HYDROGEN AS AN ESSENTIAL COMPONENT OF THE ENERGY TRANSITION

Germany and the European Union aim to be climate-neutral 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 the Helmholtz Association of German Research Centers 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. Scientists at the Helmholtz Association 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 Association 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, analyzing, 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 analyzed 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.

OUTLOOK ▶▶▶

RESEARCH FOR INNOVATIONS

The Helmholtz Association aims to strengthen its role in innovation processes in future, particularly in regions of structural change. Examples of projects include the HC-H_2 Helmholtz cluster for a sustainable and infrastructure-compatible hydrogen economy in Jülich, the iNEW innovation centers for sustainable electrochemical value chains, and the new DLR institute Future Solar Fuels. Furthermore, the Helmholtz Association is proposing to establish a center of excellence for hydrogen mobility in view of the structural change in the automobile industry.

Scientists at the Helmholtz Association believe that cross-programme and interdisciplinary research funding initiatives are necessary to strengthen and make better use of synergies resulting from interdisciplinary collaboration as part of a holistic approach to complex research topics. An example of this is sector coupling with hydrogen. Such initiatives also enable the synergistic organization of expertise for developing, producing, characterizing, and modelling materials as well as the acceleration of developments across the value chain. The scientists also aim to make increased use of supercomputing and artificial intelligence through collaborations between the research fields of information and energy.

Furthermore, the Helmholtz Association aims to press ahead with the expansion of research infrastructure. This includes the living labs for the energy transition as well as demonstration projects and pilot systems to ensure that hydrogen technologies can be used in industrial applications and brought to market as soon as possible.

The Helmholtz Association aims to accelerate the pathway from discovery to market transfer through cooperation with industry as well as national and international partners. It also seeks to open up prospects for the sustainable production of hydrogen outside Germany.

An additional focus is education and training, which the Helmholtz Association aims to expand and push forward together with universities and chambers of industry and commerce.

Contact information/Publication details

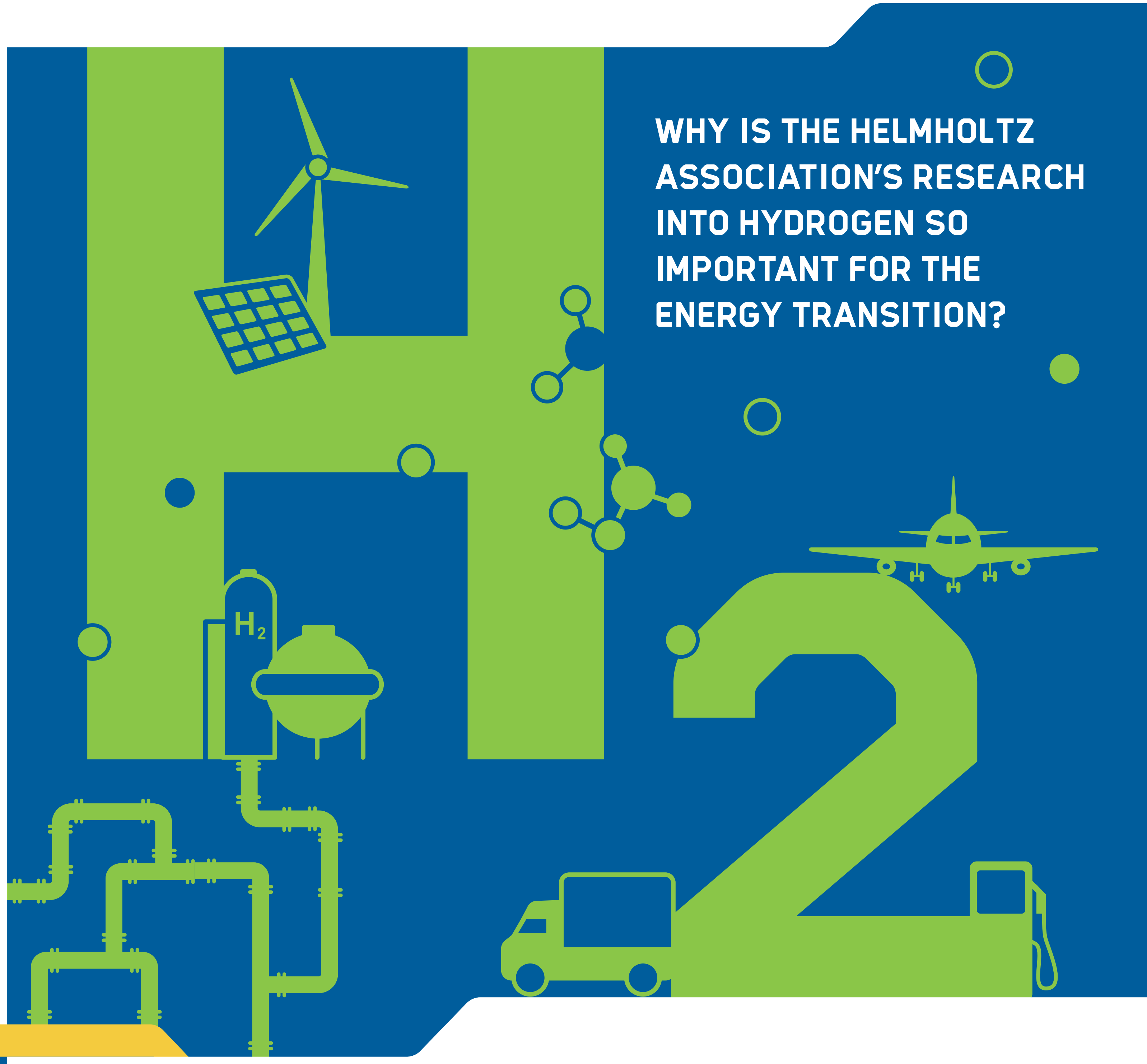
Helmholtz Association of German Research Centers
Prof. Dr.-Ing. Holger Hanselka, Vice President Research Field Energy, email: holger.hanselka@kit.edu
c/o Coordination office Research Field Energy
Karlsruhe Institute of Technology (KIT), Postfach 3640, 76021 Karlsruhe

