.

The Helmholtz Association has many, often unique, facilities for developing, analysing, and testing hydrogen technologies as well as trialling their practical application. The research infrastructure includes, for example, large facilities that produce functional coatings, coating systems, and entire components. Hydrogen technology materials can be analysed at world-leading X-ray light sources and fundamentally investigated at other facilities under cryogenic conditions. For fuel cells and electrolyzers, test stands and specialized facilities can be used for electrochemical characterization. Furthermore, Helmholtz scientists operate the world's largest artificial sun to test hydrogen production using solar power as well as operating a facility for hydrogen safety tests on an industrial scale.

Research for innovation

In recent years, Helmholtz has strengthened its role in innovation processes, especially in regions of structural change: The Helmholtz Cluster for a Sustainable and Infrastructure-compatible Hydrogen Economy (HC-H2) develops pioneering concepts for innovative and sustainable hydrogen economy and infrastructure. The incubator Sustainable Electrochemical Value Chains (iNEW 2.0) studies and develops novel and efficient electrolysis processes for sustainable Power-to-X (PtX) systems. The DLR Institute for Future Fuels works on materials, components, and processes for climate-neutral fuels.

Upgrading of research infrastructures is needed to commercialize hydrogen technologies and use them on a large technical scale as quickly as possible. Such infrastructures include real-world labs for the energy transition, demonstration projects, pilot plants, large experimental facilities, and a research ship. Helmholtz researchers are largely involved in the three BMBF-funded hydrogen flagship projects H2Giga, H2Mare, and TransHyDE. These projects focus on the series production of electrolysers to generate green hydrogen with regenerative electrical power as well as on possibilities to produce green hydrogen and its daughter products directly at sea. For this purpose, new hydrogen transport technologies are needed. Helmholtz centers collaborate in an innovation pool project to increase the purity and pressure of solar hydrogen and, hence, avoid unnecessary processing steps. Development of novel catalyst materials for the production of green hydrogen is in the focus of CatLab, the joint research platform of the Helmholtz Association, Max Planck Society, and Humboldt-Universität zu Berlin.

Helmholtz works on accelerating the pathway from invention to commercialization through collaboration with industry and national and international partners. It also seeks to open up perspectives for sustainable hydrogen production outside of Europe.

An additional focus is education and training. They will be advanced in cooperation with universities, universities of applied sciences, and chambers of industry and commerce.

