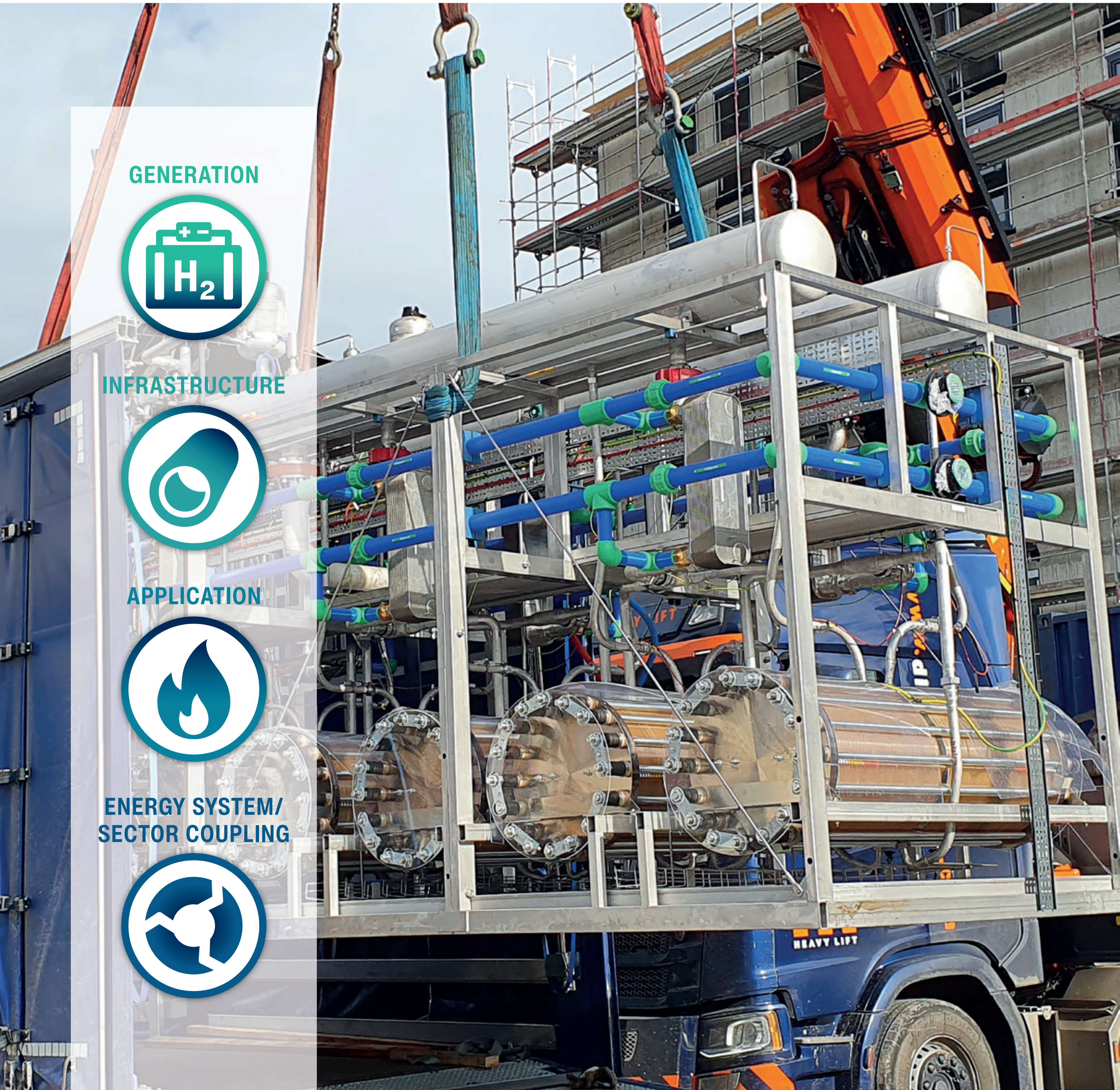
DVGW

energie | wasser-praxis konkret

REAL PROJECTS FOR A SUCCESSFUL LAUNCH OF HYDROGEN

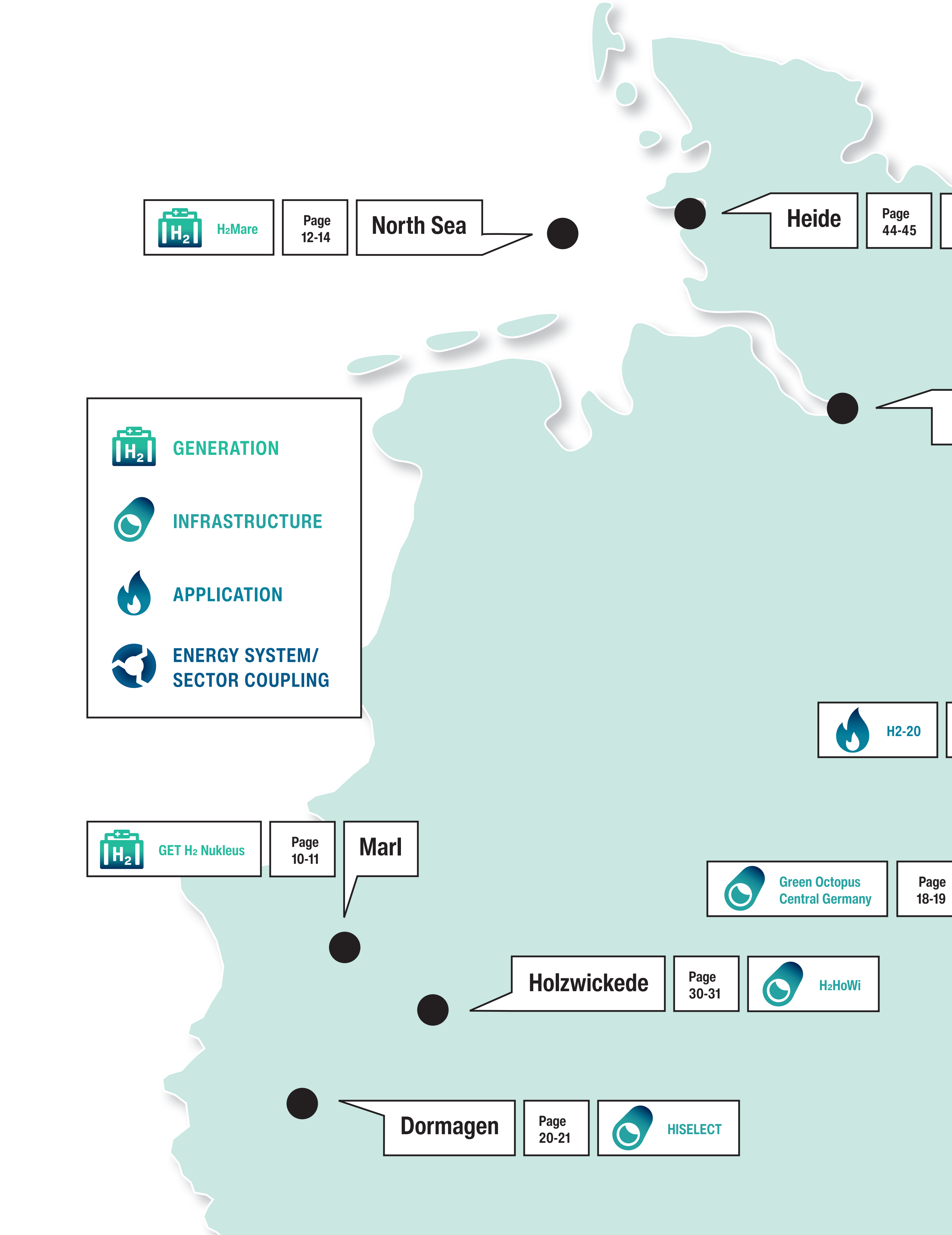


GENERATION

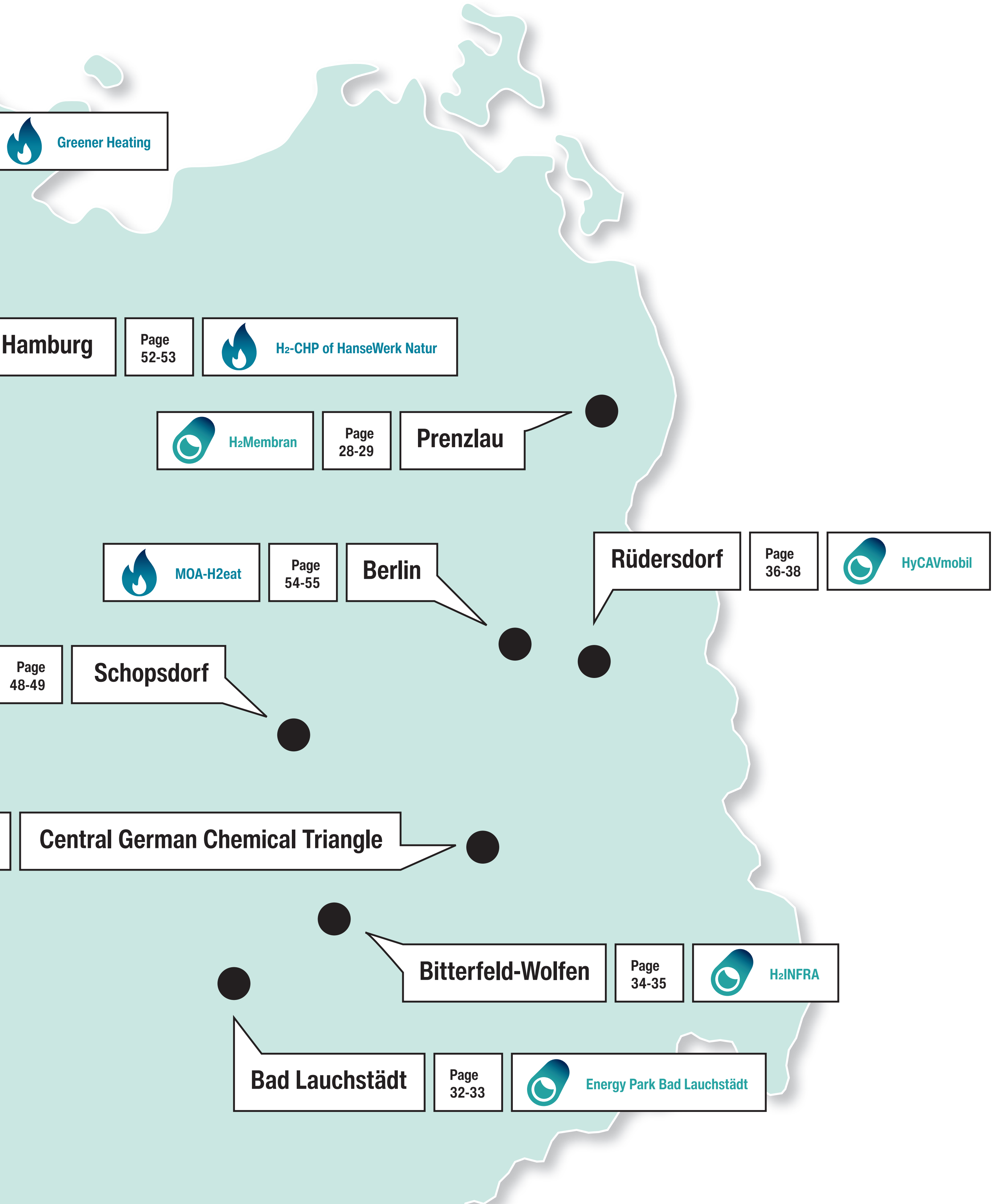
INFRASTRUCTURE

APPLICATION

ENERGY SYSTEM/ SECTOR COUPLING


H2Mare
Page 12-14
North Sea
Heide
Page 44-45
GENERATION
INFRASTRUCTURE
APPLICATION
ENERGY SYSTEM/
SECTOR COUPLING
H2-20
GET H2 Nukleus
Page 10-11
Marl
Green Octopus Central Germany
Page 18-19
Holzwickede
Page 30-31
H2HoWi
Dormagen
Page 20-21
HISELECT

Second part of the map
at the end of the booklet!



Real H_2 projects set the course for the future energy supply

by **Prof. Dr Gerald Linke** (Chairman of the DVGW Board of Directors Energy)

Germany's energy supply is to be independent, diversified and climate-neutral – and that within the space of a few years. While the climate goals of the Federal Government are to be accomplished speedily to minimise the consequences of the climate change, it is at the same time necessary to take into consideration geopolitical risks resulting from the dependence on energy imports. This complex situation makes it necessary to place the energy supply on a broad basis. However, the resulting inevitable conversion of the energy system can only be successful if all relevant technologies and options that will rapidly lower the greenhouse gas emissions are put to use – at bearable costs and risks. Apart from developing the renewable energies, propagating electrical solutions and gradually increasing the energy efficiency, this also includes the ramp-up of climate-friendly gases such as hydrogen to substitute the enormous amounts of energy that are today still being generated from fossil raw materials.

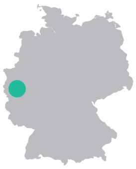
Gaseous energy carriers play a decisive role in achieving climate neutrality and a sustainably secured energy supply. It should be considered that still approx. four-fifths of the ultimate energy consumption in Germany is currently still covered by molecules and only one fifth by electrons. Although almost 50 percent of the electricity generated in Germany comes from renewable sources, this only corresponds to merely ten percent of the entire ultimate energy consumption. Conversely, this means: In the coming two decades, fossil molecules must be swiftly replaced by climate-friendly molecules. It is therefore not only necessary to dynamically advance the development of capacities for the generation of climate-neutral gases, but also their import. With hydrogen in particular, an energy carrier that is able to pave the way towards a climate-neutral society in all areas of life is ready to hand – and that already today!

The production, transport and use of hydrogen is by no means a distant dream of the future – already at the present moment, numerous projects are being implemented in Germany, which demonstrate the potential of this energy source. With this energy pulse "Real projects for a successful launch of hydrogen" in the "ewp konkret" series, we introduce a total of 28 versatile real projects of the gas industry that are all pursuing one goal: They are paving the way for the future energy supply in Germany. Depending on its emphasis, each of the projects focuses on hydrogen as core and driving force for climate-neutral gases, as connecting element in sector coupling and as catalyst for innovations in heat supply, industry, mobility and the generation of power. Each undertaking and each project demonstrates useful and practical ways of using hydrogen and how a transformation of the existing natural gas infrastructures towards the use of hydrogen can be realised. With their comprehensive know-how, all parties involved not only make an essential contribution with regard to the energy transition, but are likewise drivers of innovation and enablers for technologies and standards. In addition, this makes a perceptible contribution towards strengthening Germany as a sustainable business and industrial location.

We do not claim to have created an exhaustive summary with this compendium. Our goal has rather been the presentation of already existing real projects, which document practical applications and perspectives way beyond the research state. To this end, all projects were roughly clustered – without however claiming to sharply demarcate the respective clusters from each other. The decisive factor is the broad range of practical applications and the associated dynamics with regard to the market ramp-up of hydrogen and climate-neutral gases. Because from my point of view, one thing is indisputable: The decarbonisation of the existing power supply can only be achieved through the prominent use of climate-neutral gases, with the gas infrastructure as the key element. On this basis, climate targets can not only be achieved in a timely manner, but also in an ecologically, economically and socially acceptable way while taking into consideration geostrategic aspects.

Yours
Prof. Dr Gerald Linke
Chairman of the DVGW Board of Directors Energy

ENERGY SYSTEM/ SECTOR COUPLING



Hydrogen flagship project H_2Giga: Series production and upscaling of electrolysers

by **Dr Isabel Kundler** (DECHEMA e. V.)

Being able to cover Germany's need for green hydrogen requires large capacities of powerful and cost-efficient electrolysers. Although high-capacity models are already available on the market today, they are for the most part still crafted by hand. In this context, the flagship project H_2Giga is to support the serial and industrial production of electrolysers.

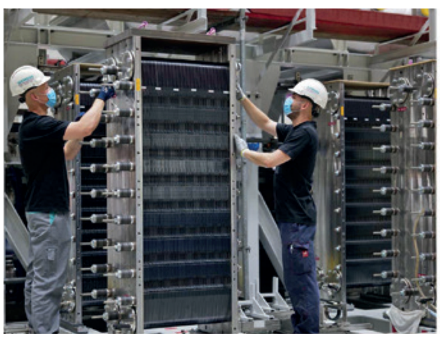
High expectations are placed on hydrogen, the smallest of all molecules: The particularly light and high-energy gas is to become an important energy source and the fuel of the future. Hydrogen can be used directly as reducing agent, but also by means of combustion or by means of re-electrification in a fuel cell. Energy-intensive sectors of industry, steel production, heat generation and mobility are examples of fields of application. In particular sectors that have until now only been inadequately covered by the energy transition can in many instances be organised in a climate-friendly manner by using sustainably produced hydrogen.

According to the national hydrogen strategy, Germany aims at installing up to 10 Gigawatt of hydrogen generation capacity by 2030. However, this is only representative of a small portion of the demand: The remaining hydrogen is to be produced in regions of the earth that are rich in sun and wind and is then to be imported. These quantities considerably exceed the currently available electrolysis capacities, at a rough estimate by nearly two orders of magnitude, so that substantial progress will have to be made to create adequate additional capacities for the production of green hydrogen. This is where the flagship project H_2Giga that is funded by the Federal Ministry of Education and Research (BMBF) comes into play.

Industrialisation of water electrolysis

The flagship project H_2Giga develops technologies for series production and the upscaling of electrolysers. Roughly 120 partners from industry and science are busy researching and developing modern production technologies. The total of 27 joint research projects of H_2Giga benefit from the expertise introduced by electrolyser manufacturers, equipment manufacturers, engineering companies, precious metal manufacturers, start-ups and prestigious research institutes and universities. Each of the leading German electrolyser manufacturers, Siemens Energy, Linde ITM, MAN-ES/H-TEC, thyssenkrupp nucera and Sunfire are jointly working with their research partners at upscaling their technology.

Similar to the automotive industry it is expected that components will roll off the production line and will be assembled in an automated manner. Only this facilitates the high output required to come closer to the development goals. Besides that, production costs are lowered and sources of error eliminated. Research work concentrates on particular on the core component of the electrolyser, i.e., the stack with its electro-chemical cells where the reactions are taking place. With a "design for production" of important core components, these are optimized with regard to their suitability



Source: Siemens Energy/thyssenkrupp AG/H-TEC SYSTEM GmbH/ITM Power Linde GmbH/Sunfire GmbH for large series production. This includes characteristics such as compatibility with the robotics during assembly, the robustness of the process, the possibility for maintenance and repair work as well as the suitability for the supply chain and the future recycling. The flagship project also comprises non-technical topics, such as contributions towards the preparation of technical rules and standards, towards dealing with approval procedures and training courses.

H_2Giga is basically open for the various water electrolysis technologies, such as PEM electrolysis (proton-conducting membrane), alkaline electrolysis (AEL) or high-temperature electrolysis (HTE). The flagship project relies on diversity of use because each of these technologies is particularly well suited for certain applications. Supplementary to this, the AEM electrolysis (anion-conducting membrane) will also be enhanced and upscaled in terms of creating a next-generation technology.

More collaboration between science and industry

Apart from the industry-led projects, H_2Giga also comprises an innovation pool where overarching topics are examined in academically established joint research projects and knowledge gaps are closed. Research topics herein are for example new materials and test procedures as well as production research and digital networking including digital equipment or product twins. All of the H_2Giga projects merge on the “Technology platform electrolysis”, a network project coordinated by DECHEMA e. V. The exchange of science and industry promoted in this manner raises synergies, establishes new contacts and is to accelerate the overall technical development.

The BMBF-funded hydrogen flagship project H_2Giga makes a contribution towards the technological leadership of German companies and research facilities as far as the production of green hydrogen is concerned. Together with the flagship projects H_2Mare (offshore generation of green hydrogen) and TransHyDE (technologies for the hydrogen infrastructure), it paves the way into the hydrogen economy and thus into a reliable, resilient and climate-friendly energy system of the future.

INFOBOX

Core data of H_2Giga

Subsidy: 456 million Euro

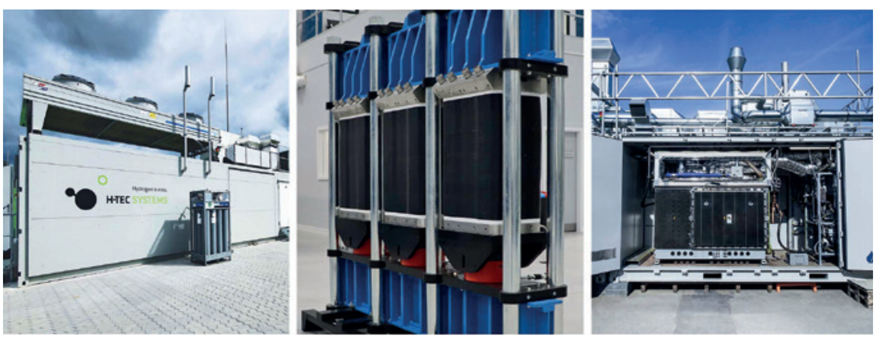
Project life span: 04.2021–03.2025

Project partners: 119 partners

The 27 joint research projects of H_2Giga are self-contained and each have their own coordinator. The overarching network project “Technology platform electrolysis” is coordinated by DECHEMA e. V.

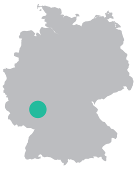
Contact:
Dr Isabel Kundler
DECHEMA e. V.
Theodor-Heuss-Allee 25
60486 Frankfurt am Main
E-mail: h2giga@dechema.de
Internet: www.wasserstoff-leitprojekte.de/leitprojekte/h2giga

Electrolysers of the manufacturers involved in H_2Giga



Since 2018, the Energy Park Mainz is in commercial operation.

Source: Stadtwerke Mainz



Energy Park Mainz:
Showcase project of the energy transition

by **Michael Theurer** (Mainzer Stadtwerke AG)

The Energy Park Mainz of the Mainzer Stadtwerke AG and Linde has already been in commercial operation since the year 2018 and has since then been producing hydrogen for a multitude of applications. The present article provides an overview of the history of its origins, explains the functional mechanisms of the system and highlights the areas of application for which the produced hydrogen is used.

Is it possible to refuel with wind? And is it possible to make heating systems or large power plants more independent from natural gas imports, thus generating power and heat in an environmentally sound manner – even if there is absolutely no wind and the sun does not shine? Linde and the Mainzer Stadtwerke AG were already convinced roughly ten years ago that this is possible. This is why by 2015 Siemens, the Linde Group, the RheinMain University of Applied Sciences and the municipal utility Mainz have jointly developed a project that was much-noticed all over Germany: Since the start of operation, the “Energy Park Mainz” produces hydrogen, amongst others by means of electricity generated in an environmentally friendly manner by neighbouring wind energy converters. The energy carrier hydrogen is easy to store and can be used as source of energy in many different ways, for example as eco-friendly automotive fuel, for the operation of gas heatings, but also for power generation in modern power stations.

Which options does the power-to-gas process offer and what are the opportunities and limits of this technologies? These Questions were impressively clarified by the research project “Energy Park Mainz”. After the successful research phase that lasted about two years and a one-year commercial test operation, the municipality utility Mainz and Linde jointly took over the system, which has been in commercial operation since 2018. Currently, the hydrogen produced in Mainz is fed into the existing natural gas grid or transported to users in industry and in the mobility sector.

All the essential modules required to store energy with hydrogen (power generation, generation from wind power, electrolysis, gas injection, hydrogen compressor, pressure accumulator, trailer filling) have been tested and explained to other users and interested parties at the Energy Park Mainz for years. That is why there is a visitor centre at the Mainz-Hechtsheim site where the mode of operation of hydrogen electrolysis and the position of storage technologies in the future energy system are illustrated. At the same time, the centre is very popular: Each year, groups of visitors from all corners of the globe obtain information about the process.

Source: Stadtwerke Mainz

At the visitor centre of the Energy Park, visitors are informed about the power-to-gas technology.

For the construction of the system it was important to find a site that was convenient for all applications. On the one hand, a direct connection to a wind farm had to be possible on the power grid-side, on the other hand, the electrical supply of the system via the grid of the general supply had to be ensured. A water connection is required to feed the electrolysis process and a sewage connection to dispose of the arising waste water. In addition, to inject the hydrogen produced into the gas grid, a site had to be found that was located in the vicinity of an existing gas infrastructure. In addition, for it to be possible to remove the hydrogen by means of a truck trailer, a corresponding road connection (and if possible a near-by highway) were a prerequisite. These conditions were perfectly met by the premises in Eindhoven-Allee 6 in Mainz-Hechtsheim.

In the opinion of the municipality utility, systems such as the Energy Park Mainz and the underlying technical concept are an important building block of the energy transition. For already today, wind power and photovoltaic systems have to be turned off at certain times due to a lack of capacities in the power grid. At the Energy Park Mainz, this "surplus" electrical energy can be stored in hydrogen and oxygen through the breakdown of water and the hydrogen produced in this eco-friendly manner can later be used in line with demand.

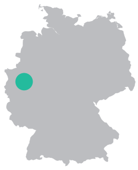
Thus, renewable energies are used in a more flexible manner and are available when they are needed. However, that requires a high dynamics of the systems, so as to be able to quickly react to the demands of the rapidly fluctuating power grid. The Energy Park with its output of up to 6 Megawatt (MW) can thus receivethe power of up to three wind turbines. To this end, three electrolysis units split water into hydrogen and oxygen. While the oxygen is released into the air, the hydrogen generated in Mainz is filled into trailers or is stored on site. The high-purity hydrogen produced in this manner is used by industrial users, for public hydrogen filling stations and by customers connected to the gas grid: Truck trailers for example bring the hydrogen amongst others to a hydrogen filling station in Wiesbaden. There, several fuel cell buses of ESWE Verkehr and a bus of the municipal utility subsidiary Mainzer Mobilität are refuelled. The climate-friendly powered vehicles are already used in regular service in Mainz and Wiesbaden.