Scientific contact partners at participating centers

DESY:	Prof. Dr. Gerhard Grübel	Email: gerhard.gruebel@desy.de
DLR:	Prof. Dr. André Thess	Email: andre.thess@dlr.de
FZJ:	Prof. Dr. Olivier Guillon	Email: o.guillon@fz-juelich.de
GFZ:	Prof. Dr. Michael Kühn	Email: michael.kuehn@gfz-potsdam.de
HZB:	Prof. Dr. Roel van de Krol	Email: roel.vandekrol@helmholtz-berlin.de
HZDR:	Dr. Gunter Gerbeth	Email: g.gerbeth@hzdr.de
HZG:	Prof. Dr. Thomas Klassen	Email: thomas.klassen@hzg.de
IPP:	Prof. Dr. Ursel Fantz	Email: ursel.fantz@ipp.mpg.de
KIT:	Prof. Dr.-Ing. Thomas Jordan	Email: thomas.jordan@kit.edu
UFZ:	Prof. Dr. Andreas Schmid	Email: andreas.schmid@ufz.de

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

COMPETENCE MAP HYDROGEN



HYDROGEN MAP

PRODUCTION

Cost-effective and sustainable

There are numerous possibilities for producing hydrogen. Scientists at the Helmholtz Association 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 Helmholtz 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