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Further Informations:
helmholtz.de/en/research/challenges/hydrogen-technologies
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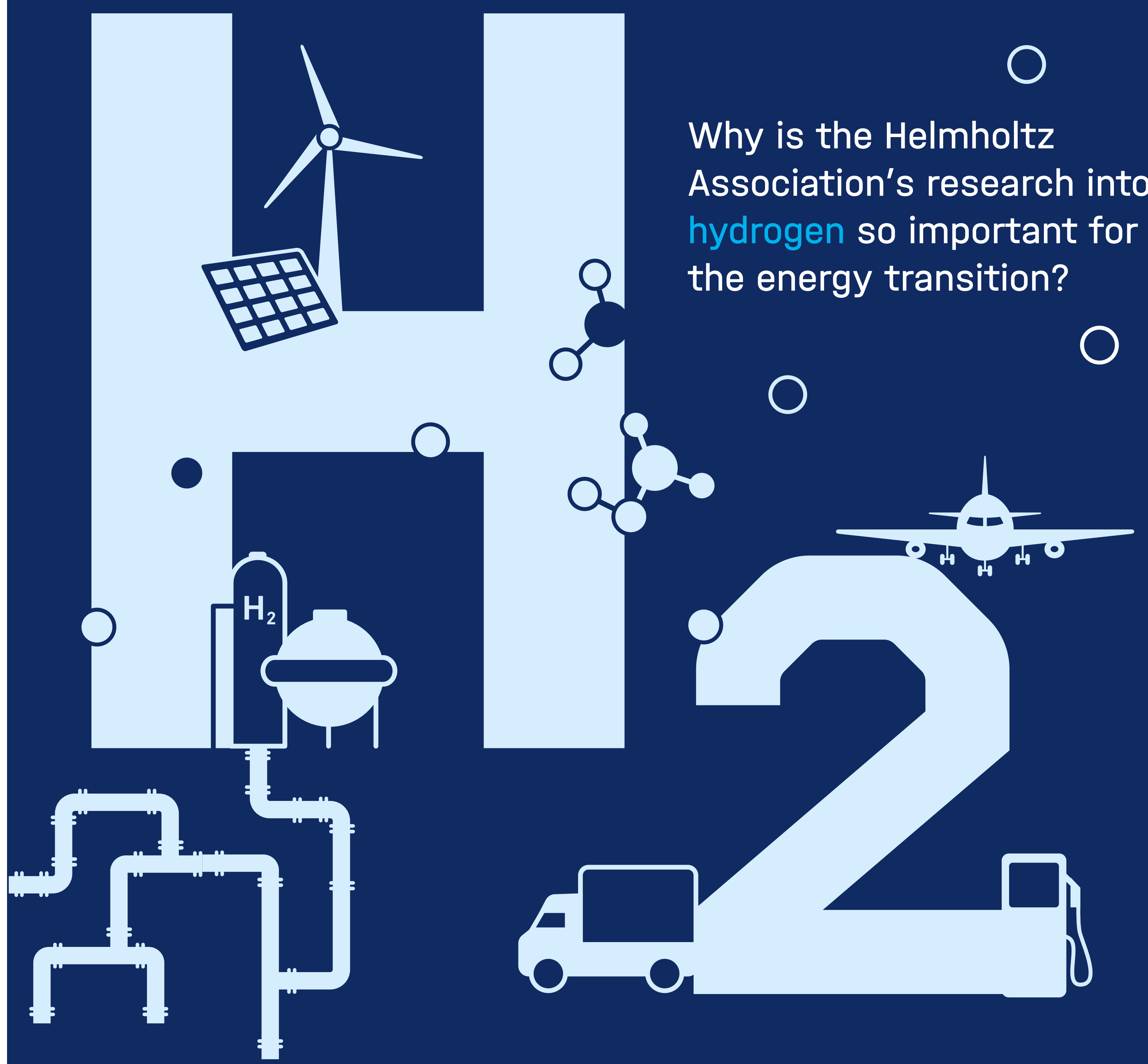


Why is the Helmholtz Association's research into hydrogen so important for the energy transition?

HYDROGEN
Competence Map

Production

Cost-effective and sustainable

There are numerous possibilities for producing hydrogen. Helmholtz scientists are working on ensuring that established production processes, for example electrolysis, are more cost-effective, more sustainable, and more reliable. One focus of their work is to transfer laboratory results to demonstration plants on an industrial scale. The scientists also research young, not yet mature technologies such as the biocatalytic production of hydrogen.

Polymer electrolyte membrane-based stack combination used for characterization in electrolysis test stand (FZJ)

HIGHLIGHTS

- Dynamic operation of 400 kW low-temperature electrolyzer (FZJ)
- 20,000 h operation of a high-temperature electrolysis stack (FZJ)
- Development of the world's largest solar reactor for hydrogen production (DLR)
- Development of methane pyrolysis and reforming in supercritical water for CO_2-free hydrogen production (KIT)
- Development of cyanobacteria biocatalysts that can release hydrogen directly from water (UFZ)
- Efficiency record for artificial photosynthesis using silicon solar cells (FZJ)
- Demonstration of a 50 cm^2 artificial leaf for producing hydrogen using solar power based on metal oxides (HZB)
- Characterization of the synchrotron radiation sources of novel catalysts for splitting water (DESY)

Storage & distribution

Diverse possibilities

Hydrogen can only make use of its advantages, such as demand-driven availability and sector coupling, if it can be safely stored until required and reliably transported to where it is needed. In future, storage for large amounts of hydrogen will be required.

Helmholtz scientists are investigating to what extent underground storage facilities and existing natural gas storage facilities could be used for the purpose of gas storage. Gaseous hydrogen could be transported via the natural gas grid, which has a good network in Germany.