Source: Stadtwerke Mainz

View into the electrolysis hall, where a total of three electrolysers generate hydrogen.

However, the hydrogen from Mainz is not only used on the spot for the local public transport: a natural gas line has been routed not far from the energy park and supplies the district of Mainz Ebersheim and its citizens with natural gas for heating and cooking. Meanwhile, a portion of the natural gas is replaced by hydrogen from the Energy Park. While in the beginning, only one to two percent of hydrogen were added to the natural gas, it was possible to gradually increase the H_2 content to ten percent. For the citizens of Ebersheim nothing changed: they do not notice the admixture of hydrogen and even the prices remain constant.

Contact:
Michael Theurer
Mainzer Stadtwerke AG
Rheinallee 41
55118 Mainz
E-mail: michael.theurer@mainzer-stadtwerke.de
Internet: www.mainzer-stadtwerke.de



GET H2 Nukleus: Core of the hydrogen infrastructure

by **Kai Tenzer** (Cyrano Kommunikation GmbH)

Combining the generation, transport and efficient use of green hydrogen is prerequisite for developing a functioning hydrogen industry in Germany. From the beginning, the systemic approach was the focal point of the project GET H2 Nukleus. Within the scope of this project, the companies bp, Evonik, Nowega, OGE and RWE jointly intend to develop one of the first publicly accessible hydrogen infrastructures by the year 2024.

At its core, GET H2 Nukleus links the generation of green hydrogen at Lingen in Lower Saxony with industrial consumers in the Northern Ruhr area via a pure hydrogen grid with a length of 130 km. In reality, the project is much more than that: As one of the first H_2 grids in the regulated sector with non-discriminatory access it creates the basis for linking large-scale industrial and local projects and for providing a growing number of private and municipal stakeholders with access to the emerging hydrogen market.

The elements of the GET H2 Nukleus

The following elements form an integral part of the nucleus:

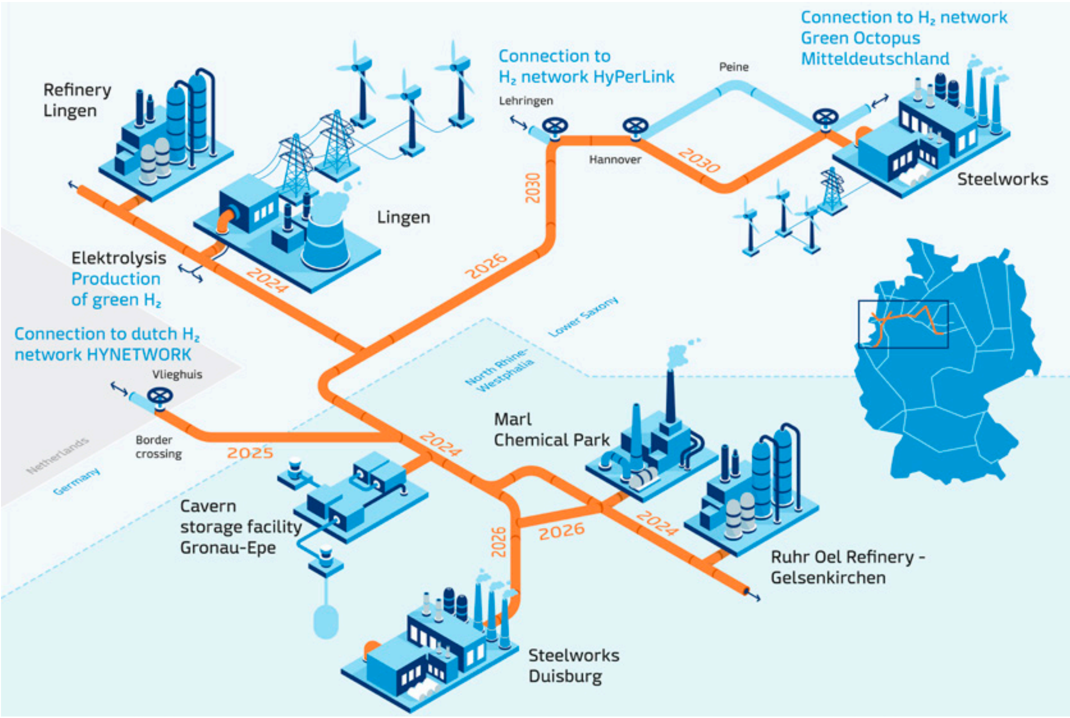
- In Lingen, RWE constructs an electrolysis system with an output of 100 Megawatt (MW) on the premises of the gas power station Emsland in the south of the city. Green hydrogen is to be generated from renewable power, which arrives in the immediate vicinity in Lingen-Hanekenfähr via the new high-voltage power line that is currently under construction. It is planned to extend the electrolysis to 200 MW by 2025, and even to 300 MW by 2026.
- The two operators of the long-distance pipeline grid, Nowega and OGE, are converting existing lines of the gas grid from Lingen to Marl (North-Rhine Westphalia) to the transport of 100 percent hydrogen. Through a market space conversion from L-gas to H-gas, the lines became free for an alternative use and have already been approved for the conversion by the Federal Network Agency. RWE injects the hydrogen into the line via a new link to the gas power station that is still to be constructed.
- The line ties up to the Marl Chemistry Park of Evonik, where green hydrogen as process gas in the chemical industry can replace the grey hydrogen generated from natural gas, which has been in use up to now. Using a line that was newly constructed by Evonik, which can be used for the transport of hydrogen, a connection to Gelsenkirchen-Scholven is established at the same time.
- In Gelsenkirchen in turn, the green hydrogen is used in the Ruhr Oel refinery. Here it also replaces the grey hydrogen that is used in the production processes and can be used as raw material for climate-friendly synthetic fuels.

The demand for green hydrogen and thus the potential for reducing CO_2 emissions is huge: The Ruhr Oel refinery in Gelsenkirchen has a hydrogen demand of up to 80,000 m³/h, the Chemistry Park in Marl of up to 50,000 m³/h. At an output of 100 MW, the electrolysis in Lingen covers approx. 22,000 m³/h of this demand – depending on the availability of renewable power suitable for the generation of green hydrogen and the runtime. The integration of further producers of green hydrogen or linking up of additional projects is therefore important to exhaust the potentials in their entirety.

Interconnections and extensions

All companies involved are partners of the hydrogen initiative GET H2. In the meantime, the network that was founded in 2019 comprises roughly 50 partners and strives to link up individual H_2-projects and to bring together a wide variety of stakeholders. With this in mind, the project GET H2 Nukleus – as already implied by its name – represents only the core. The extension by further elements and the linkage with other project is already envisaged and is partly already in the preparatory stage. Projects that tie in with the GET H2 Nukleus include:

- Storage caverns: By 2026, RWE Gas Storage West intends to construct an additional storage cavern for hydrogen at its site in Gronau-Epe. A regional planning procedure for the construction of the new pipeline link to the GET H2 Nukleus pipeline is already under way.



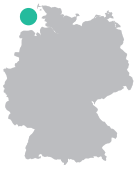
Source: GET H2

Overview of the components of the project GET H2 Nukleus in Germany and the envisaged extensions

- Hydrogen distribution grid: From 2024, a distribution grid for hydrogen that links up to the GET H2 Nukleus pipeline is to be developed in Westmünsterland. Industrial enterprises and filling stations are to be continuously supplied with hydrogen and local producers can inject into the grid. The development of the distribution grid is coordinated by the Wasserstoffentwicklungs GmbH & Co. KG, which has been founded by the Energiegenossenschaft AHLeG and further partners.
- Areal distribution: The H2 Green Power & Logistics GmbH intends to erect an H_2 filling station adjoining the Marl Chemistry Park. Furthermore, the green hydrogen is to be relayed to further areas and thus distributed to additional hydrogen filling stations and enterprises, which are busy establishing fleets of fuel cell trucks.
- Connection to the Netherlands: By 2025, the long-distance pipeline operator and GET H2 partner Thyssengas intends to implement a connection to the point of import Vlieghuis. This step creates the connection to the so-called Green Octopus – a European project initiative, which connects Germany, the Netherlands, Belgium and France through a hydrogen grid.
- Continuation Duisburg: By 2026, Thyssengas and OGE intend to construct a new hydrogen pipeline from Dorsten to Duisburg-Hamborn; for this project too, the regional planning procedure is already under way. This creates the precondition for connecting a Thyssenkrupp steel mill to the GET H2 Nukleus. At the steel mill, the green hydrogen is to replace the bituminous coal that is currently used in steel production.
- Continuation Salzgitter: By 2030, the GET H2 Nukleus is to be continued up to the steel mill of the Salzgitter AG via further natural gas pipelines to be repurposed by Nowega.

Another important connection is entertained with the research and demonstration project GET H2 TransHyDE, one of the hydrogen flagship projects of the Federal Ministry of Education and Research. Within the scope of GET H2 TransHyDE, which is also located on the premises of the Emsland gas power station, a test pipeline will be constructed. With this test pipeline, the project partners simulate the injection and transport of hydrogen and at the same time provide answers to open technicalities with regard to materials and measurements. They also perform safety and monitoring tests.

Contact:
Denise Hoeveler
Coordination initiative GET H2
c/o Nowega GmbH
Anton-Bruchausen-Str. 4
48147 Münster
E-mail: info@get-h2.de
Internet: www.get-h2.de



Hydrogen flagship project H_2Mare: Self-contained offshore generation of green hydrogen and synthesis products

by **Matthias Müller**, **Andreas Tutschke** (both: Siemens Energy), **Thomas Schwabe** (Siemens Gamesa), **Prof. Roland Dittmeyer** (Karlsruhe Institute of Technology) & **Dr Jens Artz** (DECHEMA e. V.)

At sea, excellent conditions prevail for the generation of renewable power. The direct production of green hydrogen from wind energy in offshore systems without grid connection can considerably lower the costs compared to land-based generation. Against this background, the flagship project H_2Mare will research the offshore generation of green hydrogen and other power-to-X products.

The development of a novel wind energy plant is the focal point of the hydrogen flagship project H_2Mare funded by the Federal Ministry of Education and Research: For the first time it is to be possible to directly generate hydrogen with an offshore system – owing to an integrated platform concept. The system does without a connection to the power grid, as it directly converts wind energy into hydrogen by means of electrolysis. This means that even areas that are located far offshore can be used for hydrogen production, with the added benefit that the application and construction process for grid connection is dispensed with and the transmission grid is relieved. The project is also used for the offshore production of secondary hydrogen products. To this end, a swimming PtX platform will be developed, amongst other things. Within a period of four years, H_2Mare will lay the foundation for the future hydrogen location Germany and support the achievement of climate goals with an accelerated greenhouse gas reduction. The flagship project H_2Mare is subdivided into the following four projects:

The H_2Mare project OffgridWind deals with the implementation of a system concept that realises electrolysis directly at the offshore energy plant,while at the same time aiming at a high degree of efficiency without connection to the power grid. For this, the entire wind energy system is designed and optimised accordingly.

The H_2Mare project H_2Wind aims at the development of a PEM electrolysis with an output of 5 Megawatt (MW), which is electrically directly coupled to an offshore wind energy plant. The solution requires a long-lasting system design that is optimally adapted to the offshore environment, the sea water treatment system for the provision of process water and a maximum conversion of the volatile wind conditions.

Supplementary to the pure offshore hydrogen production, the conversion into easier to transport synthetic energy carriers and fuels such as liquid methane, methanol and ammonia and Fischer-Tropsch products is investigated within the scope of the H_2Mare project PTx Wind. The synthetic gas required for this is generated from carbon dioxide and nitrogen from the air or from the sea as well as from the hydrogen arising during electrolysis. At the same time, innovative approaches such as high-temperature electrolysis to generate synthetic gas from water and carbon dioxide and direct salt water electrolysis are put to the test. The delivery of reactants by ship is also examined.

The H_2Mare project TransferWind is engaged in the knowledge transfer within the flagship project and with neighbouring projects, but also to the public. In addition, the focus in on the cross-project professional exchange.

This includes amongst others also design aspects of infrastructures, basic parameters for a safe operation in the offshore area, possible uses and potentials of the products generated offshore as well as aspects of environmental protection.

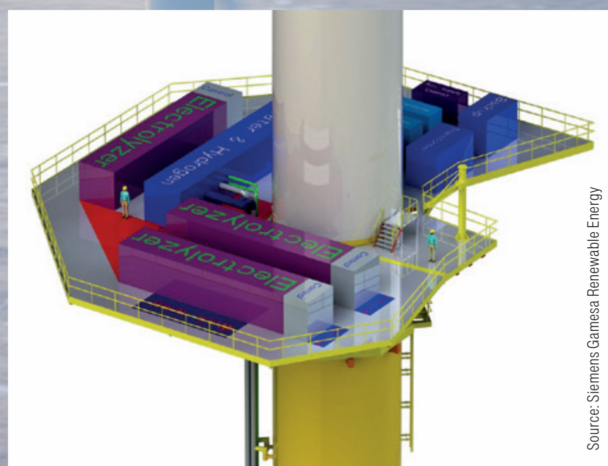
The innovative wind energy electrolysis system requires a compact construction and a platform at a safe height to be able to place the containers with the required technology components. In view of the harsh operating conditions, an enclosure with lasting resistance against splash water and saline air that protects the system components is an indispensable prerequisite. But how should the individual components be arranged in the container? How can offshore service and maintenance be ensured? And how is it guaranteed that the dynamic excitation of the platform by the movement of the waves and the rotation of the rotor blades of the wind energy system does not impair subsystem functionality? Researchers at the H_2Mare project H_2Wind dedicate themselves to these and other questions.

Making use of digital twins, the system and the interaction of offshore wind energy plant and electrolysis are further optimised; at the same time, operation management is looked at and statements with regard to the economic feasibility are made. At simulation level, a complete system model of a wind energy plant is for the first time assembled from submodels. It maps the production chain from wind via power to hydrogen. On this basis, various operating scenarios with regard to the service life of the wind energy electrolyser system are considered.

The enhancement of electrolysis for offshore operation comprises the material and design of the bipolar collector plates as well as new test and validation procedures for diagnosis and prognosis of degradation mechanisms. For a systematic investigation of these mechanisms, a test infrastructure is set up and used at the Fraunhofer hydrogen laboratory Leuna. At cell level, the project partners investigate how a very compact mechanical construction could best be achieved. For the electrolysis itself, PEM electrolysers with a maximum

Wind energy plant with electrolysis platform put in place

Source: Siemens Gamesa Renewable Energy



Source: Siemens Gamesa Renewable Energy

Design of the platform for placement of the required containers (violet: electrolysis container) output of 5 Megawatt (MW) capacity that are encased in the container are developed under the leadership of Siemens Energy. Commensurate with the performance category of the wind energy plant, three of them are to be combined on the associated platform to make up an overall output of 15 MW. Due to the difficult accessibility offshore it is specified that intervals for regular inspections should not be shorter than one year. The system thus has to be functional as self-contained island solution and the individual components must be of very sturdy design.

Within the scope of H_2Mare, a power-to-X conversion is to be additionally carried out offshore. The changing wind speeds on a self-contained production platform lead to fluctuations in the power supply, which is why the chemical conversion processes have to be laid out dynamically. Beyond the production of hydrogen, the process routes methanation to generate liquid natural gas, methanol synthesis, ammonia synthesis and Fischer-Tropsch synthesis are examined, which are to replace products from fossil base materials. Three different development stages are distinguished within the project:

- Swimming test platform (TP): autonomously operated, to analyse the effects of weather and corrosion conditions. The systems are initially tested onshore at the Energy Lab 2.0 in Karlsruhe, before they are operated offshore on the platform as composite system at the end of the project.
- Research platform (RP): A detailed concept for the RP is one of the main objectives of the project. The purpose of the RP is the clarification of the last open questions with regard to the offshore application of PtX processes.
- Production platform (PP): Conceptual work within the project. This work serves as template for the future implementation of a platform for the offshore generation of PtX products.

Another important aspect is the water supply for the electrolysis process, for which two innovative options are tested: Desalination by means of the waste heat generated by the electrolysis process is simulated at the hydrogen laboratory Bremerhaven by means of a test infrastructure. At this laboratory, the modular and scalable water treatment is examined and optimum process integration options are determined. In addition, process technology for direct seawater treatment, which meets the high demands on water quality, serviceability, long service life and the fluctuating system operation is developed.

Apart from the technical aspects of the various value-added chains, the focus at H_2Mare is also on superordinate questions with regard to certification, safety and environmental aspects. These aspects are systematically recorded across the entire project life span and compliant approaches for a safe and emission-free operation are developed. Specialists and the interested public are included in the development process from an early stage by means of stakeholder dialogues, public forums, exhibitions and novel education and advanced training concepts, thus ensuring the topic of acceptance is centrally anchored in the flagship project. The H_2Mare project TransferWind is dedicated to these questions and ensures that insights gained from the stakeholder dialogue and ecological questions flow back so that processes can be designed in a manner that takes account of all concerns in the best possible manner.

To achieve a maximum contribution for the energy transition and the development of a succeeding hydrogen economy, a total of three flagship projects funded by the BMBF cover the most important focal points: H_2Giga zooms in on the series production of large-scale electrolysers, TransHyDE develops solutions for a transport and storage infrastructure for green hydrogen and H_2Mare focuses on the offshore generation of hydrogen and PtX products.

INFOBOX

Core data H_2Mare

Subsidy:	approx. 114 million Euro
Project life span:	04.2021–03.2025
Project partners:	32 + 2 associated partners

Contact:
Matthias Müller
Siemens Energy Global GmbH & Co. KG
Otto-Hahn-Ring 6
81739 München
E-mail: h2mare@iwes.fraunhofer.de
Internet: www.wasserstoff-leitprojekte.de/leitprojekte/h2mare

Hydrogen flagship project TransHyDE: Storage and transport solutions for green hydrogen

by the **office of the hydrogen flagship project TransHyDE**

Without a suitable storage and transport infrastructure, the hydrogen economy cannot operate successfully. In particular the import of the energy carrier requires other solutions than gas pipelines. There are many ideas on this topic – however, it is not clear which solution is suitable for which application and how these can best be combined. This is why the flagship project TransHyDE develops, evaluates and demonstrates several technologies for hydrogen storage and hydrogen transport.

The demand of the National Hydrogen Strategy (NHS) that it be possible to use green hydrogen in a versatile manner countrywide and throughout the year in Germany inevitably gives rise to the need for a national transport and storage infrastructure for this source of energy. At this point, TransHyDE, one of the three hydrogen flagship projects funded by the Federal Ministry of Education and Research (BMBF) makes a pivotal contribution towards the implementation of the NHS. A total of 103 partners and associated partners in nine projects work on dispelling technological and economical obstructions, which currently impede the efficient transport and storage of green hydrogen. The technical focus of the TransHyDE platform is on four different transport options: gaseous hydrogen (gH_2), liquid hydrogen (LH_2), ammonia (NH_3) as well as liquid organic carriers (liquid organic hydrogen carriers, in short: LOHC).

The TransHyDE project System Analysis considers the various transport solutions with regard to their efficiencies, feasibility, the required demands and the economic viability. The objective of the TransHyDE project is essentially the compilation of a roadmap depicting a clustered overview of the production potentials and demands and sets forth possible development scenarios of a hydrogen infrastructure for the period up to 2045. By collaborating with the other TransHyDE projects, advantages and unique features of the hydrogen transport options in the overall system are carved out and recommended actions are derived.


Visualisation of potential LOHC handling at the Helgoland pier with a tanker.

Source: Jakob Martens

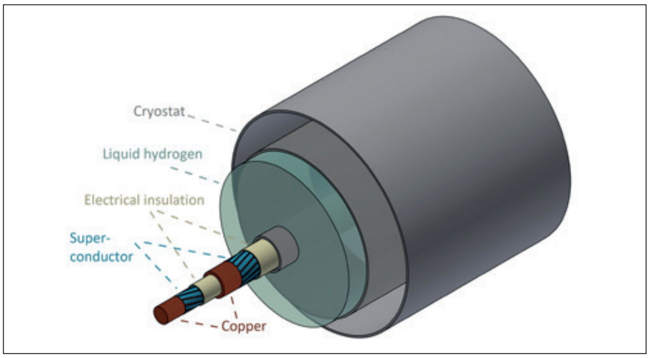
Another interdisciplinary project is the TransHyDE project Standard. Core aspect of this project is the compilation of a project-specific roadmap expounding the standardisation and certification gaps in existing sets of rules with regard to the various hydrogen transport options available. Apart from a comprehensive inventory-taking and subsequent requirements analysis, the exchange of information and the close cooperation with the TransHyDE research and implementation projects is of fundamental importance for this.

One option to transport and store green hydrogen is in gaseous, molecular form. However, because of the volatility and diffusivity of the gas, but in particular its embrittling effect, special demands are made on the materials used in components. Besides, the TransHyDE projects Safe Infrastructure, GET H_2 TransHyDe and Mukran research and test various possibilities for the accident-proof transport and efficient storage of the gaseous hydrogen. In this connection, the TransHyDE project Safe Infrastructure engages both in material testing of materials under the influence of hydrogen and in the effective detection of leakages, including the quantification of concentrations. Beyond that, the project analyses possibilities for the sensory determination of hydrogen qualities and is dedicated to the construction of a high-pressure test stand for the calibration of hydrogen flow meters and other components. Finally, by means of a roadmap that was worked out, the TransHyDE project demonstrates possibilities of converting natural gas distribution grid pipelines into hydrogen pipelines.

The focus of the GET H_2 TransHyDE project is initially on the development and ultimately on the operation of a test pipeline with a total length of 130 km for gaseous hydrogen as transport vector. The technologies required for this – from measuring flow rate and gas quality to remote gas detection of leakages – are applied in the project as well as the implementation of intelligent pigging concepts. Apart from this, material issues are evaluated in a practical context and compressor concepts are optimised to the utilisation of gaseous hydrogen.

To be able to supply future hydrogen consumers without own access to the hydrogen pipeline grid, the TransHyDE project Mukran focuses on the trimodal transport (ship, train and truck) of gaseous hydrogen in high-pressure spherical vessels. The successful operation is demonstrated by means of a hydrogen value-added chain in the harbour of Mukran on the island of Rügen in the Baltic Sea.

In scenarios where, in contrast to the gaseous hydrogen, higher volumetric energy densities are to be transported or

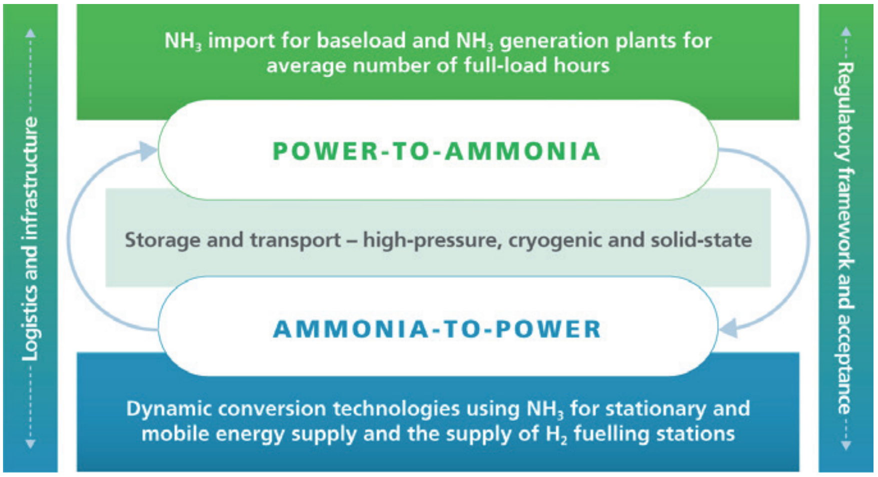


Source: AppLHy!/Michael Wolf/KIT

Schematic diagram of a hybrid pipeline through which liquid hydrogen and electric power are transported simultaneously.

stored, the use of liquid hydrogen lends itself amongst others to these tasks. In this context, the TransHyDE project AppLHy! develops technologies for the efficient liquefaction, storage and transport of liquid hydrogen. The emphasis here is as much on material and safety issues as it is on the demonstration of synergy effects through the use of the recoverable process cold generated during regasification for stationary and mobile applications.