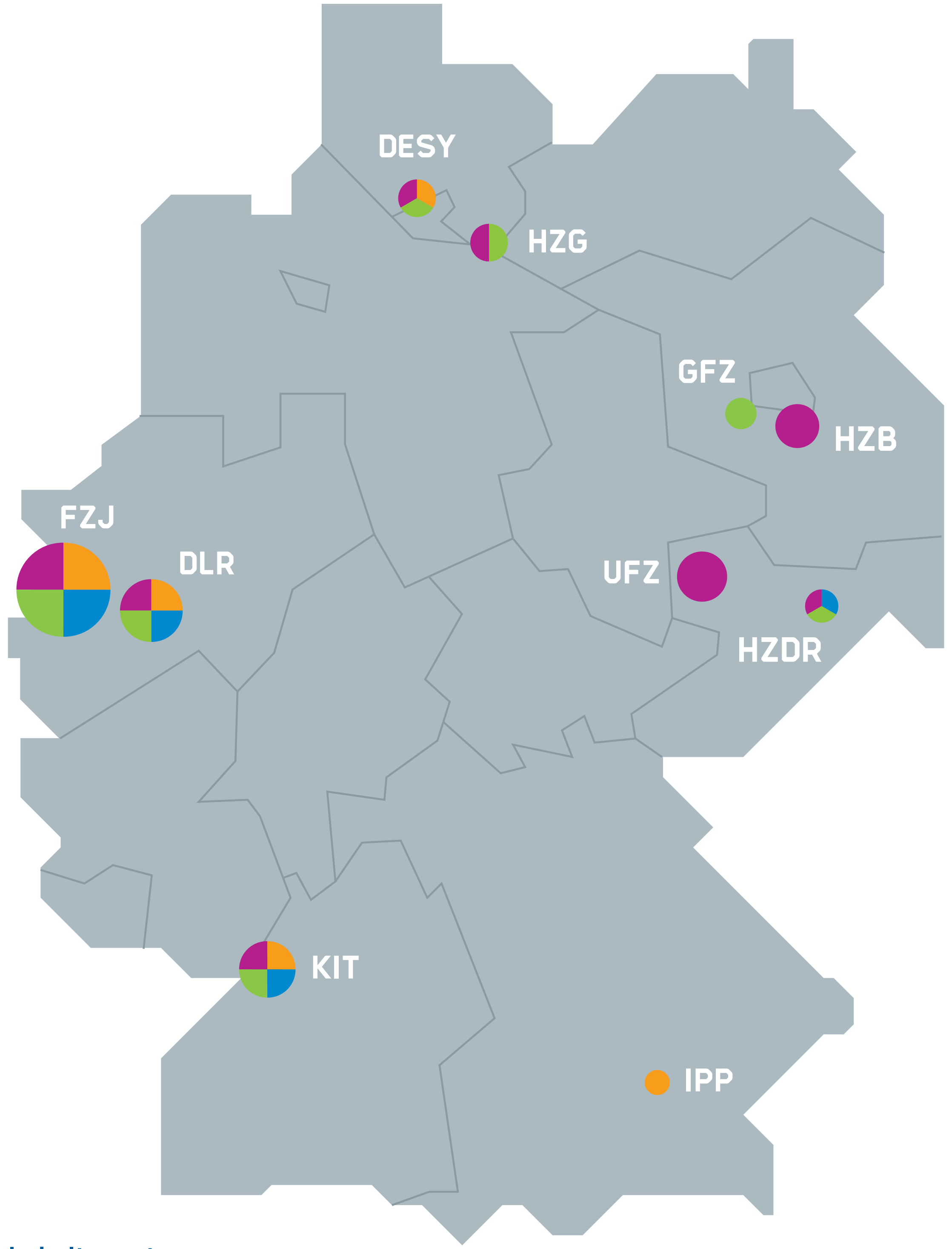
Hydrogen can only make use of its advantages, such as demand-driven availability and sector coupling, if it can be safely stored until required and reliably transported to where it is needed. In future, storage for large amounts of hydrogen will be required. Scientists at the Helmholtz Association are 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 Helmholtz 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 (HZG)
- Hydrogen safety test center for the development of new test standards and the optimization of safety technology (KIT)
- LOHC demonstration facilities (FZJ)



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 Geesthacht – Center for Materials and Coastal Research (HZG)
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.

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

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

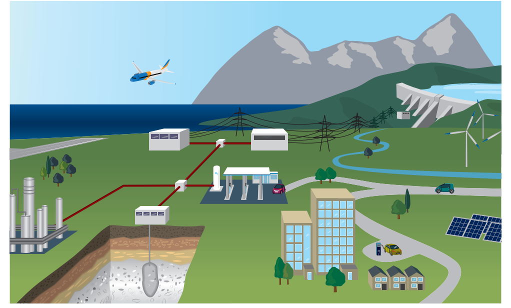
HIGHLIGHTS

- 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, the 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)