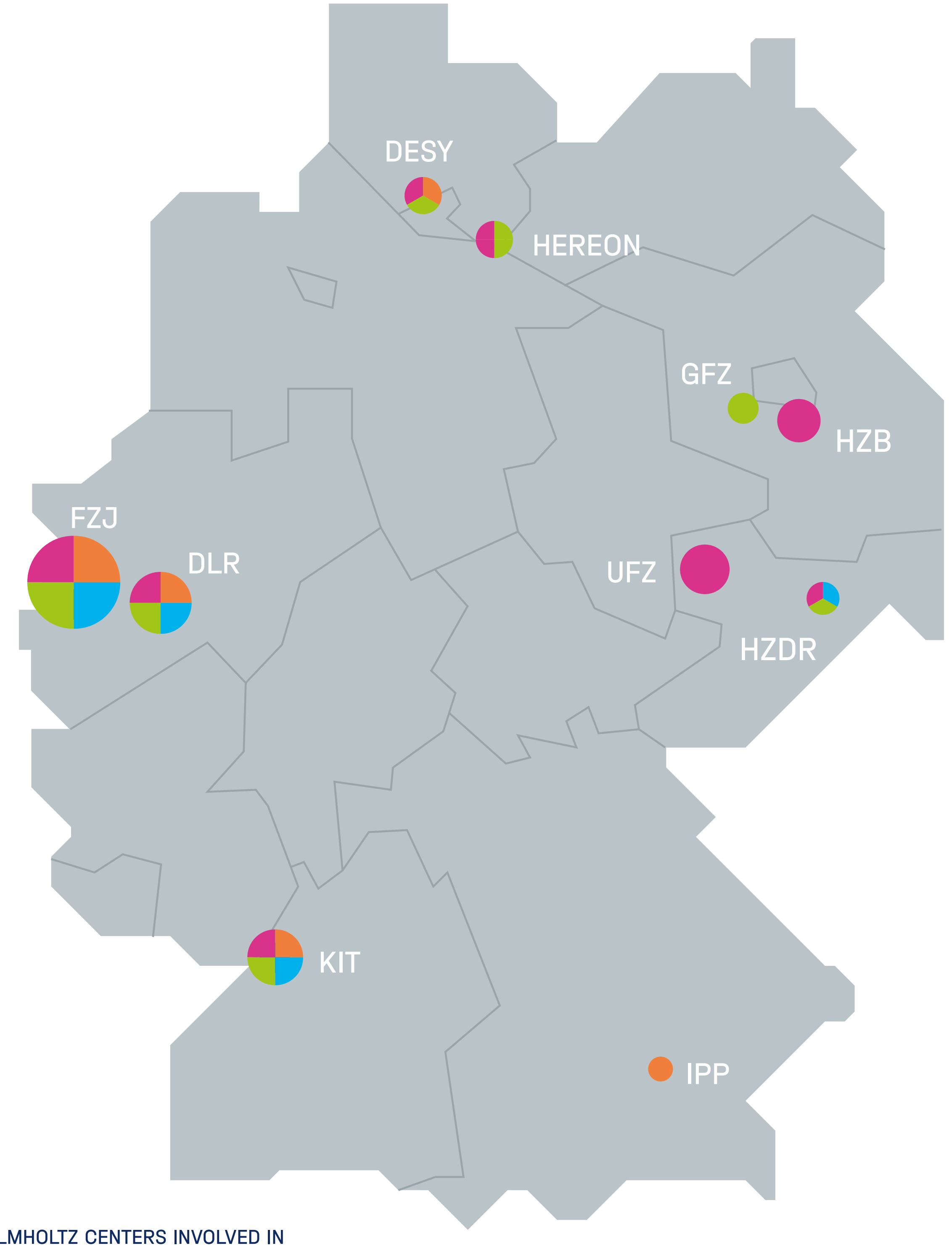
Hydrogen safety test center for the development of new test standards and the optimization of safety technology (KIT)

Hydrogen can also be stored in solids. When heated, these hydride storage tanks then release the hydrogen. Hydrogen can also react with unsaturated organic compounds to form a high-energy liquid that can then be stored and transported in a similar way to crude oil. The scientists continue to develop such liquid organic hydrogen carrier (LOHC) technologies and hydride storage tanks.