Apart from liquid hydrogen, ammonia offers another possibility to store and transport larger amounts of energy in a volume-effective manner. The TransHyDE project CAMPFIRE, based on the BMBF-funded "WE!-Change through innovation in the region" CAMPFIRE alliance, develops within the TransHyDE technology platform research and development interfaces for the implementation of an ammonia-based transport solution for hydrogen along the entire value-added chain. This comprises the generation of ammonia with load flexibility, the development of infrastructure and logistics concepts as well as refuelling systems and the use in mobile and stationary energy conversion systems. The focus of CAMPFIRE is on the development and



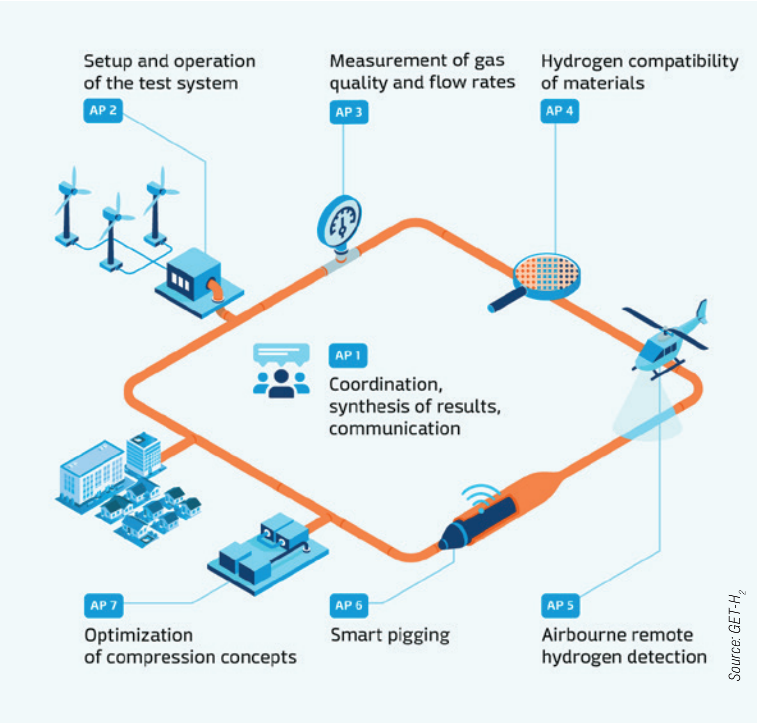
Source: CAMPFIRE Open Innovation Lab

CAMPFIRE technology development for the future global green ammonia ecosystem.

implementation of dynamic ammonia reformers in hybrid operation with gas motors on the MW scale.

In close cooperation, the partners of the Trans-HyDE project AmmoRef develop novel and cost-optimised precious-metal free catalytic converters for the reformation of ammonia to hydrogen. In association with an intelligent process control in the reformer through the control of temperature, pressure and flow rate, the catalytic converters facilitate a high degree of conversion and guarantee the hydrogen purity that is required for various applications. As further option for the transport and storage of hydrogen, an overall value added chain on the basis of LOHC is pointed out between Helgoland and the German mainland. In this connection, the TransHyDE project Helgoland tests the economic feasibility of the transport vector by means of a hydrogenation plant with attached waste heat utilisation on Helgoland, by means of tanker transport to the mainland and by means of the dehydrogenation of LOHC on the mainland.

Together with the work in the two other hydrogen flagship projects H_2Giga (series production of large-scale electrolysers) and H_2Mare (offshore generation of green hydrogen), the closely interwoven work of the partners of the TransHyDE technology platform, in intensive collaboration between industry and science, supplies solutions for the German hydrogen economy, thus making an important contribution towards the energy transition.



The project GET-H2 TransHyDE creates the practice-relevant foundations for the safe and efficient operation of hydrogen transport grids.

INFOBOX

Core data TransHyDE

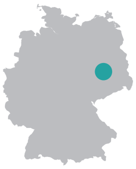
Project volume: approx. 181 million Euro

Subsidy: approx. 135 million Euro

Project life span: 04.2021–03.2025

Project partners: 83 + 20 associated partners

Contact:
Office of the hydrogen flagship project TransHyDE
E-mail: koordination@transhyde.de
Internet: www.wasserstoff-leitprojekte.de/leitprojekte/transhyde



900 km hydrogen starter grid for East Germany by 2030: Basis for developing a functioning hydrogen economy

by **Dr Ralf Borschinsky** (ONTRAS Gastransport GmbH)

The central German chemical triangle around the cities of Halle (Saale), Merseburg and Bitterfeld needs green hydrogen, as do the industries in Sachsen-Anhalt and the steel region in the Lower Saxony city of Salzgitter. The project Green Octopus Central Germany represents the future transport route and storage possibility for this hydrogen, connects the regions and in addition integrates the future hydrogen storage in Bad Lauchstädt.

Many regard green hydrogen as an essential pillar for our future energy supply: It is climate-neutral, promises independence from Russia, accelerates the energy transition and offers a solution for the long-term electricity storage problem. In addition, the energy source can be used, stored and transported like natural gas and wide portions of the existing natural gas grid are suitable for its transport. With hydrogen strategies, subsidy programs and living laboratories, politics has created promising starting conditions for the development of a hydrogen economy in Europe. The industry in turn developed numerous projects, regions competed for hydrogen centre locations and first pilot projects were launched. However, the initial momentum threatens to peter out in the morass of European bureaucracy and political ideology. Many hydrogen projects hover at the threshold to an investment decision because a reliable general framework is lacking in the long term. With the postulate "Hydrogen, the champagne of the energy transition", the eco-friendly energy carrier is argued out of the traffic and heat sector while infrastructure projects within the scope of the European hydrogen backbone threaten to shipwreck on the regulatory specifications from Brussels. Some politicians even publicly demand to start dismantling gas grids as these would soon no longer be required. However, the most cost- and time-efficient solution – as the result of numerous studies demonstrates – would be to jointly develop the power and gas grids in future, thus using the existing natural gas grid as basis for hydrogen grids. What this could look like is demonstrated by the project of a starter grid for East Germany that comprises almost 900 km of pipelines.

The energy transition requires hydrogen in all sectors

Considering the facts and the current development it becomes clear: As early as 2030 we will require large amounts of hydrogen to achieve the climate targets. The steel and chemical industry in Germany alone foresees a demand of approx. 57 terawatt hours (TWh) of hydrogen by 2030. The first electrolysers in the range up to 100 megawatt are planned (amongst others in Cologne, Lingen and Hamburg) and with the European Hydrogen Backbone, the European long-distance pipeline operators are developing a hydrogen grid that will continue to expand along with market developments. In its current version it will comprise 53,000 km of pipelines by the year 2040, backed with capacities and oriented on real needs. To reach approx. half of the target of 10 million tons or 330 TWh of hydrogen specified by the REPowerEU package, five large-dimensioned pipeline corridors for Europe would hence be required to feed this hydrogen system.

East German mammoth project

Individual grid operators such as ONTRAS are already working towards the implementation of parts of this European mammoth project: By 2030, an H_2 starter grid for East Germany comprising almost 900 km of pipelines is to come into being, of which almost three quarters will have been developed from the existing natural gas grid. Since September 2021, the project partners have been repurposing the first almost 25 km long natural gas pipeline for the use with hydrogen within the framework of the Energy Park Bad Lauchstädt (funded by the

Source: ONTRAS Gastransport GmbH

During the status analysis of existing pipelines within the scope of the project, a special measuring probe to determine crack-like defects was tested for the first time.

Federal Ministry of Economic Affairs and Climate Action as living laboratory of the energy transition).

Currently, the technical status analysis required for this purpose is performed, and for the first time a special pigging method to test for possible cracks was applied. The results will permit conclusions as to the hydrogen-suitability of the former natural gas pipeline.

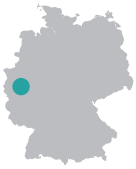
The two infrastructure projects doing hydrogen and Green Octopus Central Germany (GO!) link up to this. With doing hydrogen, the project partners initiate a platform for the hydrogen economy in East Germany and link projects of innovative producers, gas grid operators and large consumers. To this end, a total of 620 km of hydrogen pipelines create comprehensive links between the economic regions Central Germany and the Rostock region as well as the greater area of Berlin and Eisenhüttenstadt, in parts jointly with other grid operators. Furthermore, hydrogen projects in Mecklenburg-West Pomerania, Brandenburg, Berlin, Saxony and Saxony-Anhalt are to be linked to make up a powerful hub.

Green Octopus Central Germany connects the hydrogen economy between the Central German chemical triangle, the metropolitan region of Halle-Leipzig, Magdeburg and the steel region of Salzgitter and integrates the future hydrogen storage in Bad Lauchstädt. With its roughly 305 km of pipelines, the project will thus provide for the safe hydrogen transport along the entire value-added chain from 2027 onwards. Connected to other hydrogen pipelines, Green Octopus will integrate these regions into the European hydrogen backbone. A connected storage cavern with a working gas volume of 50 million cubic meters stabilises the hydrogen infrastructure and provides for a balance between supply and demand. For both projects, the project partners have applied for funding within the scope of Important Projects of Common European Interest (IPCEI). Preparatory work is to commence before the end of 2022.

The prerequisites for a start before the end of 2022 are good: The majority of the steel pipelines concerned are H_2-ready and can after thorough examination be converted to be operated with green hydrogen. Besides, new or reconditioned pipeline sections and fittings have been constructed in a hydrogen-compliant manner and the projects are waiting in the wings. However, there is a lack of a long-term acceptable general framework that would enable investors to work out a feasible business model and permit the grid operator to still own and operate the H_2 infrastructure it has created beyond the year 2030.

Nevertheless, the parties involved in the project are confident that such a general framework will still be created and that an organically growing transport system for producers and consumers of green hydrogen will then be established with the hydrogen starter grid that is due to go online between 2025 and 2030. Through the integration into the European hydrogen backbone with access to reservoirs and import points, it will map the entire value-added chain, offer security of supply and permit a fast market launch of hydrogen. This infrastructure the partners involved will develop swiftly and in a cost-efficient manner, with almost three quarters even arising from the already existing pipeline grid. In close collaboration with customers, market partners and interested parties along the entire value-added chain, the project will thus ensure that the hydrogen launch will turn into a success story.

Contact:
Dr Ralf Borschinsky
ONTRAS Gastransport GmbH
Maximilianallee 4
04129 Leipzig
E-mail: ralf.borschinsky@ontras.com
Internet: www.ontras.com



It´s the de-blending that matters

by **Dr Moritz Mickler** (Linde GmbH)

With its system, Linde GmbH demonstrates how hydrogen can be separated from blends with natural gas in a cost-efficient manner and in the required quantities. This makes the use of the existing natural gas grids for hydrogen transport economically rewarding. In other respects too, the company is intensively working on the development of the fast growing hydrogen economy.

How can the hydrogen (H_2) be transported from producer to consumer in a cost-efficient manner? Linde has decades of experience in producing a wide range of industrial gases and in customer supply. Transport in bottles, by means of road haulage, in tanks, by on-site production or via specific pipelines features most prominently in this regard. For the nationwide use of hydrogen, making use of the already existing natural gas infrastructure would be the most obvious thing to do, especially during the initial stages of the still emerging application of H_2 as energy carrier. To achieve the aspired climate targets, decarbonisation of the existing utilisation chains should start as soon as possible.

Pure H_2 grid is goal, not reality

In Europe, eleven transmission grid operators are already working on the development of the European hydrogen backbone. They are aiming at the development and extension of a dedicated hydrogen grid that is largely based on a revision of the existing natural gas infrastructure. "A specific hydrogen grid is surely envisaged and the most competitive solution," says Tobias Keller, manager of the Division Adsorption and Membrane Systems at Linde Engineering. "Such a grid could be fully functional between 2050 and 2070. But what happens until then? What is the transformation strategy?"

Using the existing gas infrastructure is of crucial importance in this regard: A good portion of investments that are due already rests in the ground and is immediately available. Consumers are already connected and can – depending on admixture ratio and purity requirements – use the blend immediately, thus instantaneously benefitting from the added hydrogen.

Blending and separating as workaround scenario

For large consumers of hydrogen, such as refineries or manufacturers of ammonia and methanol and for hydrogen filling stations, the scenario is somewhat more complex. Customers with specific hydrogen applications first have to separate the added hydrogen from the natural gas flow before they feed it into their processes. To illustrate how effectively this can be done with the technology available today, Linde has implemented the first demonstration system of the world for the recovery of hydrogen from natural gas flows at an industrial scale in Dormagen.

Technology for all degrees of purity

The system in Dormagen uses the HISELECT powered by Evonik membrane technology. The processed gas blend contains between 5 and 60 percent of hydrogen. The hydrogen that is separated by means of membrane has a concentration of up to 90 percent. If a customer requires a higher concentration for its application, a pressure swing adsorption unit (PSA) is used in addition. With this unit, a degree of purity of up to 99.9999 percent can be achieved.

Basically, other technologies could also be used for hydrogen extraction, amongst others the cryogenic method. As a supplier of all the important gas separation technologies, Linde has carried out an evaluation and has entered the market with the most efficient solution, the membrane/PSA combination.

Well-proven and cost-efficient

The hollow fibre membranes by Evonik used in Dormagen are highly selective and sturdy. They resist extreme pressures and temperatures. They are even better able to cope with the

Source: Linde GmbH

View of the demonstration system in Dormagen in North Rhine Westphalia.

Source: Linde GmbH

In Leuna (Saxony Anhalt), the world's largest hydrogen electrolysis system on PEM basis is to be built.

reversal of the membrane pressure than conventional flat sheet modules. "As a matter of principle we are using well-proven technology in our system. This combined with the highly selective membranes and our high-performance PSA technology turns extraction into an economically rewarding affair," says Keller.

Solving the chicken-and-egg-dilemma

According to Keller, a chicken-and-egg problem nonetheless exists at present: The extraction solution is only required if hydrogen is blended into the natural gas flow. However, today this happens at best in small grid sections for test purposes. And the admixture of hydrogen is only possible if the corresponding extraction technology is also at hand. Consumers along the pipeline who are not able to handle the added hydrogen need to be protected.

"To allow for the transformation and thus the gradual decarbonisation of the gas supply, a joint effort is required," says Keller. This joint effort would need to involve the hydrogen-producing industry in equal measure as the natural gas companies, the pipeline grid operators and the customers, who are interested in purchasing hydrogen in the regions. "The technology is available. We need an initiating spark to get started. The demonstration system in Dormagen is one of our contributions to accelerate the development towards a hydrogen-operated economy."

Providing many additional impulses

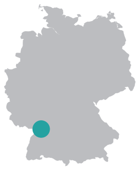
Linde Engineering is working at many key points of the hydrogen value added chain and introduces corresponding solutions to the field. Through the joint venture with ITM Power and ITM Linde Electrolysis, the company is for example representative of the latest electrolysis technology. 80 hydrogen electrolysis systems are already in production mode.

As are more than 200 hydrogen filling stations. In the U.S.A., Linde is operating the world's first storage cavern for high-purity hydrogen. In conjunction with the unique H_2 pipeline grid, which comprises roughly 1,000 kilometres, this creates the opportunity to reliably provide customers with green hydrogen even though the supply with sustainably generated power is naturally fluctuating.

BACKGROUND

For the extraction of hydrogen from the gas blend, the demonstration system in Dormagen relies on gas separation membranes. These membranes work according to the principle of selective passage through the membrane wall. Highly soluble gases with small molecules pass the membrane very quickly. Less soluble gases with larger molecules require more time. Hydrogen is a very small molecule, which penetrates the membrane to the non-pressurised side very quickly. The inherent pressure of the natural gas blend is sufficient to separate the hydrogen from the natural gas. Neither power nor additional resources such as chemicals or water are required for this.

Contact:
Dr Moritz Mickler
Linde GmbH
Dr.-Carl-von-Linde-Str. 6–14
82049 Pullach
E-mail: moritz.mickler@linde.com
Internet: www.linde.com



Transformation process for the integration of hydrogen at distribution grid level (TrafoHyVe)

by **Andreas Imiolek** (Stadtwerke Karlsruhe GmbH)

The market launch of hydrogen requires a suitable transport and distribution infrastructure. Although Germany with its well-developed gas grid has good starting conditions, municipal utilities and distribution grid operators often have unresolved questions around the conversion. In this context, the project TrafoHyVE develops an innovative planning methodology to efficiently shape the transformation process at distribution grid level.

Hydrogen is a flexible energy carrier that offers the opportunity of providing consumers and applications across all sectors with renewable energy. The use of hydrogen thus holds great potential for the decarbonisation of industrial processes and can amongst others contribute towards the climate-neutrality of the local heat market and the mobility sector. Hydrogen therefore plays an important role in the current energy and climate policy debate. With the adoption of the European and national hydrogen strategy and the political guidance due to the current geopolitical situation, the course was and will continue to be set towards the development of a comprehensive and sustainable hydrogen economy.

Project goals

However, an important requirement for the market launch of hydrogen or hydrogen applications is the availability of a corresponding transport and distribution infrastructure. With its widely branched gas grid, Germany already possesses a well-developed infrastructure for natural gas, after all, roughly 50 percent of households in Germany are directly connected to the gas grid. Also connected to the distribution grid are 1.6 million industrial and commercial ultimate consumers with an overall consumption of 750 terawatt hours (TWh).

Due to the high number of consumers and the required gas volumes, the adaptation of the distribution grid represents a huge challenge. To ensure an effective use of hydrogen in the future, the hydrogen compatibility of existing gas infrastructure and customer systems has to be ensured.

In particular in view of the practical implementation of the conversion of existing infrastructure for the hydrogen launch, municipal utilities and distribution grid operators still hold numerous open questions. Against this background, an innovative planning methodology is to be developed within the scope of the joint project to ensure the efficient configuration of the transformation process at distribution grid level.

To this end, technological, infrastructural and economic aspects will be assessed and evaluated, based on the actual state and real data of the urban and rural grids of the municipal utilities and grid operators involved, with the intention to derive strategies for the implementation of the energy transition from this and to apply these strategies in advanced projects. In this connection, the limits of the existing infrastructure with regard to hydrogen compatibility and the need for adaptation, broken down chronologically and demonstrated in the form of “transition schedules”, which permit a cost-efficient and technically reliable conversion of the existing distribution grid and the connected customer facilities to hydrogen concentrations of 20 percent by volume (% v/v) or 100 % (v/v) (H_2-ready) are to be demonstrated. An important aspect of this will be the development of proposals for the testing of existing components to guarantee the safe continued operation of the existing gas infrastructure.

Work schedule

The research project examines the conversion of existing gas distribution grids and the connected gas users to hydrogen and develops a transformation strategy. As a first step, framework data, representative gas distribution grids and a scenario-based development of gas demands are stipulated to ensure data can be compared and appraised. Based on this, the gas distribution grids are analysed for their hydrogen compatibility. On this occasion, in addition to considering the hydraulic capacity of the gas distribution grids, materials and components are examined for their hydrogen compatibility. Any gaps identified by practical tests in the laboratory are closed with the objective to hand over an as comprehensive recommendation as possible to the gas grid operators and the responsible testing and certification authorities.

In a further step, test specifications are developed within the context of the DVGW set of rules, in which, among other things, safety concepts, requirements as well as material suitabilities are considered and anchored. In a last step within the scope of defining hydrogen compatibility, the results obtained up to that point are used to derive recommendations as to which adjustments must or can be made to existing stock. In addition, recommendations for follow-up work are enclosed for the technical expert. For the subsequent development of a transformation strategy, the scenarios, existing rules and regulations and the analysis performed of the relevant infrastructure components and parts are consolidated. From this, a general planning methodology for boosting the efficiency of existing natural gas networks, measuring devices and customer systems is developed, which is then transformed into a universally valid and transferable checklist/ toolbox for the purposeful and temporally and economically optimised transformation of the gas distribution grids in Germany.

Contact:
Andreas Imiolek
Stadtwerke Karlsruhe GmbH
Daxlander Str. 72
76185 Karlsruhe
E-mail: andreas.imiolek@stadtwerke-karlsruhe.de
Internet: www.stadtwerke-karlsruhe

Wind energy converters in the Thuringian basin

Source: BOREAS Energie/Jan Oelker

Thuringian KlimaZukunft: TH_2ECO

by **Anke Kuckuck** (Green Wind Innovation GmbH & Co. KG)

An eco-friendly and affordable energy supply, independent of fossil and nuclear energy sources: This is the objective of the project TH_2ECO, which is to establish an infrastructure for green hydrogen in Thuringia. In this regard it is amongst others planned to repurpose the gas infrastructure for the transport of hydrogen and to establish a connection to the European H_2 backbone in the long run.

TH_2ECO

THURINGIA
T stands for Thuringia, the initial region for our hydrogen project.

HYDROGEN
H_2 – chemical formula of molecular hydrogen. The focus for us is on green hydrogen.

ECOSYSTEM
The abbreviation means an **eco**nomic and environmentally friendly (**eco**logical) H_2 **ECO**system for the region.

Thuringia needs a new energy future, which makes the energy supply more independent of fossil and nuclear energy sources and makes an important contribution towards the protection of our climate. The name of the matching project in this regard is: TH_2ECO (short for Thuringian H_2 ECO system). From 2025 onwards, greenly produced hydrogen from locally generated green power is to be partly transported through existing gas pipelines. Thus, TH_2ECO perspectively aims at the connection to the German and European H_2 backbone network.

Partners: Strong together

Together with equitable partners, the Ferngas Netzgesellschaft creates an initial region with TH_2ECO. The participating, well-known companies that are rooted in Thuringia include grid operators, power and electricity providers as well as specialists for renewable energies. Since 2021, they jointly push the development of a sustainable hydrogen infrastructure.

The project is pursuing decarbonisation, regionality and sustainability. A low-carbon economy will considerably reduce the CO_2 emissions in Thuringia. With the integration into existing grids it is possible to draw on existing regional structures for the provision of hydrogen. The energy transition is advanced with regenerative green hydrogen. Through intelligent sector coupling it is possible to establish an efficient long-term relationship to partners of the industry.

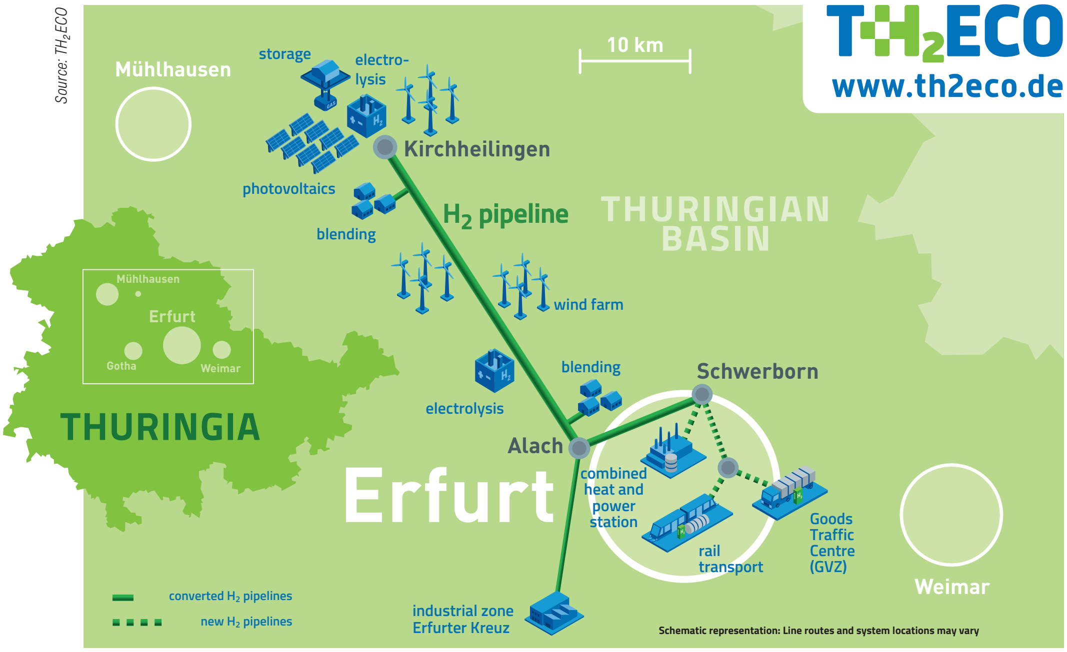
"We at TH2ECO are convinced that an affordable and successful energy transition can only succeed and set climate goals can only be achieved with the use of green hydrogen in particular," project manager Dr. Katharina Großmann (Ferngas Netzgesellschaft) describes the vision of the project. In moderated, topic-specific task groups, the partners continue to enhance the joint project. By means of wind energy and water electrolysis, Green Wind Innovation, BOREAS Energie and TEAG produce green hydrogen – as basis for developing a sustainable energy industry in Thuringia. Three electrolysers with approx. 25 Megawatt (MW) are projected.

Infrastructure: Grids and reservoirs

The Ferngas Netzgesellschaft, SWE Netz and Thüringer Energienetze are developing a grid-bound infrastructure for 100 percent hydrogen. This hydrogen is transmitted through a 42 km long H_2 pipeline. An already existing gas pipeline with a pipe diameter of 600 mm can be used for this. In addition, a 3 km long new section of the pipeline will be constructed. The storage of hydrogen guarantees a high degree of availability even in the event of seasonal fluctuations. This includes the conversion of an underground natural gas storage to H_2 by the Thüringer Energie Speichergesellschaft.

Consumers: Heat, mobility and industry

At the combined heat and power station Erfurt of SWE Energie, the hydrogen is used to generate district heating. Approx. 40



Source: TH$_2$ECO

percent of the residents of Erfurt will proportionally benefit from this. In addition, by blending H_2 into the existing gas grid, households in island grids can be supplied with green hydrogen. Both measures reduce the CO_2 discharge by approx. 16,800 t per year.

Furthermore, an H_2 mobility hub is to be created at the Goods Traffic Centre (GVZ) Erfurt East. The hydrogen will be used to refuel motor vehicles with fuel cell drive or hydrogen combustion engine at a filling station. In the medium run, one of the largest industrial locations in Thuringia, the industrial area at the Erfurt Kreuz, and the rail traffic are to be connected and the use of H_2 in the Erfurt municipal grid and in the combined heat and power station is to be increased.

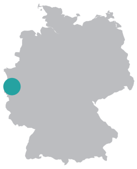
From island H_2 solution to network

TH$_2$ECO starts with a "hydrogen island" in Thuringia and is constantly expanding nationally. Both producers of H_2 and consumers from the sectors heat, mobility and industry can connect to this island solution via the developing H_2 grid, thus expanding the system. Perspectively, TH$_2$ECO is to be connected with the German and European H_2 backbone grid, a nationwide pipeline grid system for hydrogen. This enables the import and export of hydrogen from other regions and countries.

Challenges for the KlimaZukunft

Green hydrogen is produced with power from renewable energies such as photovoltaics and wind energy. These energy systems are currently in the development stage all over Germany, so that the production of green hydrogen currently does not yet yield sufficient quantities. The infrastructure for transport and storage is also still under development. This is exactly where TH$_2$ECO comes in and makes it possible to widely produce and use green hydrogen. At the same time, the project is dedicated to all stages of the value-added-chain, from the production to the use of hydrogen. TH$_2$ECO is a scalable ecosystem that enables the connection of further stakeholders to the H_2 infrastructure and is open for further companies who would like to participate. The more consumers are converting to a supply with hydrogen, the more inexpensive production will become. In this way, further consumers from all areas are to be gained by means of intelligent sector coupling. Chances are good and interest is high.

Contact:
Dr Katharina Großmann
Ferngas Netzgesellschaft mbH
Juri-Gagarin-Ring 162
99084 Erfurt
E-mail: th2eco@ferngas.de
Internet: www.th2eco.de



Hydrogen projects and approaches at Gelsenwasser

by **Friederike Konold** (GELSENWASSER AG)

Gas distribution grids play an important role when it comes to efficiently transporting hydrogen to its point of use. Gelsenwasser is among other things intensively engaged in the transformation of the gas grids and has in this connection initiated several pilot projects, which are introduced in this article.

As water and power supplier and distribution grid operator in the Ruhr area and beyond its borders, the GELSENWASSER AG is acting in an environment that is very much characterised by developments in environmental and climatic politics. Thus, the focus also shifts to the topic how the company can offer people who are currently supplied with natural gas an affordable possibility of CO_2-free heating. It is also intended to support small and medium-sized business, which are often connected to the distribution grid, with the topic of decarbonisation. In this regard, the highly promising energy carrier hydrogen is of great importance.

Hydrogen initiatives in the distribution grid, Linnich (2022)

As grid company of the organisation, the GELSENWASSER Energienetze GmbH (GWN) prepared a test section on its own premises in Linnich for the conversion from natural gas to 100 percent hydrogen (project name "100% H2 Linnich"). The objective is to examine the feasibility and practicability of a 100 percent hydrogen grid and to demonstrate how personnel and gas grids can be geared up for a conversion to hydrogen.

The test section comprises an almost 130 m long polyethylene gas supply line and two grid connections dating back to 1995 or 1999 (service building and storage hall). By means of a physical separation from the remaining supply grid, a small-scale internal hydrogen grid – from injection to the consumer – is created and put into operation.

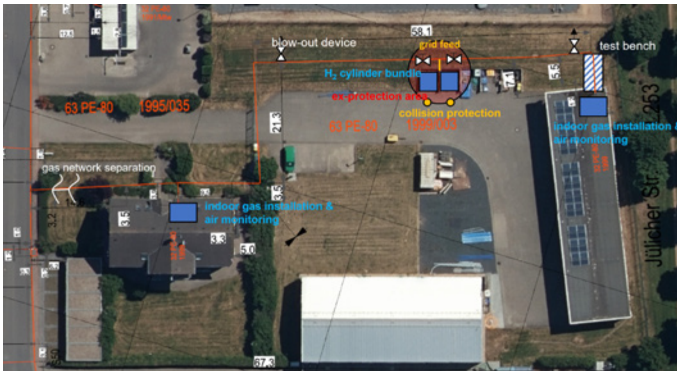
The initialisation phase and planning phase of the project have already been completed. This included amongst others the compilation of a detailed safety concept incl. risk assessments and safety instructions. In addition, special emphasis was placed on a "H_2 ready" analysis of the components and equipment in the gas pipeline grid and in the internal gas installation. The analysis was carried out on the basis of manufacturer surveys, the exchange of experience and own research regarding published research reports. The evety GmbH, a joint company of TÜV Süd, OGE and Horváth & Partners, supports the project in particular with regard to technical safety questions.

Preparations for commissioning the island hydrogen grid are running at full speed and have to a great extent been completed. Apart from adaptations to the grid, additional safety measures are implemented to satisfy the high safety requirements and standards even under conditions where hydrogen is used. Components currently installed in the internal gas installation that are not compatible with H_2 (for instance gas meters, gas pressure regulators and condensing appliances) are accordingly exchanged against suitable system components or their range of functions is to be examined during normal operation with hydrogen. A regularly performed gas leak detection as well as additionally installed isolating devices and blow-out devices in the grid as well as H_2 detection and warning systems in the domestic area increase the safety requirements.

As soon as the hydrogen condensing boilers for the service building and storage hall are delivered, the physical separation will take place and the grid will then be fed from an external hydrogen source (gas cylinder store).

The project is to run over a total period of twelve months in normal operation, during which time in particular the interaction between grid and residential installation incl. gas systems will be examined with regard to functionality and compatibility. Apart from monitoring, various working methods and operating procedures established in the field of natural gas are tested on the test stand and are where necessary adapted to the operation with 100 percent hydrogen. Upon completion of the year-long test operation, a decision will then be taken with regard to an expansion to the adjacent industrial area.

Source: GELSENWASSER AG



Overview of the layout of the pilot system “100% H2 Linnich”

Source: GELSENWASSER AG

Connection of the H_2 injection plant to the existing gas grid

Münsterland (2023/2024)

The GWN is also testing possibilities of adding up to 30 percent of hydrogen to their distribution grid. In this connection, the company will probably purchase green hydrogen from Thyssengas in the Münsterland from 2024 and add it to a section of the grid. This admixture is to be done from the site of a biogas treatment system that is expanded by an electrolyser and injects hydrogen into the transport grid of Thyssengas via the already existing injection system. From this too, the GWN hopes to gain insights into the compatibility of materials, safe operation and working methods and of course also with regard to the ultimate consumer response as their heating systems will have to be adapted/replaced accordingly.

In general, it is highly relevant how the ultimate consumers in a future energy system can be supplied at a later stage. In this respect, it is also important to engage in solutions for this target group. The companies from Gelsenwasser are also dealing with this topic.

Solutions for end users, process gas (2022)

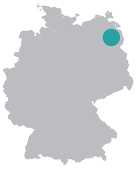
In recent years, the company Kueppers Solutions GmbH from Gelsenkirchen has developed a series burner with optimised heat recovery, which is produced by means of 3D printing. The burner iRecu can be operated in bi-fuel mode with natural gas, hydrogen and blends, thus making it possible to use hydrogen in thermal processes in industry and commerce. This in turn is an important contribution towards transforming gas grids into hydrogen grids. Gelsenwasser has supported the development financially as shareholder and also supports the company with regard to the imminent market launch. In spring 2022, the burner was awarded the innovation prize for climate and environment by the Federal Ministry for Economic Affairs and Climate Action (BMWK).

Fuel cell heatings (2022/2023)

Not only industry, small and medium-sized business and commerce are facing an enormous challenge – domestic consumers too want to still be reliably and safely supplied with heat. An important contribution in this regard can be made by fuel cell heating (FCH), which (similar to a gas power station in miniature format) produces electricity and uses the waste heat generated for heating purposes. The decentralised power generation holds considerable advantages: First of all, the energy invested is used very efficiently, a factor of growing importance in particular in view of high energy prices and low quantities supplied. Secondly, it is an ideal supplement for a continued electrification, because locally generated power relieves the power grids and counteracts an expensive extension of the power grids.

Initially, fuel cells were developed for operation with hydrogen and are therefore a particularly suitable application technology for gas grids that have been converted to transport hydrogen. However, contemporary FCH also operate with natural gas so that the launch of this heating technology can and should already take place now, independent of the conversion of the gas grids. To be in a better position to assess the factors mentioned and to provide a little push for the launch, Gelsenwasser sets up a model for FCH in households within the scope of a pilot project.

Contact:
Friederike Konold
GELSENWASSER AG
Willy-Brandt-Allee 26
45891 Gelsenkirchen
E-mail: friederike.konold@gelsenwasser.de
Internet: www.gelsenwasser.de



H_2Membran: *Testing various membrane materials for separating hydrogen from natural gas-hydrogen blends*

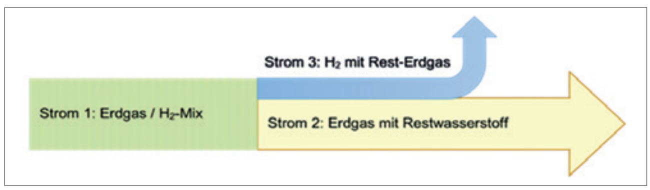
by **Udo Lubenau** (DBI Gas- und Umwelttechnik GmbH)

Hydrogen is an important energy carrier, which in future will link up the power and gas infrastructures into one energy system. It can be proportionally added to the natural gas grid, transported and made available as needed for applications in mobility, industry and on the heat market. For applications that do not tolerate gas blends, the hydrogen needs to be removed again. This concerns in particular industrial customers sensitive to gas quality. Membranes that separate the hydrogen from the natural gas could take over a protective function. At the same time, this raises the question whether the membranes can in addition make available the hydrogen for H_2 utilisation. This would result in a useful function at the end user's, which reinforces the transport function of the hydrogen in the pipeline grid.

Making use of the favourable general framework provided at the hydrogen injection system of ONTRAS Gastransport GmbH in Prenzlau in Brandenburg, a mobile pilot system in container design for the customised generation of natural gas-hydrogen blends with up to 20 percent hydrogen was constructed. Membranes of various European manufacturers, whose membrane material varies in size and geometry, will be examined. Appraisals take place under high pressure up to 25 bar and at flow rates on a pilot-scale that are adapted to the membrane sizes. The objective of the separation is to stay below the hydrogen limit of 2 percent in natural gas in the treated gas flow, as stipulated in DIN 51624, with low losses in methane. Interested manufacturers of membranes for the specified separation purpose are in this connection invited to get in touch with the project partners. The overall project has two components:

- The construction and start-up of a pilot system for testing membranes with regard to the separation of hydrogen from natural gas and
- the performance of tests with membranes with the involvement of membrane suppliers.

The set-up of the system was financed by ONTRAS Gastransport GmbH, GRTGaz (France) and the Mitteldeutsche Netzgesellschaft Gas GmbH and is complete. Currently, a pilot system operating with basic parameters is in use, which offers sufficient flexibility for testing various types of membranes. During these tests, the gas flow, the concentration of hydrogen in the natural gas and the pressure are varied, there being technical limits to the variation. It is possible to implement multi-level membrane circuits that correspond to the real conditions of membrane processes.



Overview of hydrogen separation

Source: DBI

The appraisals are performed within the scope of the DVGW research project "H_2Membran" (funding code: G 201920). Among other things, the tests are to clarify the following questions:

- Which membranes are sufficiently stable in natural gas? Disrupting elements are possibly increased hydrocarbons, water or sulphur compounds.
- What are the separating properties (selectivity and permeability) of these membranes under real-life conditions? In real-life operation, separation is always worse compared to the laboratory testing, but permeability and selectivity determine the costs of the process. In

addition, the initial concentrations are relatively low with 10 to 20 percent by volume (% v/v) hydrogen and challenging for the membrane materials to be analysed.

- Do the membranes have adequate long-term stability?
- What purity can be achieved with a one- or two-level process? And how can the qualitative requirements of fuel cells on hydrogen (mobile or stationary) be met?

The project is to determine the possibilities of the actual technical implementation. This concerns the pressure stages, the operation modes, the necessity of pre-cleaning as well as possibilities for combining different types of membranes. The project aims at determining membranes that are suitable for the task of separating hydrogen/natural gas, testing being independent of type and material of the membranes. Apart from these technical questions, aspects of the scalability of membranes, the timelines for conversion into practical use and supply availability are also taken into consideration by involving the manufacturers or membrane developers.

Source: DBI

The tests are carried out at the H_2 injection facility in Prenzlau (Brandenburg).

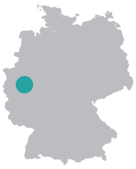
Figure 2 shows the ONTRAS location Prenzlau with the electrolysis in the large building in the background and the smaller injection system in the front. Apart from these buildings, two test containers were set up which contain the technical equipment (gas blend, membranes, measurement technology etc.). The pilot system is connected to a MOP 26 bar pipeline into which 2 mol percent of hydrogen can be dosed.

The hydrogen is provided by the company ENERTRAG and can be added to the natural gas in a range from 2 to 50 percent, with testing primarily covering the range up to 20 percent of H_2 in natural gas. The membranes can be heated; Pd-membranes need to be heated to approx. 400 °C. With 2 m³/h, the flow rate across the membrane is not very large, but adequate to achieve the goal. A gas chromatograph measures the gas quality on site, the system is automatically monitored and controlled. With every membrane, pressure and temperature programs are run and the gas composition is varied. The maximum test pressure is 22 bar. Cross-sensitivities can be examined by adding components, for example water, to the gas flow. The following membrane types will be examined:

- different polymer membranes
- Pd membranes from a European manufacturer
- anorganic membranes (for instance carbon membranes)

Testing with the polymer membranes has already demonstrated that the membrane method can be used for the protection of systems against hydrogen. In the process, the polymer membrane examined turned out to be stable in natural gas, but to achieve higher H_2 purities in the separated hydrogen flow, several levels of polymer membranes must be used. Preliminary tests with a carbon membrane revealed that this membrane type can produce high H_2 purities. Tests will be continued.

Contact:
Udo Lubenau
DBI Gas- und Umwelttechnik GmbH
Karl-Heine-Str. 109/111
04229 Leipzig
E-mail: udo.lubenau@dbi-gruppe.de
Internet: www.dbi-gruppe.de



Westenergie is Germany-wide pioneer: Existing natural gas line is converted to transport 100 percent hydrogen

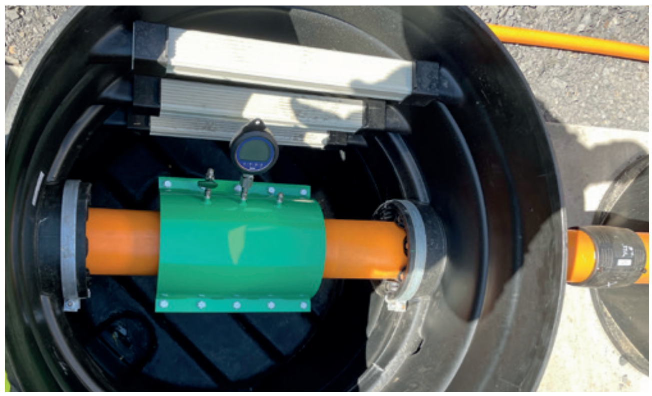
by **Jens Kleine Vennekate, Carsten Stabenau** & **Dietmar Ewering** (all: Westnetz GmbH)

Together with its distribution grid operator, Westnetz GmbH, Westenergie AG delivers an important innovation for the energy supply with the new research and development project "H_2HoWi": For the first time in Germany, an existing natural gas pipeline in the public gas supply will be converted to transport pure hydrogen.

At the World Climate Conference 2015 in Paris, a limitation of global warming to well below 2 °C, preferably though to below 1.5 °C compared to the preindustrial level, was specified. For it to be possible to achieve these goals, it is necessary to press ahead with the development of renewable energies. But not all applications can be technically electrified in a meaningful manner. Hydrogen as energy carrier will therefore become indispensable for all those applications where the direct use of green power is not possible or not reasonable for technical or commercial reasons. To this end, we require a coupling of the various sectors of energy consumption. Due to the CO_2-neutral implementation, amongst others in the field of heat supply and mobility, the use of pure hydrogen is a forward-looking solution. Especially in the field of heat supply, a great need for climate-neutral gases will still be given beyond the year 2050, which will require more than the use of heat pumps. The use and adaptation of the existing natural gas grid for the transport and distribution of climate-neutral gases is in this connection an important requirement for the energy transition to succeed. With the project "H_2HoWi", Westnetz is dealing more closely with this topic and analyses to what extent it is technically possible to repurpose an existing natural gas pipeline for the use with hydrogen. To this end, an existing medium pressure natural gas pipeline (DP 1) in Holzwickede in North-Rhine-Westphalia is first separated from the natural gas grid and then connected to a hydrogen reservoir. This reservoir is filled with climate-neutral hydrogen of the quality 3.0 and the hydrogen is then stored at max. 40 bar. The reservoir is equipped with a sensor, which signals a low level online directly to the gas supplier. In this case, a truck with a 200 bar hydrogen trailer is immediately sent to the municipality to replenish the reservoir.

Source: Westnetz GmbH

Hydrogen tank on the site in Holzwickede



Source: Westnetz GmbH

Permeation measurement cell mounted on a PE pipe

During operation, this hydrogen is relaxed to 0.35 bar via a gas pressure control line, is odorised and then fed into the repurposed natural gas pipeline. This pipeline was built in the year 2005 from PE 100 (PEC) and will in the scope of this R&D project supply four commercial customers with pure hydrogen. Permeation measurement cells provided by the company DBI - Gastechnologisches Institut gGmbH from Leipzig are installed on this pipeline to quantify the permeation (penetration of the gas through the material) on the PE pipe.

Due to the molecule size of hydrogen, a higher permeation compared to a pipeline operated with natural gas is assumed.

Source: remeha

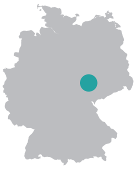
Front of the condensing appliance used

However, permeation will presumably be in an uncritical range. The corresponding measuring cells are on the one hand fitted to the continuous PE pipe, but also at a welded joint between two PE pipes and on a branch fitting. In addition, it is planned to fit measuring cells on a polyamide (PA) pipe. It is intended to introduce approx. 12 m of the new pipe material into the old natural gas pipeline to make up a distribution grid so that a statement can be made whether in future it will be possible to use other materials than steel and conventional polyethylene (PE) in the distribution grid. The DBI evaluates the measurements at regular intervals. The hydrogen is to be used to generate a portion of the required space heating for the four commercial customers. Apart from a conversion of the natural gas pipeline, this also requires adaptations to existing customer installations. Condensing appliances that are available on the market to date are not able to burn pure hydrogen. For this reason, newly developed hydrogen-compatible condensing appliances from the company Remeha with an output of 24 kilowatt (kW) are installed at these customers'. Remeha will have an online connection to the devices so that the operating data can be used to gain further insights and to further advance the development of these appliances, in particular in the field of high-performance burners for industry. Maintenance of the 24 kW appliances at Holzwickede will be exclusively carried out by employees of Remeha.

Another new field of activity in this project is the odorisation of hydrogen. The project at Holzwickede will in this regard resort to initial findings of the project "HYPOS: H2 grid", which has amongst others been undertaken by the affiliated company MITZ-NETZ GAS at the chemical park in Bitterfeld-Wolfen (Saxony-Anhalt). The concentration of the odorant at Holzwickede is regularly monitored by means of sampling. At the same time, hydrogen sensors are installed in the installation space of the condensing boilers, which will immediately detect any leakages. In this case, the hydrogen supply to the burner is instantly stopped by means of a check valve at the house wall. The units hydrogen reservoir, gas pressure control and odorisation are installed on a site that was purchased within the scope of this project in the industrial area of Holzwickede. The project primarily aims at demonstrating that the natural gas distribution grid is also able to transport 100 percent hydrogen and can thus make a huge contribution to the success of the energy transition.

The measure is carried out after prior coordination with the grid owner, the Energienetze Holzwickede GmbH, who has not only agreed to a partial delivery of hydrogen to its grid customers within the illustrated pilot project, but explicitly supports the implementation. Thus, the Westenergie AG, together with Germany's largest power and distribution grid operator Westnetz GmbH, sets an important milestone for the sustainable public supply in the municipality of Holzwickede through the project "H_2HoWi". The entire project is planned, set up and operated by Westnetz. The first hydrogen is to flow at the beginning of October 2022 and by the end of 2023 is to generate a portion of the required space heating for the commercial customers. A continuous scientific supervision is to confirm, amongst other things, that the hydrogen has no influence on the texture of the raw material and the leak tightness of the existing infrastructure. Thus, experiences can be gathered and important know-how built to convert parts of the German natural gas grid to transport hydrogen in the future. This is an essential element in reducing the discharge of CO_2 emissions.

Contact:
Carsten Stabenau
Westnetz GmbH
Florianstr. 15–21
44139 Dortmund
E-mail: carsten.stabenau@westnetz.de
Internet: www.westnetz.de



*The **Energy Park Bad Lauchstädt** as catalyst for energy transition and structural change*

by **Juliane Renno** (VNG AG)

The Energy Park Bad Lauchstädt is a regulatory sandbox for the intelligent production of green hydrogen from wind power as well as its storage, transport, marketing and utilization in Central Germany. Within the scope of the project, the entire value chain is for the first time set up and tested on a large industrial scale. The objective of the power-to-gas project: to store renewable energies in the long term, in order to ensure security of renewable energy supply independent of the energy generated from wind and sun.

With this objective, the project does not only make a significant contribution towards the energy transition and to the shift away from fossil energy carriers, but is also an important catalyst for structural change in a region characterised by lignite and consumers with intense energy demand.

Green hydrogen as key energy carrier

Green hydrogen is of essential importance for a successful energy transition: Produced from renewable power by electrolysis, it is eco-friendly, easy to store and enables an efficient sector coupling by balancing weather-related fluctuations in solar and wind power generation. In addition, it can be used in different sectors, for instance in the chemical industry, in the mobility sector, but also for the power and heat supply. So far though, the development of a world-wide hydrogen economy is still in its early stages. This is exactly where the Energy Park Bad Lauchstädt comes in: The project makes a contribution towards testing the future technologies for green hydrogen along the entire value chain and develop them to market maturity. Thereby, the regulatory sandbox proofs that sector coupling can succeed.

Development of the integrated value chain

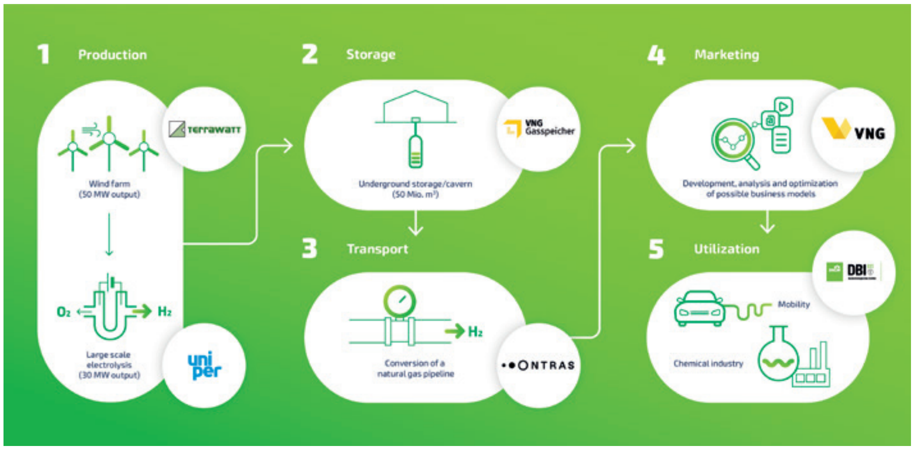
At the Energy Park Bad Lauchstädt, the entire value chain of green hydrogen is set up at an industrial scale: From the generation of renewable power and electrolysis to storage and transport and the utilization. As a world first, the direct coupling of wind power from a nearby 50 megawatt wind farm and a large electrolysis plant with up to 30 megawatt is tested at the Energy Park - wind power is directly converted on site into climate-neutral green hydrogen. In addition, the first large scale hydrogen storage in salt caverns with a working gas volume of 50 million standard cubic meters is planned at the Energy Park Bad Lauchstädt. Through a repurposed 25 km long natural gas pipeline, the green hydrogen is transported to the chemical industry in Central Germany and beyond that will perspectively be used for urban mobility solutions.

In the scope of the project technologies related to green hydrogen are tested and business models are deveolped on the results and experiences. For a successful use of the

Source: VNG

The Energy Park Bad Lauchstädt is a regulatory sandbox for the generation and use of green hydrogen.

green hydrogen, all parts of the value chain are analysed, developed and optimised.



Overview of the production and value chain at the Energy Park

Source: VNG

Site of the Energy Park Bad Lauchstädt

The Energy Park Bad Lauchstädt is located in the South of Saxony-Anhalt, about 20 km to the south-west of Halle, between the municipalities of Bad Lauchstädt and Teutschenthal. The windy area is particularly well suited as site due to its geological structures, the already available natural gas and hydrogen infrastructure and the spatial proximity to the existing chemical triangle with large-scale hydrogen consumers. Located in the Central German lignite district, the Energy Park Bad Lauchstädt contributes towards an innovation-based structural change in Central Germany through the preservation and development of regional added value and employment. as regulatory sandbox of the energy transition. With an overall project volume of more than 140 million Euro, an investment into the future of the energy region Central Germany is made through the development of a green hydrogen economy, thus creating the basis for a sustainable industrial site. The Energy Park Bad Lauchstädt builds on the preparatory work of several research projects within the scope of the HYPOS network.

Blueprint for a successful sector coupling

The Energy Park Bad Lauchstädt is a blueprint for many other comparable innovative hydrogen projects that will develop in the future energy system. Not only the handling of large amounts of green hydrogen along the entire value chain is tested here, but the required regulatory setting is also identified and business models are developed, which provide security of invest for investors and incentives for future hydrogen customers. With this, an important contribution towards the development of a hydrogen economy in Germany is made. As the Energy Park is located in a region in the East of Germany that is affected by the structural change, it is a blueprint for the energy transition and an important symbol for the successful transformation of an area that has been an industrial region for decades.