HIGHLIGHTS

- Experiments and modelling for the safe and efficient storage of H_2 in solid storage systems, from the lab to technical implementation (Hereon)
- Hydrogen safety test center for the development of new test standards and the optimization of safety technology (KIT)
- LOHC demonstration facilities (FZJ)

Hydrogen competence map



HELMHOLTZ CENTERS INVOLVED IN HYDROGEN RESEARCH:

Forschungszentrum Jülich GmbH (FZJ)
German Aerospace Center (DLR)
Karlsruhe Institute of Technology (KIT)
Helmholtz Center for Environmental Research (UFZ)
Helmholtz-Zentrum Berlin (HZB)
Helmholtz-Zentrum Hereon (Hereon)
Deutsches Elektronen-Synchrotron (DESY)
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)
German Research Center for Geosciences (GFZ)
Max Planck Institute for Plasma Physics (IPP)

The size of the spheres indicates how many employees are researching hydrogen technologies at the respective centers.

- Production
- Storage & distribution
- Use
- Systems analysis

Use

Fuel cells and synthetic fuels

Helmholtz scientists are working on improving the efficiency, durability, and performance of fuel cells. Fuel cells convert hydrogen directly into electrical energy and are of interest for many different uses. These include for electric drive or the on-board power supply of lorries, buses, planes, ships, forklift trucks and passenger cars, as well as for combined heat and power units and for supplying electricity to devices that are off the grid. Various cell types are ideal for different applications due to their properties and operating conditions.

HY4 – first four-seater passenger aircraft powered solely by a hydrogen fuel cell battery system (DLR)

Hydrogen can also be used to produce synthetic liquid fuels and base chemicals. Researchers are developing corresponding methods right up to industrial scale.

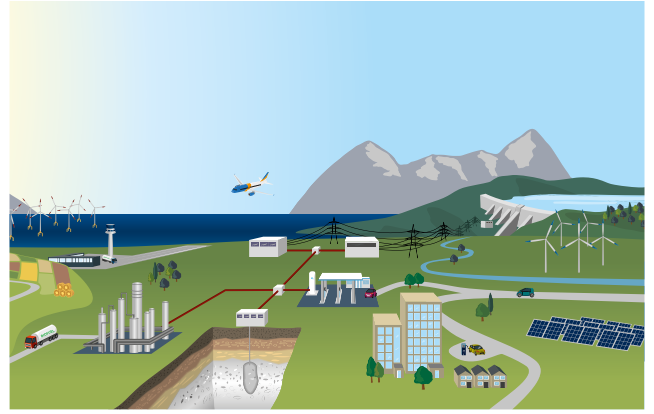
HIGHLIGHTS

- 100,000 h continuous operation of a solid oxide fuel cell stack (FZJ)
- Compact fuel cell module for on-board power supply of mobile applications (FZJ)
- World's first hydrogen-powered ferry (DLR)
- Development of burners for gas turbines in which pure hydrogen is burned (DLR)
- Development of chemical reactor technologies that can be used to convert hydrogen and CO_2 locally into synthetic energy carriers and chemical substances (KIT, FZJ)

Systems analysis

The energy system of the future

Decisions made with respect to the energy sector, energy policy, and research funding have long-lasting impacts and are of relevance for almost all areas of society. Knowledge of systems analysis is needed to act with foresight, to identify the opportunities offered by new technologies, and to reduce the risks posed to the environment and the economy. Helmholtz scientists are therefore developing cross-sector models of the German, European and global energy system that integrate hydrogen technologies. They evaluate these technologies and take aspects related to safety, economy, ecology, and society into account. The scientists also design concepts to decarbonize energy-intensive industrial sectors by using hydrogen, i.e. switching to low-carbon or carbon-free production processes. Furthermore, they devise hydrogen supply systems and analyze industrial-scale storage options.



Representation of a sustainable networked energy infrastructure (FZJ)

HIGHLIGHTS

- Study: Pathways for the German energy transition by 2050 (FZJ)
- Living labs for intelligent networked energy systems based on renewable energy sources (FZJ, KIT, DLR)