Project partners

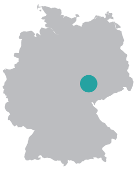
The project is implemented by a consortium of six companies. These include Terrawatt Planungsgesellschaft mbH, Uniper, VNG Gasspeicher GmbH, Ontras Gastransport GmbH, DBI – Gastechnologisches Institut gGmbH Freiberg and VNG AG. The project was launched in September 2021 and is funded over its five-year project period by the Federal Ministry for Economic Affairs and Climate Action with roughly 34 million Euro

Contact:
Cornelia Müller-Pagel
Energiepark Bad Lauchstädt, c/o VNG AG
Braunstr. 7
04347 Leipzig
E-mail: info@energiepark-bad-lauchstaedt.de
Internet: www.energiepark-bad-lauchstaedt.de

Gefördert durch:

Bundesministerium für Wirtschaft und Klimaschutz

aufgrund eines Beschlusses des Deutschen Bundestages



Efficient and safe operation of hydrogen distribution grids: The project: H_2INFRA

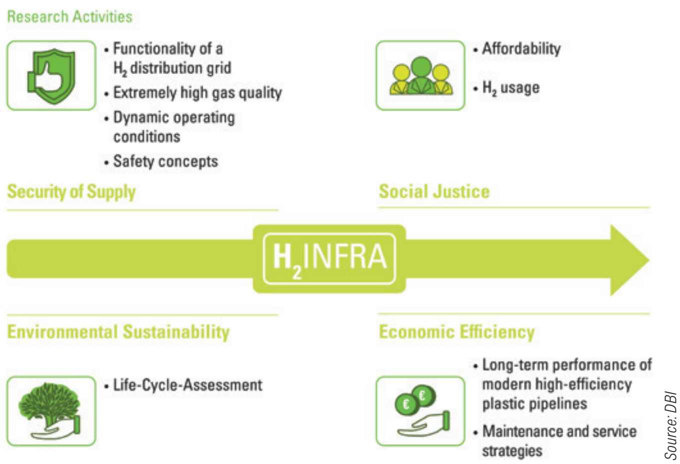
by **Anna Schwert** (Mitteldeutsche Netzgesellschaft Gas GmbH) & **Robin Pischko** (DBI Gas- und Umwelttechnik GmbH/ Leipzig University of Applied Sciences (HTWK Leipzig)

On 1 January 2022, the project H_2 Infrastructure – Efficient and safe operation of hydrogen distribution grids (H_2INFRA) was launched, which is funded with approx. 1.6 million Euro by the Federal Ministry for Economic Affairs and Climate Action (BMWK). The project focusses on ensuring the functionality of a H_2 distribution grid including all its components under dynamic operating conditions and in particular on the provision of an extremely high gas quality and security of supply for the future applications.

The consortium behind the project, consisting of DBI Gas- und Umwelttechnik, MITNETZ Gas and HTWK Leipzig, continues the research work of the projects "H_2 grid" and "H_2 home", funded by the Federal Ministry of Education and Research (BMBF) in the course of the HYPOS initiative within the scope of the funding program "Twenty20 - Partnership for Innovation". The unique research infrastructure for hydrogen distribution grids in Bitterfeld-Wolfen that has been developed in the context of the projects will be used and enhanced to clarify numerous open questions.

Modern plastic materials for a safe hydrogen distribution grid infrastructure

Research topic is the qualification of an ecological, economical and safe hydrogen distribution grid structure, based on high-performance plastics offering the longest possible service life of all system components. Besides, pipeline materials and grid components are tested by dynamic load changes under realistic boundary conditions. The objective is to survey the hydrogen compatibility and long-term performance of materials and components. It has been found that the plastic materials previously used for gas distribution grids are releasing residues into the transported hydrogen in a magnitude that ranges above the permissible limits, for instance for stationary and mobile fuel cell applications. The project therefore is to identify the residues and their origin (pipe materials, manufacturing process) and develop optimised manufacturing processes for new pipe materials, which satisfy the high purity specifications of the hydrogen transported by them. The safety of the distribution grid infrastructure is reviewed and assessed by means of extensive monitoring. By assessing the greenhouse gas emissions of the infrastructure, the environmental optimisation potentials are determined and the ecological and economical advantage of a grid-bound hydrogen supply of the end consumers is mapped out.

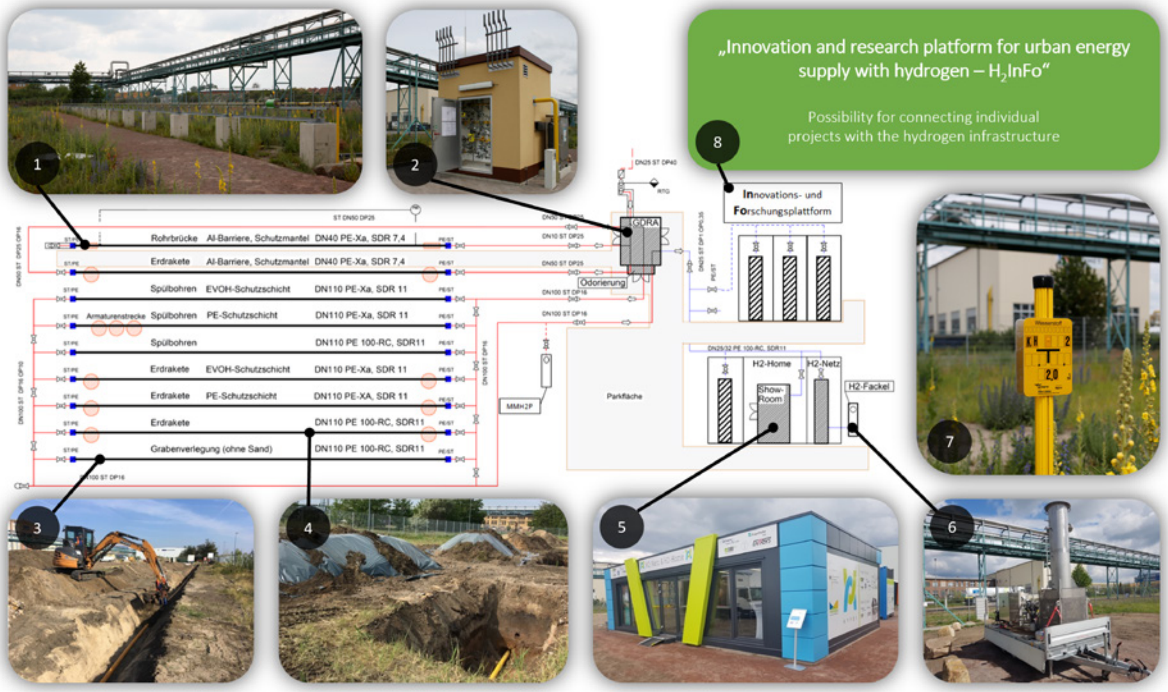


Focus of research in accordance with the energy policy square

An overview of the main focus of research

The research project focuses on the following topics:

- Safety and functionality of the H_2 distribution grid including all its components under dynamic operating conditions
- Guaranteeing the security of supply for future H_2 application technologies



Source: DBI

Test facility of the project H_2INFRA: (1) plastic pipeline laid above ground (pipeline bridge) with permeation measurement cell; (2) Gas pressure control and measuring system with odorisation system; (3) Plastic pipeline, open trench laying; (4) Plastic pipeline, trenchless laying with soil displacement hammer; (5) Energy pavilion with H_2-CHP (HYPOS H_2-Home); (6) Mobile excess hydrogen burner; (7) Label changed to hydrogen; (8) H_2-InFo

- Providing an extremely high gas quality
- Long-time testing of the components and safety technology used
- Enhancing the maintenance and servicing strategies for hydrogen-carrying systems
- Evaluating occupational health and safety concepts
- LCA of the hydrogen value-added chain
- Profitability analysis of the H_2 grid and transfer to future infrastructures

Innovation and research platform for urban power supply with hydrogen

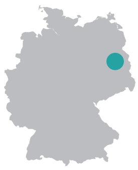
To link the various research projects, the innovation and research platform for urban power supply with hydrogen – in short: H_2InFo – was created. H_2InFo forms the consistent connection to the preceding BMBF projects “H_2 grid” and “H_2 home” and is also intended to permit the future docking of supplementary individual projects in the field of the H_2 distribution grid infrastructure and H_2 use to be able to deal with research and development tasks that can currently not yet be clearly specified and to close knowledge gaps. Finding answers to the questions is precondition for the implementation of a need-based, cost-efficient, safe and environmentally sound hydrogen supply for urban areas and thus also for the implementation of the national hydrogen strategy for the population at large and for companies beyond the large consumers in the chemical industry or in metallurgy. Research work aims at a high Technology Readiness Level (TRL) of the tested hydrogen infrastructure and the associated systems, so that results can be swiftly implemented later on.

H_2InFo offers the following opportunities for networking and cooperation:

- Separate R&D projects with regard to H_2-operated appliances for household and commercial applications
- Modular incorporation into the H_2 infrastructure
- Demonstration and long-term operation of H_2-operated appliances
- Successive development of further research infrastructure
- Provision of infrastructure for network partners

Contact:
Robin Pischko
DBI Gas- und Umwelttechnik GmbH
Karl-Heine-Str. 109/111
04229 Leipzig
E-mail: robin.pischko@dbi-gruppe.de
Internet: www.dbi-gruppe.de/h2-infra

Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages



Construction of the first underground hydrogen storage: H_2 underground test cavern is in the making in Rüdersdorf in Brandenburg

by **Nadine Auras** (EWE Aktiengesellschaft)

Within the scope of the energy transition and the associated hydrogen market launch, the ability to store the generated hydrogen in the long term is of crucial importance. In this context, it is currently demonstrated by means of an underground cavern storage erected as part of the H_2 storage project HyCAVmobil that the underground storage of hydrogen in the existing facilities is possible.

With green hydrogen, the transformation of the energy system to achieve climate-neutrality can succeed. Apart from the spatial distribution, the temporal distribution of larger amounts of energy is also required in a system that is dominated by the generation of energy from wind and sun. This can only be achieved by means of green gases. At the same time, this raises the question how the hydrogen can be conveyed from the point of generation to the point of application. The answer to that is: Through the integrated, need-based development of hydrogen value added chains that are made up of generation, transport, application and last but not least storage. Because this makes it possible to compensate the volatility of sun and wind and to use the renewable energies in an intelligent and efficient manner, particularly when they are needed, not when they are generated.

The energy provider EWE aims at making a distinct contribution towards the development of a green hydrogen economy with activities along the entire value-added energy chain. The hydrogen storage project HyCAVmobil in Rüdersdorf in Brandenburg makes up an essential part of these plans. The proof that hydrogen can be safely stored in underground cavities and is of appropriate quality for future application after its removal is an important step for the transferability to large storage caverns. With 37 salt caverns, EWE owns roughly 15 percent of all German storage caverns that could perspectively be used to store hydrogen. This would be an important base to build on for making hydrogen generated from renewable energies capable of being stored in large amounts and used as needed and to reach the set climate goals.

Inside a 250 million year old salt dome below Rüdersdorf, the energy provider EWE is constructing a hydrogen test cavern at a depth of 1,000 m.

Source: EWE/C3 Visual Lab

Pioneer role in pure H_2 storage

Since spring 2021, EWE has been constructing a storage cavern in the salt rock in Rüdersdorf at a depth of roughly 1,000 m where 100 percent hydrogen is to be stored for the first time. The test cavern will have a volume of 500 m³ and will thus reach the dimensions of a single-family dwelling. A first milestone has already been reached by EWE at the end of 2021 with the installation and cementation of 160 steel pipes down to a depth of 1,000 m. With this, the energy provider has established the basis for the planned small test cavern to be constructed in the salt dome. For this, EWE has installed a pipe-in-pipe system, a so-called double pipe casing. To be able to use the inner pipe for the material tests, a flexible system was developed. The purpose of this is that the inner pipe can be dismantled again and used for tests without destroying the material.

Until autumn 2022, preparatory work for leaching out is under way during the construction of the hydrogen test cavern. In spring 2023, EWE will store hydrogen for the first time and start the tests. “With the large-scale hydrogen storage we also want to demonstrate to the responsible authorities that hydrogen caverns are just as safe as natural gas caverns. Due to the stringent quality requirements of some applications, our tests are of particular importance for the use of hydrogen, for instance in the mobility sector,” explains EWE hydrogen ambassador Paul Schneider. In the course of the research project, EWE expects in particular insights into the level of purity of the hydrogen after it is retrieved from the cavern. This criterion is particularly important for the application of hydrogen in the mobility sector.

Research for future applications

For this project, EWE cooperates with the Deutsche Zentrum für Luft- und Raumfahrt (DLR). The DLR Institut für Vernetzte Energiesysteme in Oldenburg researches and assesses amongst others the quality of the hydrogen before it is stored in and after it is retrieved from the cavern. Research under controlled conditions in the laboratory is followed by tests on the test cavern under real-life conditions. At the same time, the DLR examines both materials and components and the effects of modes of operation of an exemplary surface system in terms of an integration into the energy system in the region. The operating conditions in the cavern with pressures up to 180 bar, combined with further specific environmental conditions can have an influence on the materials used,

Pipe-in-pipe-system: For the upcoming material tests in the research project “HyCAVmobil“ the engineers have developed a sophisticated flexible system.

Source: Andreas Prinz

for example on metals or sealing materials. One problem the DLR is investigating is whether any substances are released or reactions occur which will contaminate the stored hydrogen. To begin with, the researchers simulate the salt cavern with regard to pressure and temperature under a hydrogen atmosphere in special reactors in the laboratory.

Under laboratory conditions, the purity of the hydrogen before and after storage can be determined more accurately. Besides, limits for contaminations, i.e. corrosive gases for the fuel cell, extend far down into the ppb range (parts per billion), for example for sulphur components. "Already these extremely low concentrations, which can only be proven by means of trace gas analysis, can permanently damage the fuel cell of a hydrogen vehicle. Considering the conversion of natural gas caverns, even smallest amounts of methane contained in the hydrogen can for example have a negative influence," explains Dr. Michael Kröner from the DLR Institut für Vernetzte Energiesysteme in Oldenburg. In combination with gas analysis, the reaction of many materials with hydrogen can be investigated and many different contaminations demonstrated in the high-pressure test reactors of the DLR. If after storage in the cavern, the hydrogen no longer meets the stringent purity requirements for fuel cell mobility, the project team will also investigate on a laboratory scale different physical filtering methods to restore the purity of the gaseous hydrogen.

Further questions are, which systems and controls are needed to inject hydrogen into and retrieve it from the cavern under pressure and how renewable energies can cover the need for this despite their volatility. Besides, it would also be conceivable to produce sustainable hydrogen directly on site by means of electrolysis and store it. Against this background, the DLR models the upstream high-voltage grids in Brandenburg and in particular at the cavern site to integrate this and further hydrogen caverns in the best possible manner into the existing energy system and to ensure their technical connection to the power grid. Detailed power grid simulations are used to evaluate the location of further sites suitable for H_2 generation and storage and how these could offer useful flexibility for the power grid. At the same time, in many cases a further use as system services can be depicted. Moreover, it is possible to use the cavern system in a targeted manner to diminish grid bottlenecks.

Large-scale application

It is to be possible to transfer the insights gained through the research cavern to caverns with the thousandfold volume. The goal is to use caverns with volumes of 500,000 m³ for large-scale hydrogen storage in the future. With this, it would be possible to use green hydrogen generated from renewable energies on a terawatt hour scale in a storage-oriented and demand-driven manner. Hydrogen would thus become an indispensable component for achieving the set climate targets and for coupling the four sectors mobility, power, heat and industry.

The investment volume of the project amounts to approx. 10 million Euro – 4 million of which come from EWE's own funds. The remaining sum the project partners receive as funding from the Federal Ministry of Transport and Digital Infrastructure within the scope of the National Innovation Program Hydrogen and Fuel Cell Technology.

Contact:
Nadine Auras
EWE Aktiengesellschaft
Hegermühlenstr. 58
15344 Strausberg
E-mail: nadine.auras@ewe.de
Internet: www.ewe.com

DLR Lampoldshausen combines space transportation with trendsetting energy research

by **Michael Füting** (Deutsches Zentrum für Luft- und Raumfahrt e. V.)

Due to its energy density, hydrogen as rocket propellant has always played an important role in space transportation. So it comes as no surprise that the energy carrier is also regularly used at the Institute of Space Propulsion at the German Aeropsace Center (DLR). With a view to the decarbonisation of the DLR, several projects to make available climate-neutral hydrogen at a large scale are currently ongoing at the Lampoldshausen site.

Energy-intensive applications are both the origin and the future of hydrogen: Since several decades, the energy carrier has been an integral part of space transportation. The German Aeropsace Center (DLR) with its Institute of Space Propulsion based at Lampoldshausen in Baden-Württemberg works on modelling and enhancing the entire process from regeneratively produced hydrogen, its storage and liquefaction to its application. To harness this know-how and the existing infrastructure also in other sectors, thus supporting the development of large hydrogen applications towards high degrees of technological maturity, transfer projects from space transportation into the fields of mobility and energy were started through the use of green hydrogen.

Research and demonstration platform H2ORIZON

In 2015, the DLR Lampoldshausen entered into a partnership with ZEAG Energie AG, the operator of the most powerful wind farm in the south west of Germany to develop a research and demonstration platform in the megawatt range for the regenerative production of hydrogen within the scope of the project "H2ORIZON" Through a direct connection to the wind farm "Harthäuser Wald", hydrogen is produced in a climate-neutral manner with 100 percent wind power: With an electrical system output of one megawatt (MW), the PEM electrolyser produces up to 14.1 kg of hydrogen per hour, which is stored in a tube trailer after it has been compressed to 300 bar. Thus, the hydrogen can either be used in a mobile manner on the premises of the DLR or can be made available to partners. In addition, the project "H2ORIZON" comprises two natural gas combined heat and power units where hydrogen can be added for research purposes, while simultaneously contributing to the site energy supply.

Zero Emission – Hydrogen Site Lampoldshausen

This is the basis on which the project "Zero Emission – Hydrogen Site Lampoldshausen" is built to demonstrate the opportunities of a wide application of green hydrogen as key factor of sector coupling. The project aims at supplying the Lampoldshausen site with hydrogen produced in a climate-neutral manner and to provide test opportunities for the entire hydrogen process chain. To this end, the project is subdivided into the three subsectors "Green space transportation", "CO_2-neutral Site" and "H_2 Technical Center".

Source: DLR

For more than 60 years, the Institute of Space Propulsion has been designing, developing and testing space propulsion systems and components for an independent European access to space.

Source: ZEAG

Hydrogen from wind power: This is how the energy flows

For the sector "Green space transportation", the sustainable hydrogen production is expanded by a PEM electrolyser with an electric system output of 2.6 MW and direct connection to the wind farm. This permits up to 300 t of green hydrogen per year to be produced in Lampoldshausen and to be used in the test stands and at the H_2 Technical Center associated with the project. Besides, through the construction and testing of a mobile hydrogen liquefier, cryogenic liquid hydrogen is to be produced on site from 2024 onwards. The goal is to use the liquefied hydrogen both for engine tests of the European launcher Ariane on the large-scale test stands and for testing new hydrogen-based technologies.

Another topic is the CO_2-neutrality of the DLR-site Lampoldshausen. The focus is here on the sustainable supply with power and heat and the operation of hydrogen vehicles. The additionally integrated measurement technology in the vehicles permits the investigation of questions dealing with the fuelling process and the validation of optimisation models. For the purpose of achieving a sustainable and CO_2 free power supply, researchers at the DLR work out an optimised power supply system while taking into account various climate predictions.

The third core topic addresses the expansion of test activities beyond the field of space transportation. In doing so, the DLR uses its know-how in dealing with large-scale hydrogen test stands and the existing safety infrastructure to create a research and development platform for hydrogen technologies. The "H_2 Technical Center" is to enable partners from industry and science to develop and test technologies for use in the hydrogen economy under real conditions. At the same time, the modularly built test environment permits a flexible response to customer requirements. With that, the project supports the technology transfer in the economy and promotes cooperations with other research facilities.

Well prepared for the future: CO_2 savings in site supply

The two projects "H2ORIZON" and "Zero Emission" have already caused a substantial reduction of the CO_2 emissions at the Lampoldshausen site. The combined heat and power units cover almost the entire heat requirement of the site and have replaced the old oil-fired boilers. While the combined heat and power station is running, the electricity demand is also largely covered. The two electrolysers provide green hydrogen, thus

	CO_2 Reduction
H_2ORIZON BHKW	901 t/a
H_2ORIZON PEMEL	2.888 t/a
Zero Emission PEMEL	5.599 t/a
Overall reduction	**9.388 t/a**

Source: DLR

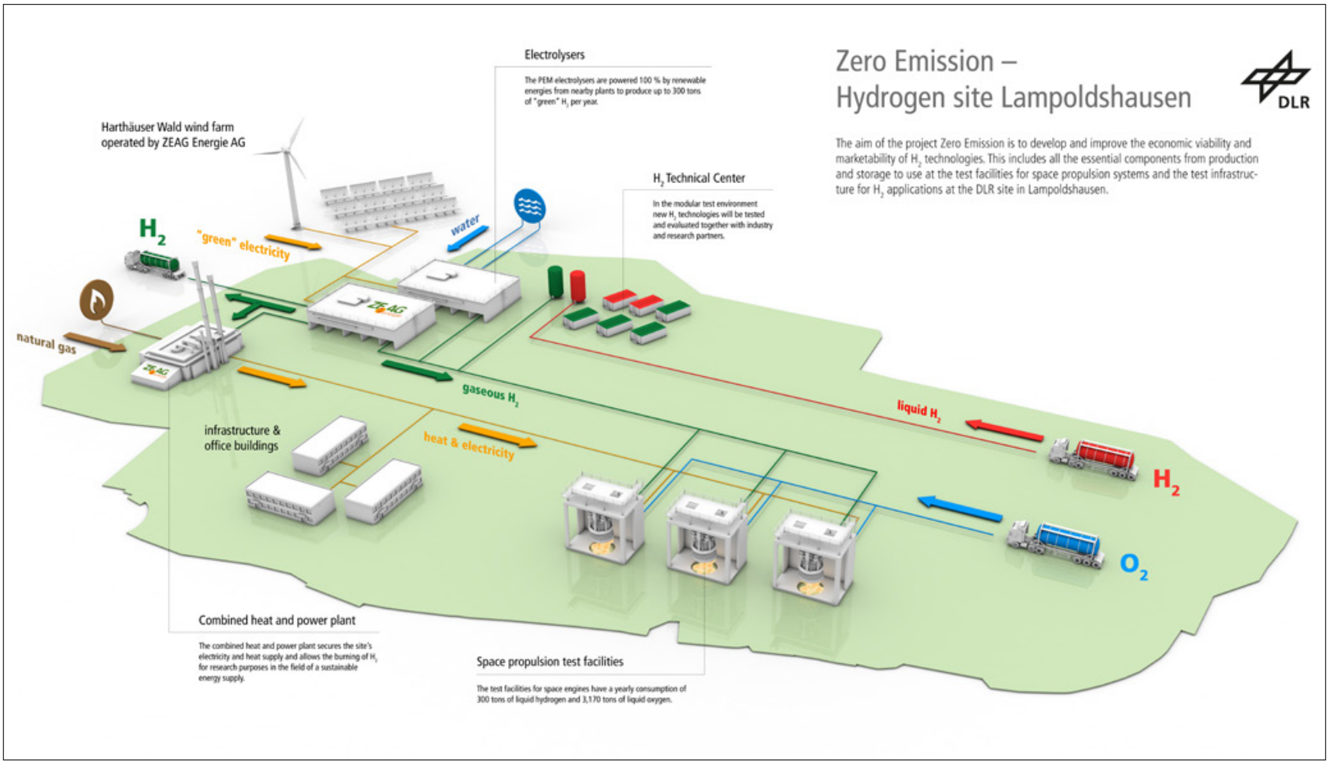
Overview of CO_2 savings in site supply substituting the gaseous hydrogen required for the rocket test stands that was previously obtained through steam reformation or had to be delivered and will later on also be used for the H_2 Technical Center and the Hydrogenium. This makes for annual savings totalling more than 9,300 t CO_2 – this corresponds to a reduction of 68 percent of the emissions caused by the DLR in Lampoldshausen.

Hydrogenium: Test, application and transfer center

Prerequisite for the hydrogen technology to be successful is a modern test infrastructure For this reason, the DLR is constructing another test, application and transfer center for small and medium-sized companies within the scope of the “Hydrogenium“ at the Lampoldshausen site. It will support the development and testing of hydrogen technologies to promote innovative solutions from the brainstorming stage to market maturity of systems and components.

The Heilbronn University of Applied Sciences, the Technical University of Munich (TUM), the Fraunhofer Institut für Arbeitswirtschaft und Organisation (IAO) and the DLR Institute of Space Propulsion are jointly working towards creating a test environment that is unique in Europe and makes use of gaseous and in particular large amounts of liquid hydrogen. At the same time, the DLR Institute of Space Propulsion introduces its decades of experience in the construction, planning and operation of large hydrogen systems, including all upstream and downstream processes such as risk analysis, simulation and test procedures.

Contact:
Michael Füting
Deutsches Zentrum für Luft- und Raumfahrt e. V.
Im Langen Grund
74239 Hardthausen
E-mail: michael.fueting@dlr.de
Internet: www.dlr.de



Source: DLR

Zero Emission – Hydrogen Site Lampoldshausen

Hydrogen Island Öhringen: Joint commitment for a climate-neutral heat supply

by **Dr Heike Grüner** (Netze BW GmbH)

With the project Hydrogen Island Öhringen, Netze BW together with the residents of the town of Öhringen in Baden-Württemberg demonstrate in a practical manner that already today, up to 30 percent of hydrogen can be fed into the natural gas grid – without the need for an expensive adaptation of the existing infrastructure. The article provides an overview of the course of the project and takes a look at the future development.

Source: Netze BW GmbH

System layout (from the right): spare storage, electrolyser and blending system (inside the container)

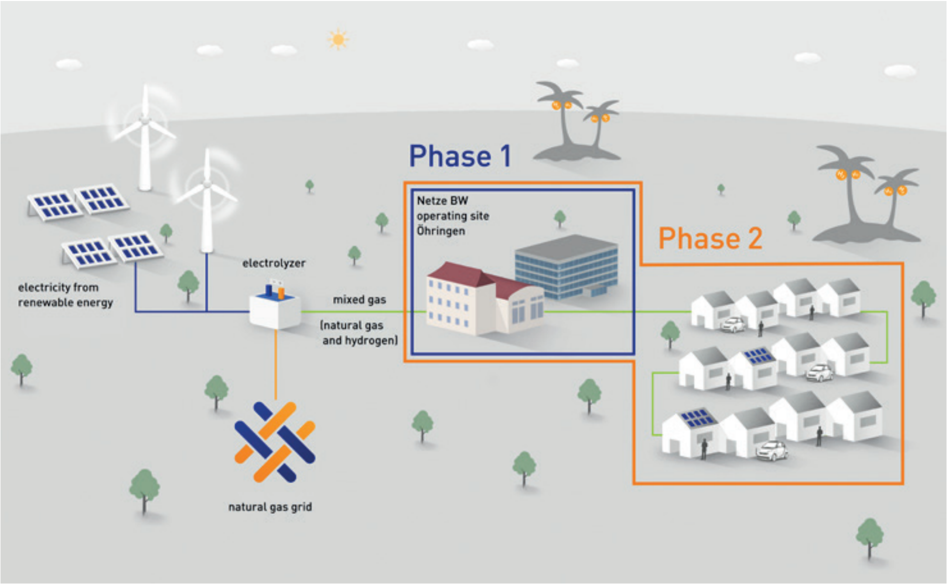
In the context of the project, the effects of increasing hydrogen percentages on the gas distribution grid and on the end consumer appliances under real conditions and taking into account all stakeholders (citizens, municipality, chimney sweeps, plumbers, fire brigade, etc.) are investigated. With a hydrogen content of up to 30 percent in the existing infrastructure (among others gas grid and gas appliances), the project is in this form so far unique in Germany.

The energy transition is mostly about wind turbines, PV systems, and electric cars. However, the heat supply is just as important, as it ranges among the sectors with the largest energy consumption in Germany. Netze BW would therefore like to gain important insights into how hydrogen can establish itself on the heat market in the future. Against this background, the company is testing already today the admixture and technical feasibility of 30 percent hydrogen in the natural gas grid. At the same time, a possible way of how the storage problem of renewable energies – a central challenge of the energy transition – can be solved is illustrated with the H_2. It is a fact that renewable energies are subject to strong fluctuations caused by the weather. If it is not possible to use the electricity in phases of high production levels, this leads to the shutdown of wind and photovoltaic systems.

Hydrogen can be of key importance in this regard: with excessive power that arises in corresponding weather conditions in the wind and photovoltaic power stations, hydrogen can be generated by means of electrolysis. The hydrogen can then be fed into the gas grid, where it can be stored and transported.

Project course

The hydrogen Island is based on the following principle: An area is disconnected from the existing natural gas grid, similar to an island. In this “island area“, which includes the owner-occupied property of the Netze BW and roughly 30 households, gradually up to 30 percent of hydrogen are added to the natural gas grid. In the future, the required hydrogen will be generated by an electrolyser located directly on the premises. In the process, water is split into its components hydrogen and oxygen. The power required to do so comes from renewable energies. In further systems, the hydrogen is stored temporarily, added to the natural gas grid and the resulting blended gas is fed into this “island grid”. The arena for this flagship project of the energy



Source: Netze BW GmbH

Phase model of the "Hydrogen Island" Öhringen

transition is Öhringen, a town in the north east of Baden-Württemberg.

Current status and prospects

In December 2021, Netze BW started phase 1 with the supply of its own premises. After gradually increasing the hydrogen percentage, the target of 30 percent was reached at the beginning of June 2022. Phase 2, which will integrate the surrounding households, will start in the summer of 2022. From this point onwards, the residents of this island area can make their personal contribution towards more climate friendliness.

Project goals

With this project, Netze BW is able to demonstrate that already today, the natural gas grid facilitates a climate-friendly power supply by means of regeneratively produced hydrogen and that a safe and reliable gas supply with less CO_2 emissions can be guaranteed through the use of regeneratively produced hydrogen. Thus, the natural gas infrastructure can in future serve as one of the building blocks of the energy transition as it can be used as storage reservoir for renewable energies.

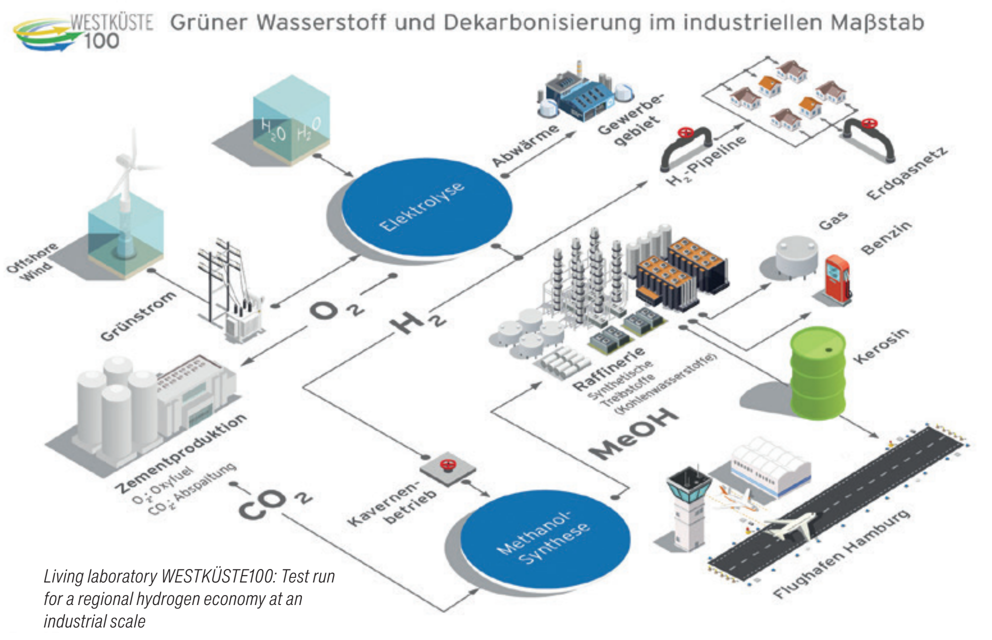
As a result, the CO_2 footprint of each individual for heating and cooking can be reduced, but industry and commerce/trade/tertiary sector) likewise benefit from a climate-friendly gas supply. The goal for the future: 100 percent regenerative hydrogen that can completely replace natural gas and make a contribution towards achieving the climate targets.

Challenges

The project is supported by several partners, from science and local crafts to industry – and not to forget by the citizens on the spot, who will be integrated during the second phase. Already during initial considerations and preparatory work it became clear that many stakeholders need to be involved in the project. The foundation is first of all that the consumers, i.e. the local residents in the island area, have to be able to comprehend the importance of the project so that they will lend their support by participating. In the course of an information evening, the project team explained the technology applied and the planned approach already early on. A close exchange with the participants is entertained throughout the entire test period. Fortunately, the project quickly received obvious support from the mayor, the town council and the citizens. However, a number of talks were necessary before the participant agreements could be signed.

Before the island can be turned into a nation-wide solution, many basic regulatory parameters will have to be adapted. The project Hydrogen Island wants to provide important insights in this regard and make a ground-breaking contribution.

Contact:
Dr Heike Grüner
Netze BW GmbH
Schelmenwasenstr. 15
70567 Stuttgart
E-mail: wasserstoff-insel@netze-bw.de
Internet: www.wasserstoff-insel.de



Living laboratory WESTKÜSTE100: Test run for a regional hydrogen economy at an industrial scale

Source: Thüga

Greener heating with hydrogen

by **Dr Kay Bareiß** & **Lisa Bauer** (both: Thüga Aktiengesellschaft)

Heating in a more sustainable manner in future: that is one of the goals of the living laboratory WESTKÜSTE100. Within the scope of the project, a regional hydrogen economy at an industrial scale is to be modelled and scaled. Especially at the west coast of Schleswig-Holstein, the preconditions for this project are unique: Here a region with strong wind energy and excellent geological storage conditions meets innovative companies, who want to actively shape the future and make an important contribution to achieving the climate protection goals.

As part of the living laboratory WESTKÜSTE100, the municipal utility Heide, Thüga and Open Grid Europe (OGE) are starting a model project for eco-friendly heating. To this end, hydrogen is to be gradually fed into a section of an existing gas grid, thus significantly reducing the CO_2 emissions. With this, they are delivering a blueprint for the decarbonisation of the gas grids.

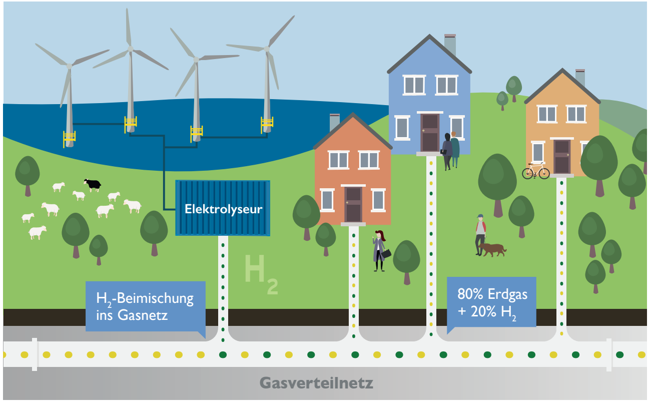
Around 200 households in a residential area in Heide are to be supplied with the natural gas-hydrogen blend. With this, Thüga and the Stadtwerke Heide want to demonstrate that the components of an existing gas grid in practice meet all the requirements for the injection of hydrogen. They show that the heat supply can be gradually converted to renewable gases - without requiring extensive investments into the gas grids or by the gas consumers. Apart from that, the project creates empirical values with regard to the supply characteristic of the new energy carrier on the heat market.

New pipeline technology in use

The hydrogen (H_2) is to be produced in a 30 megawatt (MW) electrolyser at the refinery Heide in Hemmingstedt – from renewable energies to live up to the "green" label. It then reaches the Stadtwerke Heide via a pipeline for 100 percent hydrogen with a pressure rating of up to 40 bar, which will be built by OGE. To this end, a novel pipeline technology is used to install a complete hydrogen infrastructure based on the model of the natural gas grid which will then be tested under real operating conditions. OGE investigates how hydrogen can be integrated into the existing gas infrastructure in the long-term.

Modern gas infrastructure "can do" hydrogen

On their premises, the Stadtwerke Heide plan to erect a gas injection facility, which precisely meters the hydrogen, adds it



Source: Thüga

Greener heating with hydrogen from regenerative energies: up to 20 percent of hydrogen are added to the natural gas

to the natural gas and injects it into the separate subgrid area. In the process, the H_2 percentage is to increase from initially 10 to up to 20 percent. At the core of "Greener Heating" is the proof that the decarbonisation of the heat sector can be initiated through the admixture of hydrogen, as the components of a modern gas infrastructure are suitable for hydrogen as far as leak tightness, corrosion resistance and the general material compatibility are concerned. Components include amongst others pipelines, the control equipment at the municipal utility, installation fittings and measuring instruments as well as terminal devices at the customers'.

No conversions required for domestic customers

The Stadtwerke Heide have chosen the grid section B-plan 48 because it can be separated from the rest of the grid with little effort. In addition, its low age and the materials installed in it are best suited for the purpose of hydrogen admixture in the planned magnitude. Conversions are not required as the existing gas systems are well suited and can, after testing, be used without problems with a blend of natural gas and hydrogen. The construction of a new tap line for the direct supply of the separated subgrid area with a H_2 natural gas blend has already started.

Safety check

In preparation for this, the DBI Gas- und Umwelttechnik GmbH, an independent testing institute of the gas sector will subject all gas systems (connection, heating, gas stove, boiler) in the households to a safety check and approve them for operation with hydrogen. Customers in the subgrid area can become acquainted with the project during an information event. No additional costs will arise for them through the project.

In addition, Thüga will, in cooperation with an independent testing institute, compile a measurement concept for the gas blend as well as innovative consumption billing, which rules out disadvantages for the end user. For this, a virtual simulation of the gas grid is being planned. This simulation is to be verified afterwards by measuring the gas composition during real-life grid operation. The Eichdirektion Nord is integrated in the project as supervising authority.

Living laboratory WESTKÜSTE100

The goal of the living laboratory WESTKÜSTE100 is the development and successful implementation of a regional hydrogen economy at an industrial scale. By means of wind energy and on the basis of a 30 MW electrolyser, green hydrogen is to be generated and used for industrial purposes through the interconnection of different sectors. To achieve this goal, regional and international companies from industry, development and research have joined forces to produce, store, transport and utilise green hydrogen. As a strong wind energy region with excellent geological storage conditions and innovative companies, who wish to actively co-design a climate-neutral future, the west coast of Schleswig-Holstein offers ideal conditions.

The living laboratory WESTKÜSTE100 offers the opportunity of accelerating the technology and innovation transfer from research into practical application. During the project life span from 2020 to 2025, technical, economic and regulatory problems and questions will be identified. As one of the first living laboratories undergoing a practical test, WESTKÜSTE 100 is particularly active in developing the basic regulatory framework for the use of renewable hydrogen in various sectors. Thus, critical development steps for the market launch and the use of hydrogen can be initiated. The project is funded with 36.5 million Euro by the Federal Ministry for Economic Affairs and Climate Action (BMWK).

Contact:
Lisa Bauer
Thüga Aktiengesellschaft
Nymphenburger Str. 39
80335 München
E-mail: lisa.bauer@thuega.de
Internet: www.thuega.de

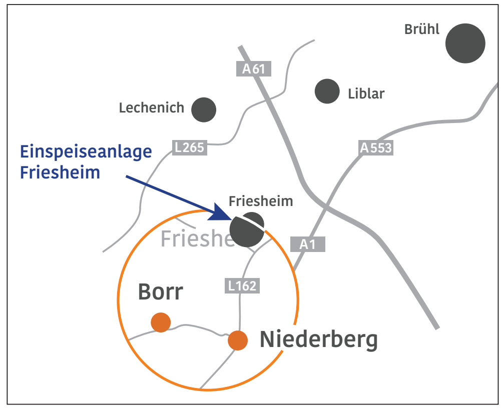
Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

H_2-MiX – Futurity in Erftstadt

by **Michael Thys** (GVG Rhein-Erft GmbH) & **Felix Schönwald** (Rheinische NETZGesellschaft mbH)

In Erftstadt-Niederberg and -Borr and in the industrial area Erftstadt-Friesheim, hydrogen is used for the first time in North-Rhine Westfalia for the heat supply of end users. Hence, up to 20 % (v/v) of H_2 is to be fed into the L-gas grid of the two districts of Erftstadt by late summer 2022 to supply local households with the hydrogen-natural gas blend. The pilot project H_2-MiX is a crucial step towards a climate-neutral heat supply. Before the injection facility feeds a proportional amount of hydrogen into the natural gas grid, the project partners will examine all materials and components of the grid down to the smallest detail. This also comprises the respective gas applications of the end users.

Source: GVG/RNG



Overview of the location of the project area

Masterminding this pilot project H_2-MiX are the GVG Rhein-Erft GmbH (GVG) and the Rheinische NETZ Gesellschaft mbH (RNG). Besides, the independent testing services provider TÜV Rheinland Energy GmbH actively supports them in implementing this project by providing them with its services.

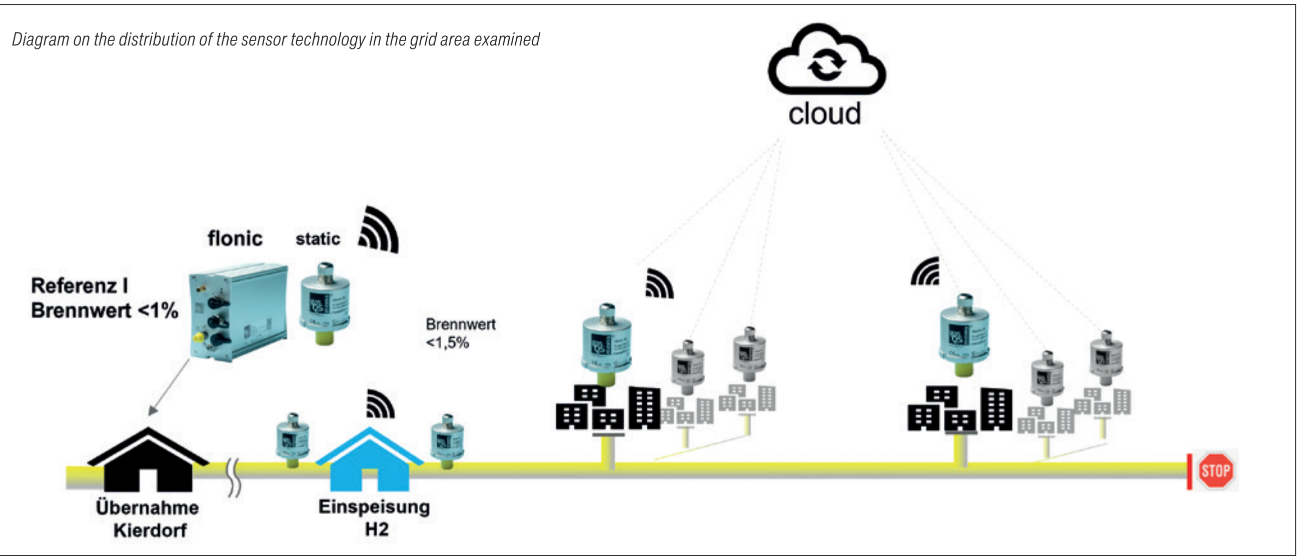
A successful energy transition that is on top of that affordable for the end users will only succeed if all available technologies are used where they are best suited. In this regard, hydrogen can for example play an important role on the heat market and the already existing gas infrastructure with a pipeline length in excess of 500,000 km offers ideal conditions to transport green hydrogen exactly there where it can be put to efficient use. In this context, pilot projects such as H_2-MiX are to demonstrate that an admixture of hydrogen can be quickly implemented without any difficulty. This is an important milestone on the road to a climate-friendly energy system of the future. A prerequisite for the fast launch of a functioning hydrogen economy is a stable demand and planning reliability for investments.

The two districts in Erftstädt selected for the project, Niederberg, Borr and the industrial area of Friesheim, are particularly well suited for the pilot project due to their grid structure and age: A total of almost 100 service lines are distributed along the pipeline length of altogether approx. 4.5 km, and these exclusively consist of single-and multi-family dwellings as well as commercial customers. Subscribers who might possibly be more sensitive to higher hydrogen admixtures (for example industrial customers or natural gas filling stations) cannot be found in the grid area. The grid to be examined is a terminal grid, which has been constructed from the year 2007 onwards and completely consists of PE 100. Thus, not only the pipeline materials installed are very well suited for the admixture of hydrogen, but the unilateral injection additionally makes it easier to monitor and track the gas blend in the grid. If unlikely irregularities occur during subgrid operation, the injection system is immediately switched off automatically and residents are once more supplied with natural gas.

To involve end users in the grid section concerned at an early stage, comprehensive information material was sent out in the run-up to the project. In addition, the project partners GVG and RNG invited them to several information events to give a detailed account on the project together with representatives of the TÜV Rheinland Energy GmbH and to respond to questions and concerns voiced by users. The events were very positively received and have made an essential contribution towards creating a broad basis of trust for the project.

For the concrete implementation, all grid components and materials as well as gas consuming appliances at the end users were recorded. After completion of this phase, a test gas (consisting among others of 23 % (v/v) of hydrogen) was used to individually test the customer systems for their hydrogen compatibility, faultless function and leak tightness. By the end of the year, the hydrogen content is to be gradually increased to a maximum of 20 % (v/v) of hydrogen.

Diagram on the distribution of the sensor technology in the grid area examined



Source: GVG/RNG

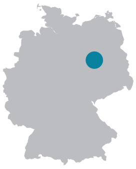
The company Schwelm Anlagentechnik GmbH was commissioned with the construction of the injection system. This system was implemented in a modular design so that the system is portable and can theoretically also be used in other grid areas of the RNG/GVG. The hydrogen is temporarily stored on the premises of the injection system in special hydrogen storage cylinders. The hydrogen used in the project has its origin in an industrial park in the region and arises in large amounts as a by-product of the so-called chlorine-alkali electrolysis. It is currently planned to start with the first phase of the injection during October 2022. Initially, the admixture is to be carried out over a period of approx. one year. However, it is currently already examined whether the period can be subsequently extended again.

The main focus of this examination is – apart from supplying the consumers during the heating period 2022/2023 – mainly on determining the life span of the hydrogen concentration in the natural gas grid. Apart from this, the use and testing of a sensor technology system that is resilient in terms of the legally required calibrations forms an essential ingredient of the project. For this purpose, state-of-the art correlative measuring systems were not only installed at the nearby transfer station and injection system, but also in the entire project area behind each branch and in each dead-end pipeline and in sections > 500 m. The devices do not directly determine the output values, but rather measure the thermal conductivity, thermal capacity and density of the gas blend. These values are used as input parameters for a correlation model to compute the calorific value and hydrogen content of the blend.

This technology facilitates a very dense and low-maintenance monitoring of the entire gas grid. A total of almost 30 of these sensors are used in the project area and their measurement data can be retrieved at any time in real-time via a corresponding cloud. This guarantees that not only the hydrogen concentration but also the calorific value can be continuously monitored across the entire project-area and project run time. Apart from the direct use of a sensor technology that is resilient in terms of legally required calibrations, the insights from the project also make an essential contribution to the digitisation of the infrastructure.

Contact:
Michael Thys
GVG Rhein-Erft GmbH
Max-Planck-Str. 11
50354 Hürth
E-mail: michael.thys@gvg.de
Internet: www.gvg.de

Felix Schönwald
Rheinische NETZGesellschaft mbH
Parkgürtel 26
50823 Köln
E-mail: f.schoenwald@rng.de
Internet: www.rng.de



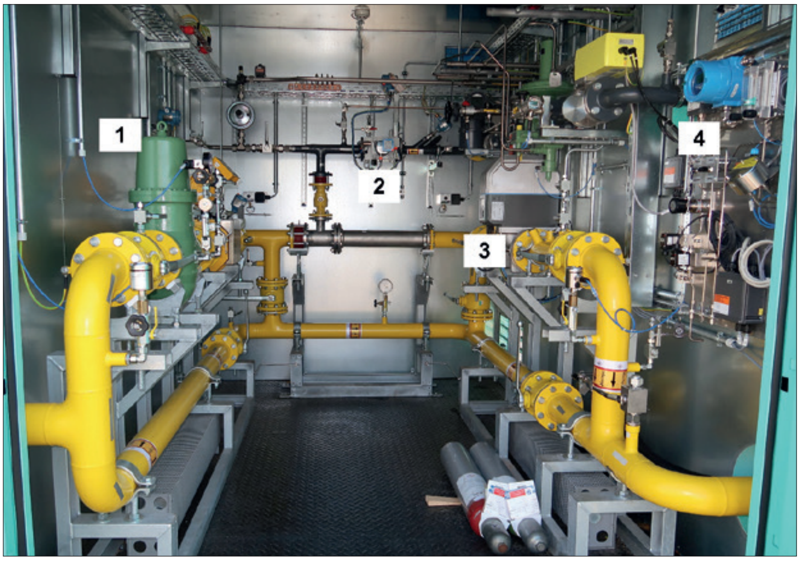
H2-20: Successful admixture of 20 % (v/v) of hydrogen in the model region Fläming

by **Dr Holger Dörr** (DVGW Research Center at the Engler-Bunte-Institute), **Angela Brandes** (Avacon Netz GmbH), **Dr Stefan Gehrmann** (DVGW e. V.), **Martin Kronenberger** & **Nils Janßen** (both: Gas- und Wärme-Institut Essen e. V.)

In the context of the project H2-20, the admixture of up to 20 % (v/v) of hydrogen to natural gas will be examined in the model region of Fläming for a total of 340 gas customers on a largely unchanged existing system. With this project, the CO_2 footprint of the energy carrier gas is to be reduced. Apart from a reduction of the CO_2 emissions, the admixture of hydrogen also exhibits positive effects on the quality of combustion, which is reflected in reduced CO and NOx emissions. No safety-relevant abnormalities occurred during the injection phases of 10, 15 and 20 % (v/v) of H_2.

As part of the hydrogen strategy of the DVGW, the admixture of up to 20 % (v/v) of hydrogen to natural gas is examined in the grid area of the Avacon Netz GmbH. The project H2-20 aims at demonstrating that the admixture in a largely unchanged existing system comprising gas grid, gas installations and gas appliance settings can already be applied now as part of the defossilisation in the gas sector, as diverse laboratory tests have shown. The project team of H2-20 includes the DVGW Research Centre at the Engler-Bunte-Institute as project coordinator and responsible for the analysis of the existing system, the grid operator Avacon Netz GmbH for the provision of the grid area, the construction and operation of the injection facility and the Gas- und Wärme-Institut Essen e. V. for the investigation of the customer systems in the model region. Numerous manufacturers of heating technology and further experts from the gas industry support the project with data analyses and service organisations.

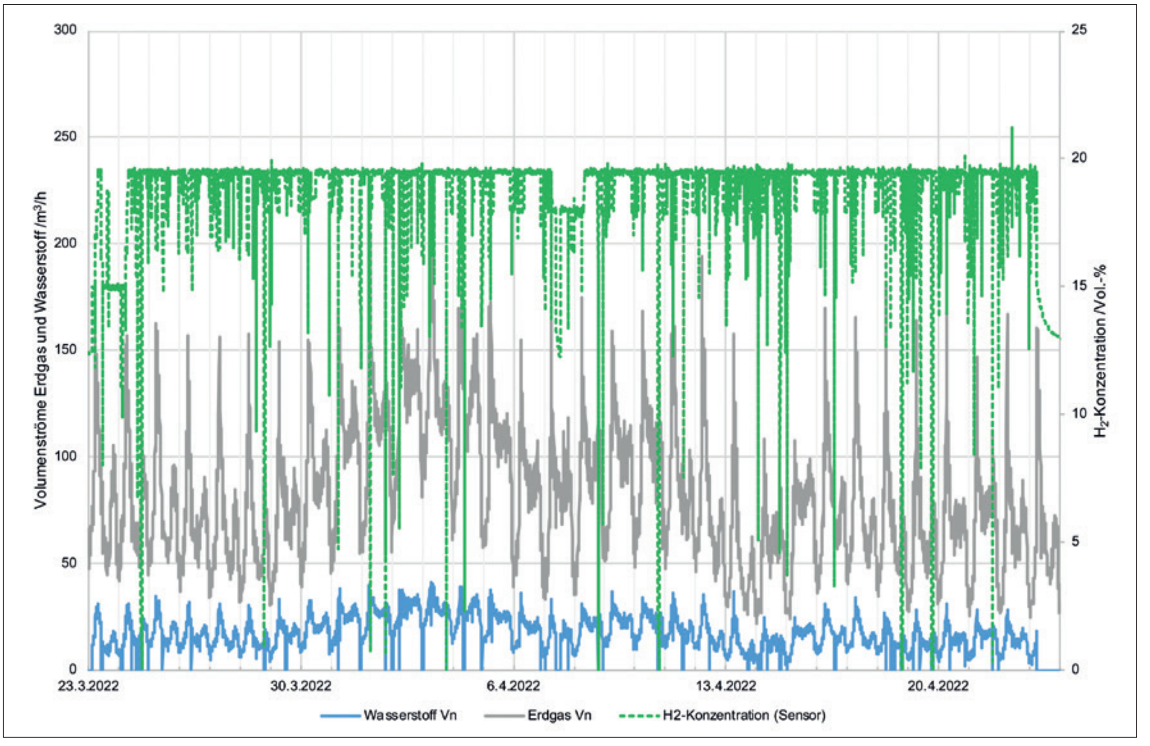
The model region Fläming is located in Saxony-Anhalt between Magdeburg and Berlin. This rural region is producing a great surplus in renewable power and – via various biomethane injection facilities – a high portion of renewable gases in the gas grid that was established in 1994. A delimited grid area for a single-side feed and a predominantly domestic gas use met amongst other things the selection criteria for this demonstration project.



Source: EBI

View into the injection facility in a 20-foot container with volumetric measurements for natural gas (1), hydrogen (2) and mixed gas (3). The continuous H_2 concentration measurement (4) is carried out via a tap line.

At a 20 % (v/v) H_2 admixture to natural gas, values fall short of the tightness requirements according to DVGW standard G 260, which is why according to section 4.2.2 of the standard, an individual assessment of the gas installations with the gas appliances is required. Within the scope of a coordinated safety concept, the gas distribution grid and all gas installations, including the gas appliances, were therefore surveyed "as is". As far as the gas appliances are concerned, measurements were made during operation with natural gas as well as with the hydrogenous test gas G 222 (23 % (v/v) H_2 in methane) under full load and, where possible, under partial load, to demonstrate the proper



Source: EBI

Curves of the volumetric flows of natural gas, hydrogen (left ordinate) and associated hydrogen concentration measurement (right ordinate) during the stage of 20 % (v/v) H_2 admixture that lasted four weeks

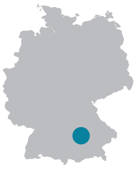
operation even when hydrogen is added. The measurement data of each gas appliance were screened and evaluated both by the project team and by the respective appliance manufacturer.

The injection facility for the project was implemented in a 20 foot container and dimensioned for maximum flows of 500 m³/h for natural gas and 100 m³/h H_2, which are recorded with suitable flow meters. Amongst others, H_2 measurements in the blended gas by means of a continuous H_2 sensor and an external intermittent PGC are integrated in the safety chain. The measurements of the PGC are also used in coordination with the calibration authorities and the Physikalisch-Technische Bundesanstalt (PTB) within the scope of fiscal gas billing.

The survey of the existing stock prior to injection yielded a bimodal age distribution of the gas appliances: The first mode from 1989 to 2009 is connected with the construction of the gas grid, while the second mode is characterised by modernisations of heatings from approx. 2010 in addition to some new systems. The distribution of output and load is - like the existing stock in Germany - mainly characterised by smaller heat generators below an output of 35 kilowatt (kW). For a total of eight appliances, excessive CO values were measured especially during partial load measurements with natural gas. The tightness tests of the gas installations yielded an unrestricted usability in 97.7 percent of the gas installations, while eight gas installations exhibited a restricted usability with leakage volumes between 1 and 3.9 l/h. The rectification of the 16 defects was documented within the scope of the safety concept.

During the heating season 2021/22, hydrogen was added in increments of 10, 15 and 20 % (v/v). On the spot, more than 250 random sample measurements were taken to determine the leak tightness of the gas installation also with the hydrogenous blended gas, the hydrogen content and the emissions were measured and the proper function was checked. During random sampling and from the feedback of customers, no safety-relevant abnormalities could be determined during the injection phases. So far, the project H2-20 has shown that an admixture of up to 20 % (v/v) of H_2 in a largely unchanged existing system in the model region is possible and safe. Besides, for comparable grids, the admixture of H_2 practised as an ad-hoc method is already today in many places able to flexibly integrate renewable hydrogen into the public gas supply.

Contact:
Dr Holger Dörr
DVGW Research Centre at the Engler-Bunte-Institute
Engler-Bunte-Ring 5
76131 Karlsruhe
E-mail: doerr@dvgw-ebi.de
Internet: www.dvgw-ebi.de



Hydrogen project H2Direkt: H_2-based heat supply demonstrates sustainability of the gas distribution grids

by **Julia Leopold** (Energie Südbayern GmbH)

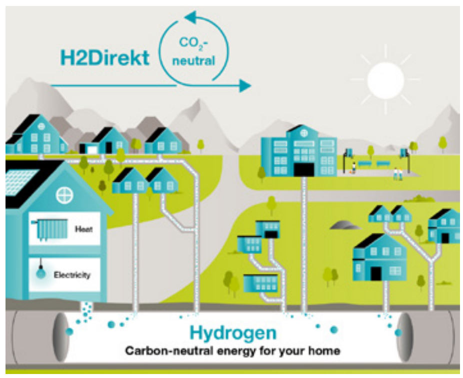
The conversion of an existing gas grid to 100 percent hydrogen will be tested within the scope of H2Direkt, as part of the TransHyDE project “Safe infrastructure”. In doing so, those involved in the project not only want to gain practical experience with a pure hydrogen grid, but also draw up a universally valid conversion guideline, which can serve as blueprint for similar projects. The article introduces the project H2Direkt and explains the conversion approach.

The climate change is one of the central challenges of our time. Lowering greenhouse gas emissions turns into an elementary task in this connection, in which the heat sector plays a crucial role because even today, fossil fuels such as oil, gas or coal are still predominantly used to heat buildings. At the same time, the heat supply makes up more than 50 percent of the German final energy consumption and thus carries great weight in the greenhouse gas balance.

Accordingly, the heat sector must make its contribution towards the energy transition. A key factor for this is hydrogen, because no harmful emissions arise through its use as energy carrier. The focus is here on green hydrogen, which is generated with power from renewable energy sources and will in future be able to replace fossil natural gas.

The goal: Heat supply with 100 percent hydrogen via an existing gas grid

Against this background, H2Direkt is one of the most important pilot projects in Germany to demonstrate the sustainability of the gas distribution grids and to develop a blueprint for a decarbonised heat supply. In the innovative field test, Energie Südbayern GmbH (ESB) and Thüga AG are repurposing an existing natural gas grid of the Energienetze Bayern (ENB) for the use with 100 percent hydrogen. There are already subgrid areas in Germany where within the scope of research projects, up to 30 percent of hydrogen are added. H2Direkt takes the next step and implements a heat supply with 100 percent hydrogen. With that, the gas infrastructure can make a contribution to the energy transition. Also in view of the current discussions around the security of supply, green hydrogen offers a clear perspective. ESB and Thüga share the results of the research project with the roughly 100 partner companies of the Thüga Group. With that they are making an important contribution to create the technical and social basis for the sustainable conversion of 511,000 km of gas pipelines in Germany.



Source: Thüga AG/ESB GmbH

As innovative, research project, H2Direkt investigates the 100 percent supply with hydrogen

The project partners

In this project, Energie Südbayern is responsible for the implementation and on-site technical support of the field test. Contractual matters and billing are also the responsibility of ESB, who act as direct contact for the test households. The Energienetze Bayern GmbH & Co. KG (ENB) in turn is the grid company in the group of companies of the ESB and the largest regional gas distribution grid operator in south Bavaria. Thüga supports with conceptual and operative technical expertise

Source: ESB GmbH

Planned grid section for the conversion: the new housing estate "Am Kerschberg II" in the municipality of Markt Hohenwart

and experiences gained from previous research projects for the conversion of distribution grids to hydrogen.

Project implementation and conversion measures

The conversion of the gas grid to hydrogen takes place in Markt Hohenwart in the building zone "Am Kerschberg II". The site offers very good conditions, because it is a young gas grid that can be easily separated and only few components need to be replaced. A total of ten households and one nursery as commercial customer will be provided with 100 percent of hydrogen for initially 18 months. Whether a continued supply will be possible afterwards will be evaluated in the course of H2Direkt – the declared aim is the continued operation taking into consideration the insights gained from the project. Currently, H2Direkt is in the conception phase. The conversion measures are planned for 2023, the heat supply with hydrogen will begin at the start of the heating period 2023/24. The aim is the exclusive use of green hydrogen.

The hydrogen grid is designed for island operation: A part of the existing natural gas grid is separated from the rest and separately supplied with hydrogen. No pipes need to be replaced for this. On site, a hydrogen trailer and an injection facility are set up; the hydrogen will be transported on trucks in tube bundle reservoirs. The injection facility contains a pressure control and an odorisation system. In the households, all gas components are checked for their H_2 compatibility. Customary condensing boilers can handle a certain percentage of hydrogen – however, for a conversion to 100 percent it is necessary to replace the existing gas systems. Components like meters, gas pressure regulators, gas flow detectors and service entry combinations are checked and where necessary replaced.

Universally valid conversion guideline

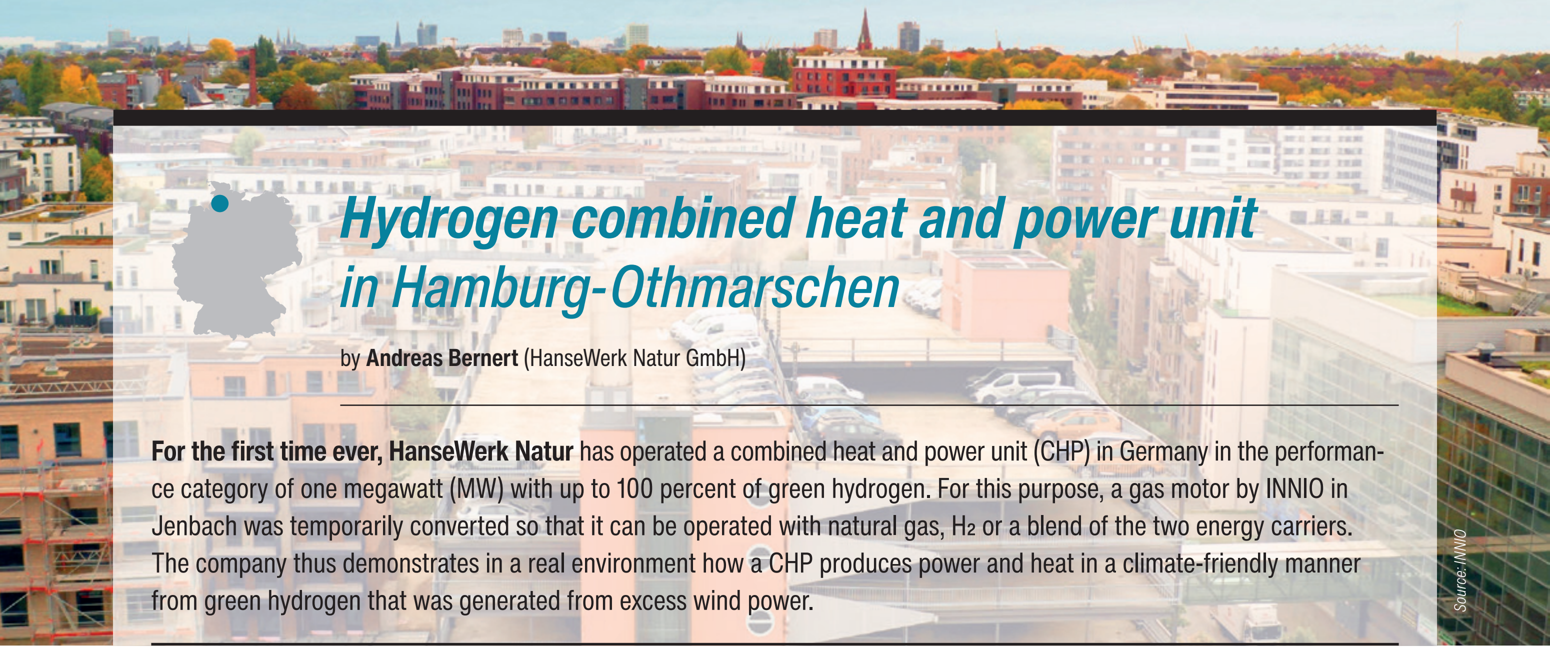
H2Direkt creates a basis for the future role of the gas grids. At a technical level, accident safety, reliability and service life of distribution grids that are operated with 100 percent H_2 are under review. To this end, an innovative gas sensor technology is tested; in addition, a specific, tested safety concept as well as a measuring and billing system for hydrogen are developed. ESB and Thüga are bundling all technical and organisational processes into a guideline, which puts on record a universally valid path for converting the gas infrastructure to transport hydrogen. Besides, H2Direkt increases the level of information with regard to alternative heat technologies and thus also customer acceptance.

Well-known partners with many years of experience

For H2Direkt, ESB and Thüga trust in the expertise of well-known partners with many years of experience: The company Vaillant will produce and install the H2 condensing boilers for the participating households, the research institute DVGW-EBI and the keep it green GmbH support the project implementation as scientific service providers who also deal with the planning aspect. H2Direkt is sponsored with funds of the Federal Ministry of Education and Research (BMBF) and as cluster within the TransHyDE project "Safe infrastructure" forms part of the hydrogen flagship projects of the BMBF.

Contact:
Julia Leopold
Energie Südbayern GmbH
Ungsteiner Str. 31
81539 München
E-mail: julia.leopold@esb.de
Internet: www.esb.de

Thüga – Das große Plus der Gemeinschaft
Energienetze Bayern – Ein Unternehmen der ESB Gruppe
ESB ENERGIE SÜDBAYERN
Leitprojekt TransHyDE
GEFÖRDERT VOM Bundesministerium für Bildung und Forschung



During the field test, this district in Hamburg-Bahrenfeld was supplied with heat from the H_2 CHP by HanseWerk Natur.

Source: INNIO

Hydrogen combined heat and power unit in Hamburg-Othmarschen

by **Andreas Bernert** (HanseWerk Natur GmbH)

For the first time ever, HanseWerk Natur has operated a combined heat and power unit (CHP) in Germany in the performance category of one megawatt (MW) with up to 100 percent of green hydrogen. For this purpose, a gas motor by INNIO in Jenbach was temporarily converted so that it can be operated with natural gas, H_2 or a blend of the two energy carriers. The company thus demonstrates in a real environment how a CHP produces power and heat in a climate-friendly manner from green hydrogen that was generated from excess wind power.

In the context of sector coupling, the hydrogen was used locally in Hamburg to operate charging stations, to feed power into the grid and to supply a total of 30 residential buildings, a day-care facility for children, a sports facility and a recreational centre with heat. At the same time, several test series in the years 2020/21 yielded important insights for the implementation and feasibility of the H2 operation. With this, HanseWerk Natur sets the course for a greener, safer, more flexible and forward-looking power supply.

Unique features of the project

According to its manufacturer INNIO, the H_2 CHP is the first motor worldwide in the size class of one megawatt, which can be operated with 100 percent green H_2. For the field test, the gas motor was converted in the real field to mixed operation with H_2 or natural gas-H_2. Besides, the system is equipped with separate H_2 peripheral equipment. In contrast, previous projects only worked with a clearly lower H_2 admixture to the natural gas and/or in inconsiderably lower performance categories.

The test series were carried out in a real operating environment in the urban area. It is the first motor that was converted to hydrogen operation in the field. With this field test, HanseWerk Natur prepared for a future CHP operation which obtains green H_2 from pure hydrogen grids.

First test series: Feasibility

After the CHP motor had been operated exclusively with natural gas during the first few weeks after its start-up, HanseWerk Natur tested various H_2 percentages as well as pure H_2 operation during its first test series in autumn 2020. Within the scope of this test series, various systems were tested during H_2 and mixed operation, motor settings were adjusted and the safety features and equipment monitored. A total of 828.13 kg of hydrogen (72 cylinder bundles, each with a useful capacity of 11.5 kg each) were used in this test series.

The technical breakthrough had been achieved when it was possible to operate the motor for several hours with hydrogen without failure – the feasibility of a 100 percent operation with H_2 in the real field has thus been demonstrated. In this test series, a CHP motor in the size class of one MW was for the first time operated with 100 percent of H_2. Besides, this test series yielded that the operating costs of the CHP with natural gas, H_2 or a blend of the two fuels are approx. the same. Only the fuel costs for the use of green H_2 are currently still too high for an economic operation due the regulatory requirements.

Second test series: Efficiencies

During the second test series in autumn 2021, HanseWerk Natur then placed the focus on efficiencies. Compared to the first test series, it was here possible to achieve an increase in performance: The performance has thus increased by roughly 10 percent, during peak load operation even by more than 20 percent.

During the test series, the electrical efficiency during mixed operation with natural gas and hydrogen ranged at 43.1 percent. For comparison: With natural gas, the CHP had previously reached an electrical efficiency of 42.4 percent. Thus, HanseWerk Natur not only achieved the goal of operating the combined heat and power unit with the same efficiencies in mixed operation with natural gas and H_2 as in operation with natural gas, but was even able to increase it slightly.

Potential for increasing the percentage of renewable energies

The H_2 CHP can in future play a key role in the energy transition to help achieve the goals of the Federal Government to achieve climate neutrality by 2045. If enough power is available in the grid, the CHP is switched off to relieve the grid and the heat is temporarily made available through boilers. If, on the other hand, there is too little power in the grid, the CHP feeds power into the grid and with this regulatory energy guarantees an adequate power supply. For this purpose, HanseWerk Natur has established a virtual power station with 70 systems in Northern Germany, which - depending on demand - reduces or increases the production of power.

As soon as regulatory requirements permit, green H_2 would perspectively be used as preferred fuel for the operation of CHP motors, which is made available through pure hydrogen grids. If too little H_2 is available, natural gas could be used as an interim.

With the two successful test series, HanseWerk Natur has created the prerequisite to operate its CHP fleet, which currently comprises more than 200 motors, with H_2 in the future, as soon as regulatory requirements permit. According to DVGW specifications, a maximum of 10 % admixture of H_2 is permitted in the natural gas grid to date, at surrounding natural gas filling stations this percentage is even as low as 2 percent. If in future, higher H_2 percentages are permitted in the natural gas grid (so that H_2 does not enter the combustion chamber via a separate fitting, but simultaneously with the natural gas), the CHP motor would also be equipped for this. Valves and gaskets would then have to be of a different consistency and a different control software would be required in the motor.

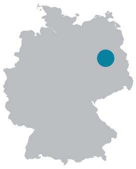
To date, operating a motor with 100 percent green H_2 is not yet economical. An important leverage would be the exemption from levies for the generation of green hydrogen from excessive wind power. It is expected that the H_2 percentage in the gas grid of currently maximum 10 percent may in the foreseeable future rise to 20 percent.

Through this pipeline, the green hydrogen enters the combustion chamber.

The gas motor by INNIO in Jenbach was temporarily converted for the field test.

Soon, a lot will happen in Hamburg to facilitate the production and the transport of H_2. Apart from Hanse-Werk's plans to build and operate an electrolyser with a 25 MW output in the port of Hamburg, a first pure H_2 grid with a length of 60 km is also planned in the Hanseatic City of Hamburg, which is to be constructed by 2030. With its three heating grids in Hamburg, HanseWerk Natur would thus be an ideal consumer of the hydrogen to generate climate-neutral heat for the households and industry of Hamburg. The simultaneously generated power can be fed into the grid in the context of sector coupling. Apart from that, district solutions with pure H_2 grids are conceivable in the future, for which HanseWerk Natur can use the insights gained from the field test for the operation of further pure hydrogen motors. With the insights from its field test, HanseWerk Natur can thus powerfully advance the energy transition and also supports the Freie und Hanse-stadt Hamburg in achieving its climate targets.

Contact:
Andreas Bernert
HanseWerk Natur GmbH
Am Radeland 25
21079 Hamburg
E-mail: presse@hansewerk.com
Internet: www.hansewerk-natur.com



Hydrogen from methane: Hotel MOA in Berlin creates negative CO_2 balance for the heating process

by **Dr Jens Hanke** (Graforce)

The hotel MOA Berlin and the Berlin technology company Graforce, a specialist for sustainable and economic hydrogen technologies, have jointly implemented a trend-setting project: With the plasmalysis project developed by Graforce, the MOA Berlin generates its heat in future not only emission-free, but even contributes to decarbonising the air – to date, a worldwide unique case.

Source: Graforce

The Mercure Hotel MOA Berlin is located in the heart of the district of Moabit.

In December 2019 the Senate of Berlin was the first federal state to proclaim a climate emergency. In this connection, the German capital city has set itself the goal to optimise the Berlin CO_2 balance faster to act in a climate-neutral manner already before 2050. This can only succeed with an improved energy efficiency, reduced demand for CO_2-intensive products and services and the use of decarbonising technologies in all sectors. The heat sector plays an important role in this regard, because currently the energy required for heat and hot water still generates a five-fold higher consumption than the entire power consumption. This circumstance shows how urgently action is required.

The MOA Berlin is an upscale design and conference hotel of the Mercure Group with a total of 336 rooms and more than 40 conference rooms, spread over more than 7,500 m² and three storeys. The five heating boilers used there have a heat capacity of 314 kilowatt (kW) each and have emitted up to 800 t CO_2 per year. To absorb this volume out of the atmosphere would in purely mathematical terms require more than 65,000 trees – 25 % more trees than can be found in the entire district of Berlin Tiergarten.

The solution: The plasmalysis project by Graforce

This solution works thanks to the methane-plasmalysis process developed by Graforce. It decomposes methane with very little energy input into hydrogen and solid carbon. In doing so, a high-frequency electric field is generated from solar or wind energy and methane is split into its molecular components hydrogen (H_2) and carbon (C). Thus, 4 kg of methane and 10 kilowatt hours (kWh) of power are turned into 1 kg of hydrogen and 3 kg of elementary carbon. With this, a zero-emission heat generation without combustion is achieved. The hydrogen can then be directly used in hydrogen CHP or SOFC fuels cells for the production of CO_2-free heat and power. What's more: Unlike electrolysis which splits water into hydrogen and oxygen by means of electricity, plasmalysis decomposes molecular compounds into different basic materials, thus saving up to 75 % of electric power. From the hydrogen, the hotel produces emission-free energy by means of modified gas condensing boilers by Viessmann and a combined heat and power unit.

The elementary carbon, the so-called carbon black, is a valuable raw material, which is used in paints and ceramics, by the electric industry or – as in the case of the MOA Berlin – to produce bitumen. In the process, the CO_2 contained in the methane is not released any more, but is permanently bound in products. Graforce has thus for the first time succeeded in developing a marketable technology for the reduction of CO_2 and an alternative to the carbon capture storage (CCS). If biogas is used during the methane plasmalysis, where plants have withdrawn CO_2 from the air beforehand, the CO_2 balance is even negative.

The implementation: Green heat at guest request

For its new, ecological heat generation, the MOA Berlin uses modified gas condensing boilers. The methane plasmalysis system regulates the mixing ratio for the heating boilers: Heat

Source: Graforce

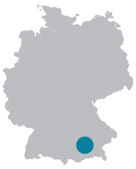
Close-up view of the plasmalysis system

generation starts off with a blend of up to 30 % (v/v) of hydrogen and 70 % (v/v) of biogas or natural gas. This is on the one hand achieved with the methane plasmalysis process using a gas blend and on the other hand through the combustion control “Lambda Pro Control” by Viessmann, which measures the ionisation current directly in the flame. The current in turn indicates the combustion quality and thus provides for an efficient and low-emission combustion. The MOA initially operates two of the five Viessmann heating boilers with a blend of natural gas and hydrogen. In this manner, the CO_2 emissions with pure natural gas are reduced by about 7 percent. In future, the heat supply is to be covered with hydrogen alone – and thus the CO_2 emissions reduced to zero.

The benefits

The project demonstrates impressively that each individual can make a contribution to climate protection: The guests at the MOA Hotel can chose during check-in whether their room is heated with hydrogen from natural gas or with biogas and thus make an active contribution towards relieving the atmosphere by up to 800 t CO_2 per year. Due to its enormous market and climate potential, the innovative system concept was awarded the Innovation Prize of the German gas economy in autumn 2020.

Contact:
Dr Jens Hanke
Graforce GmbH
Johann-Hittorf-Str. 8
12489 Berlin
E-mail: info@graforce.de
Internet: www.graforce.de



The future is taking place: Real H_2 projects

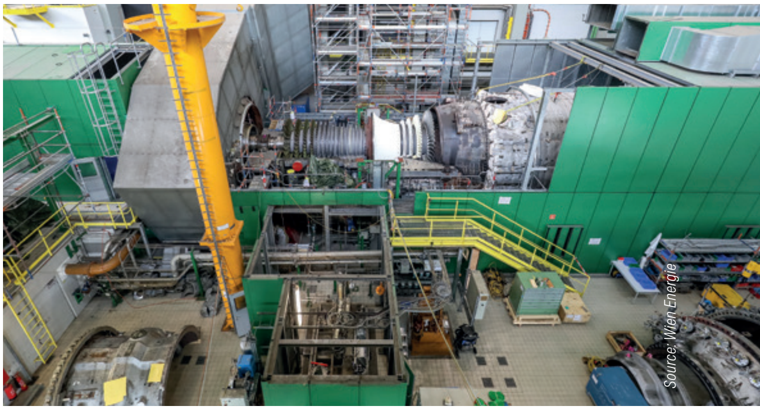
by **Ertan Yilmaz** & **Erik Zindel** (both: Siemens Energy)

The renunciation of fossil energy carriers in the context of the energy transition will see to it that in future, gas turbines will be increasingly fuelled with the energy carrier hydrogen. In this context, the article introduces several H_2 projects, where existing turbines are already today repurposed for the use with hydrogen.

In the years to come, power stations that are fuelled with green hydrogen will be brought on line, thus pointing the way into the decarbonised future. There are still only a few pilot projects, but they demonstrate the feasibility of the technology and provide energy producers with important insights as to how the energy transition can succeed. “Hyflexpower” is the name of the project which will be the first worldwide to operate a commercial power station with up to 100 percent of hydrogen. It will supply a factory in Saillat-sur-Vienne in France, which is specialised in the manufacture of recycling paper. The modernised 12-MW power station is to be operated with green hydrogen for the first time in 2022. The hydrogen is first gained from renewable energy, is then stored and when needed reconverted into power. The project will start off with an H_2 admixture to the natural gas and subsequently the hydrogen content will be gradually increased to 100 percent. This is to save 65,000 t of CO_2 per year.

Real H_2 projects worldwide

The energy transition will not make thermal power stations obsolete. On the contrary: During phases when no renewable energies are available, power stations that can step into the breach to cover the power demand will still be needed. However, they should as far as possible not use any fossil fuels and ultimately generate CO_2-neutral power. Therefore, in recent years, the focus has increasingly shifted to power generation by means of green hydrogen. In this way, power is to be generated during dark doldrums and a contribution is to be made to stabilising the energy system and increasing its flexibility. Thus, hydrogen is an important building block for climate-neutral energy generation and the energy transition. Another reason is that it is able to decarbonise other areas of the economy – such as industry, buildings or mobility.



The gas turbine at the power station Donaustadt is prepared for the use of hydrogen.

A project such as Hyflexpower thus deserves attention. This is also mirrored by the fact that a consortium consisting of Siemens Energy and eight other companies and universities is involved in its implementation with the assistance of the EU. However, this is by far not the only project that demonstrates how gas turbines can be operated with hydrogen. These projects can be found in South America, Germany, but also in Austria.

A power station assists Vienna in becoming climate-neutral

At the power station Donaustadt in Vienna, Siemens Energy, RheinEnergie, Wien Energie and the Austrian power company VERBUND are also planning to fuel a gas turbine with a hydrogen blend from 2023 onwards. Initially, 15 percent (v/v) of green hydrogen are added to achieve an annual saving of roughly 33,000 t of CO_2. It is planned to double this amount afterwards. It is the first project where an existing gas power station is retrofitted with a class-F turbine for the use of green hydrogen. With that, the project supports the plan of the city of Vienna to become climate-neutral by 2040.

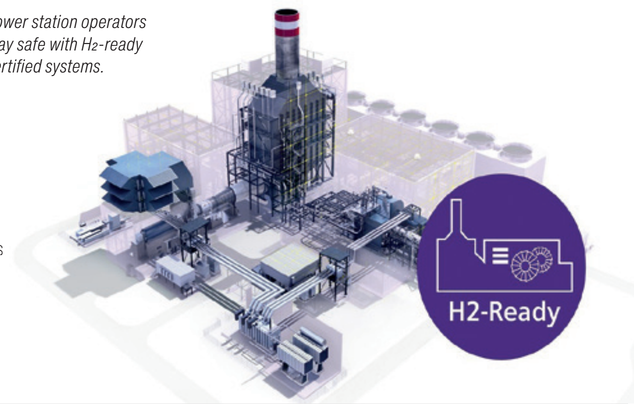
Up to 100 percent of hydrogen

Even if the underlying business model is still fossil energy, the combustion of this gas blend still leads to a significant reduction of greenhouse gases.

Ultimately, two new gas turbines for the combined heating and power station Leipzig Süd will be installed in Leipzig, which are to be operated first with up to 30 percent (v/v) of green hydrogen and with up to 100 percent of hydrogen energies in the long-term. However, real projects as the ones mentioned will surely not be where this development stops. All large manufacturers of gas turbines have asserted that they will deliver gas turbines by 2030, which are able to fire up to 100 % of hydrogen. Depending on the turbine type, already 30 to 75 percent (v/v) are possible at Siemens Energy. For this to work, the gas turbines and power station systems need to be adapted. However, the greater reactivity of hydrogen is a challenge: The much higher flame velocity of hydrogen blends leads to the flame moving upstream in the direction of the burners. This distinctly increases the risk of a flashback. The hydrogen combustion can also lead to higher nitrogen oxide emissions. Furthermore, hydrogen has a negative influence on certain materials due to the so-called "hydrogen embrittlement". The team at Siemens Energy has therefore optimised the design of the gas turbine burners for the use of hydrogen with the aid of 3D-printing. Other components of the gas turbine such as guide vanes or heat shields were adapted.

Development of the European distribution grid for hydrogen

Of course, an optimised gas turbine on its own does not make a "hydrogen summer". What is needed are financing programmes, which promote the generation of hydrogen at a large scale. One example of this is the REPowerEU programme, which wants to bring about the independence of the EU from fossil fuel imports and to promote the development of green H_2. By 2030 a minimum of 20.6 million t of green hydrogen therefore are to be produced. At the same time, today's state-of-the-art of the hydrogen industry can be compared with the inception of wind and solar energy. To ensure that an adequate amount of green hydrogen and other climate-neutral fuels are available, the production of renewable energy and of electrolysis systems is to be increased further, while at the same time, production costs must be decreased.



Power station operators play safe with H_2-ready certified systems.

Source: Siemens Energy

The infrastructure for the distribution and storage of hydrogen is also still largely missing today. Together with more than 30 infrastructure operators, the European Hydrogen Backbone initiative has made it its mission to change this – it wants to massively expand the European distribution grid for hydrogen. All this will not come about without the support of the regulatory authorities. They need to abbreviate approval procedures, stipulate decarbonisation targets and promote business models which create financial incentives for investments.

H_2 readiness certificate

If a new gas power station is erected today, it will not be possible to fire it with green hydrogen. However, given the typical service life of such a system, it is very probable that a later conversion to hydrogen will be required. Therefore, a plant has to be constructed with foresight so that the later conversion will be technically possible at acceptable costs. At the same time, operators can assure themselves that they are on the right track. The TÜV SÜD has developed an international certificate for "H_2 readiness" for gas power stations to be newly constructed, which ensures that they will be able to convert their new system to complete hydrogen combustion at a later stage. As is demonstrated by the first pilot projects, this is not only technically feasible – the future is already taking place.

Contact:
Sabine Sill
Siemens Energy Global GmbH & Co. KG
Rheinstr. 100
45478 Mülheim an der Ruhr
E-mail: sabine.sill@siemens-energy.com
Internet: siemens-energy.com

Source: Maximilian Kamps/Agentur Blumberg GmbH

Climate-neutral urban quarter – new western city of Esslingen

by **Jörg Eckert** (Stadtwerke Esslingen)

Within the scope of the research project "Climate-neutral urban quarter – new western city of Esslingen", a trendsetting energy concept is being realised at urban quarter level in Esslingen on the Neckar, a town in Baden-Württemberg. As part of the project it is possible to convert excess green power on the spot into green hydrogen by means of an electrolyser. This power is stored and turned into useable power for the quarter, for an emission-free mobility and for industry.

On the site of the new western city in Esslingen an urban quarter with showcase character comprising 450 dwelling places, office and commercial spaces as well as a new building for the Esslingen University of Applied Sciences is coming into being on an area of 100,000 m². Within the scope of the research project "New western city – climate quarter" a sustainable energy concept is to be implemented at urban quarter level. Using power-to-gas (PtG) as key technology, excessive green energy is converted into green hydrogen and prepared for gas grid injection, for use in the mobility sector and in industry.

Core of the technologically innovative urban quarter is the energetic supply concept that provides for a coupling of the sectors power, heat, cooling and mobility. To this end, a central supply infrastructure with energy centre is to be built in the middle of the quarter. The heart of this centre is an electrolyser that converts excessive green power (generated locally and nationally) to hydrogen, (H_2) thus turning the energy into a commodity that can be stored. The regenerative hydrogen produced in this manner is then used in the mobility and industrial sector and can additionally be fed into the existing

Source: Maximilian Kamps/Agentur Blumberg GmbH

The H_2 storage reservoir is an essential component of the energy centre.

natural gas grid. For this, it is planned to build a H_2 bottling station, a hydrogen filling station and a gas grid injection station in the quarter. If at a later stage, the urban quarter once more requires power, the hydrogen can be quickly and easily reconverted into electricity by means of combined fuel and heat units. This grid-stabilising operation of electrolysers is considered an important building block in the context of transforming the German energy system into a purely renewable power supply.

Apart from the goal of achieving a high degree of self-supply from renewable sources, the waste heat arising during the electrolysis process is fed into a local heat grid to increase the overall efficiency. Thereby, the efficiency can be raised from approx. 55 to 60 percent to a level of 80 to 85 percent. This infrastructure covers the demand for heating and warm water of the buildings and through the integration of adsorption refrigeration system in summer enables cooling energy to be made available.

The electrolyser system has a size of 1 megawatt (MW). At approx. 4,500 hours of full use and a system-serving mode of operation, the electrolyser produces around 2,800 MWh of hydrogen per year (Ø 250 kg/d). Roughly 600 MWh per year of useable waste heat are then available from the electrolysis process. For the year-long full supply with heat, it is planned to install a bi-fuel CHP in the energy centre (natural gas: 300 kW, H_2: 138 kW) and in addition a natural gas peak load boiler. The individual blocks are supplied with heat from the underground energy centre via a local heat grid (in total ~ 1.400 MWh per year).

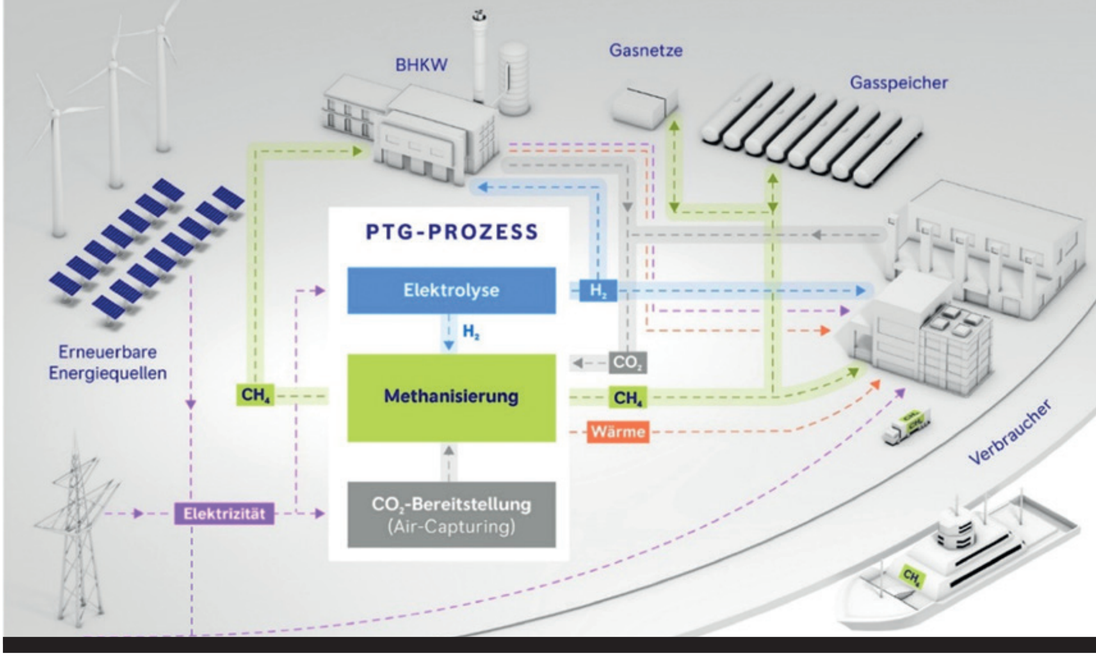
Utilisation of hydrogen

The system-serving utilisation of the regeneratively produced hydrogen takes place through local and national marketing channels. It serves the temporally and sectorally decoupled use in the fields of heat, power, mobility and in industry. The energy of a small portion of the hydrogen produced can be directly utilised in the energy centre. If in times without adequate supply with photovoltaic power, the buildings in the urban quarter require power and heat, the hydrogen can be quickly and easily reconverted into electricity by means of the bi-fuel CHP (H_2 and natural gas).

To be able to convey the green hydrogen to uses outside the quarter, a H_2 bottling station and a hydrogen filling station will be constructed in the "new western city" on the former premises of the Stadtwerke Esslingen. During the first expansion stage, the hydrogen will be transported via a pipeline from the energy centre to the gas grid injection and the H_2 bottling station. The better part of the hydrogen (100 to 400 kg per day) is to be loaded onto trailers with tube bundle reservoirs at a bottling station from where it will be transported to customers in the industry or public transport sector on trucks. At a pressure of 200 bar, such a truck trailer has a volumetric capacity of approx. 400 to 500 kg. Depending on the operating mode of the electrolyser, this results in a collection of the trailers once a day or every two days. H_2 quantities that cannot be marketed by means of trailer filling are fed into the natural gas grid.

During the second expansion stage, a complementary H_2 filling station is used to refuel individual vehicles. On the vehicle side, refuelling the passenger cars requires a pressure level of 750 bar. To generate a corresponding demand in this regard, a great number of potential customers needs to be activated. Potential consumers are amongst others fuel cell vehicles of private people, of fleet operators (for instance mobility sharing providers, municipal vehicles) or of companies maintaining their own pool of vehicles.

Contact:
Jörg Eckert
Stadtwerke Esslingen
Fleischmannstr. 50
73728 Esslingen am Neckar
E-mail: J.Eckert@swe.de
Internet: www.swe.de



Source: Erdgas Südwest GmbH

Schematic diagram of a regional energy system

Regional zero-greenhouse gas emission strategies on the example of the model region Upper Swabia (RegioTransH_2O)

by **Dr Armin Bott** (Erdgas Südwest GmbH)

In order to shape the energy transition in Germany as effectively and cost-efficient as possible, it is always necessary to take into consideration and involve already existing infrastructures, the local potentials of stakeholders and regional energy productions. In this connection, the project RegioTransH_2O is to map the energy system as model, with the aid of which different strategies can be simulated and relevant decisions taken.

According to the European Green Deal and the climate protection law, ambitious goals to accelerate the energy transition and to contain the climate change have been specified by politics. These goals are openly designed and must now be implemented in measures and spatial allocation. It can be put on record that in order to succeed, the energy transition requires national solutions, but in particular also fast regional solutions, to master the central challenges of the energy transition – to store and distribute the regenerative power gained from sun and wind and the chemical energy carrier hydrogen produced from it in all sectors. Here, the direct and indirect storage of electricity from renewable energies can minimise the shut-down of wind power and photovoltaic systems in times when there is a lot of wind and sun and also cost-intensive re-dispatch measures that use fossil fuels for power generation. Therefore this research project investigates the complex task of transforming a fossil energy system into a regenerative energy system from the technical side at a regional level as far as the distribution of power, gas and heat are concerned.

Project goals

When implementing regional measures to achieve the energy transition, the local potentials of stakeholders, the existing infrastructure and the regional power generating facilities must be taken into consideration to guarantee a secure and efficient power supply at minimum costs. The success of this complex task can no longer be efficiently guaranteed by planning that only considers a specific sector. For this reason, the project RegioTransH_2O is to map the energy system in a model and simulate it for future developments. The simulation method offers the advantage that different situations with different developments can be compared and used for strategic decisions.

This means, that from the results, regional strategies to accelerate the defossilisation and to achieve climate neutrality of the regions examined are to be developed later on, while taking into consideration existing grid structure and consumer stock and integrating regional potentials for the generation of renewable energies. Dependent on the strategies, business models for the stakeholders, for example energy providers and energy producers, municipal utilities and industry, are to be derived. The focus of the work will be on the integration of biomethane and regenerative hydrogen. At the same time, it is to be demonstrated that a selective use of hydrogen can serve as nucleus for a region and generates regional added value. Another focal point of the investigation is the identification of synergies to increase the efficiency in the region and to make proposals regarding the use taking into consideration the economic viability.

Model description

The heart of these investigations will be a modelling of the region. The model will on the one hand determine the energy demand of the consumers and interlink the producers of power, heat, biomethane and hydrogen with for example weather data and business models via power, heat and gas grids. To this end, different modelling tools are coupled with each other via a co-simulation platform to achieve flexibility with regard to different specialised modelling tools and to make use of the particular advantages. Within the scope of RegioTransH_2O it is planned to use Mosaik as co-simulation platform and Modelica, Stanet and PandaPower as modelling tools.

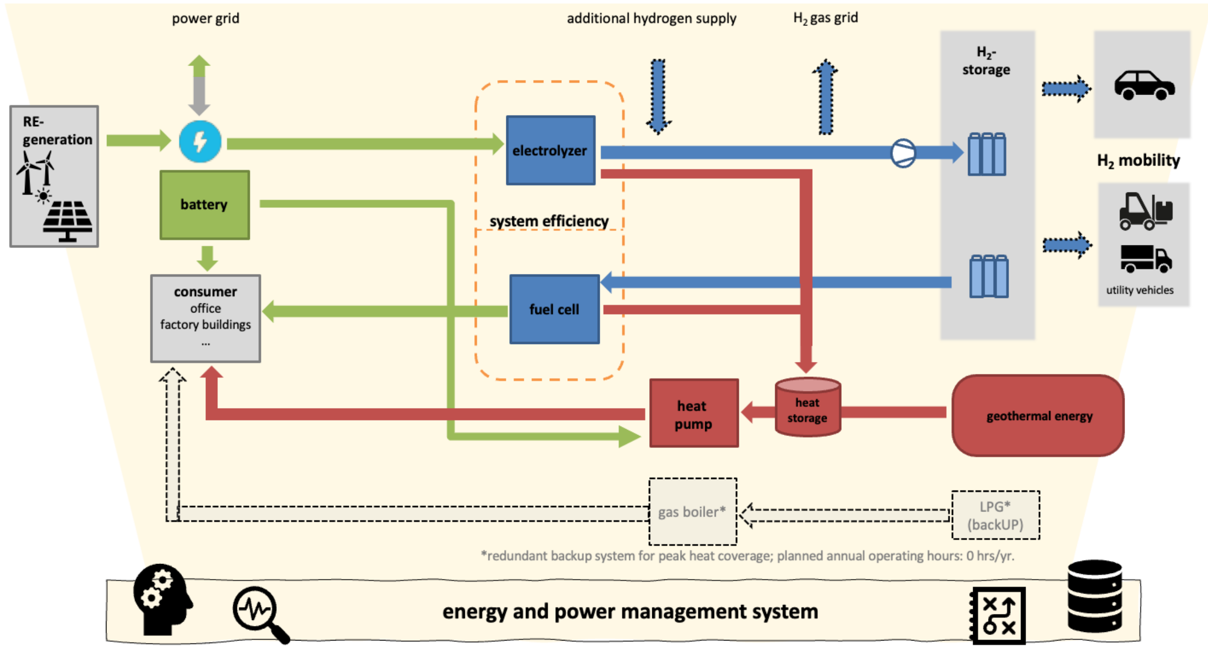
Modelica is used for the dynamic simulation of energy systems, consumers, producers and facilities for cross-sectoral analysis. Here, sluggishly responding components can be easily and resiliently simulated jointly with fast reacting components. The gas and heat grids will be mapped with the commercial modelling tool Stanet and the power grids with the open source modelling tool PandaPower. These modelling tools that are specialised in power grids are based on GIS data (geo information system). Thus, they can for instance transfer the time delays occurring during the energy transport from real areas to the modelling environment and are also specialised in the mapping of static and dynamic grid conditions. Hence, they are able to detect for instance problematic grid conditions, which in turn can lead to measures in the energy system via the regulation of the modelling environment. As simulation result, the models make available costs and energy flows as well as bottlenecks in the grid. From this, energy storage needs and, among others, also development needs of the infrastructure can be derived.

Work schedule

The research project starts with the comprehensive provision of the actual data for the administrative districts to be considered at this point in time for model development, and for parameterisation of the start point and for model verification. In this connection, three administrative districts are analysed in a very detailed manner and six administrative districts in a simplified manner. The energy system models of the administrative districts to be considered are compiled in parallel. The developments that are regionalised in scenarios from literature (for instance BMWi long-term scenarios) to the administrative districts in RegioTrans-H_2O, are afterwards implemented in the models.

After completion of the preparatory work, the simulation of the three administrative districts analysed is then carried out. Subsequently, one of the three administrative districts is selected, by means of which it will be tested which input data are mandatory for compiling a model and simulation and which are not essential, without diminishing the quality of the result too much. Based on this simplification strategy, the remaining six administrative districts are modelled and simulated. Afterwards, the results are consolidated and evaluated to propose measures and business models and to present a road map for the transformation of the administrative districts towards a zero-greenhouse gas energy system.

Contact:
Dr Armin Bott
Erdgas Südwest GmbH
Siemensstr. 9
76275 Ettlingen
E-mail: a.dr.bott@erdgas-suedwest.de
Internet: www.erdgas-suedwest.de



Source: GWI

Hydrogen-based, integrated power and heat system at the Gifhorn site

Innovative hydrogen concepts in stock clusters

by **Wolfgang Köppel** (DVGW Research Centre at the Engler-Bunte-Institute of the KIT)
& **Janina Senner** (Gas- und Wärme-Institut Essen e. V.)

A central challenge of the energy transition is the storage of regeneratively produced power from sun and wind. An intelligent energy concept, for instance on the basis of hydrogen, with adequate storage capacity is required for the optimised use of these energies. At the level of the quarter, cross-system power supply concepts, which combine the direct use of power from renewable energies with the use of green hydrogen, are therefore aimed at.

The conversion of quarters, peripheral company locations and industrial sites to renewable energies is increasingly becoming a challenge in attempting to meet the escalating requirements on emission reductions and ever rising CO_2 costs. At the same time, security of supply, affordability and timely implementation have to be taken into consideration as premises to be able to implement a year-round integrated heat and power supply with renewable energies. To be able to make the volatile peaks in photovoltaic and wind generation storable and thus compensable all year long, the focal point will particularly shift to the use of hydrogen technologies. Following the boundary condition that hydrogen is, at least at the start of the introduction, a shortage resource, urban quarters with a high benefit that can be implemented easily and quickly should be selected. These requirements are for instance met by industrial areas that can then serve as nucleus for a further expansion.

Project goals

In the context of the project HyBEST, different concepts of a hydrogen-based power supply are examined on the example of three industry clusters with applications available there. The objective is to make industry and commerce and the connected infrastructure compatible for a flexible provision of H_2 and to examine which measures are necessary for this and how these perform in the implementation phase. This is examined within the scope of the project at three sites and put into practice:

- Technical Centre Herten – Hydrogen on experimental R&D-platform: Experimental studies to prepare the implementation and validation of the simulation environment

- Industry cluster Gifhorn – Hydrogen in the urban quarter: Implementation of an energy storage and supply system at the regional waste management centre
- Industry cluster Karlsruhe – Hydrogen in the harbour quarter: Conceptual design and implementation of a heat concept in an existing quarter characterised by industry/commerce

Within the scope of scientific monitoring, the implementation of the hydrogen technologies within the industry clusters will be supervised. In this connection, digital twins will, amongst other things, be developed for the sites to perform a detailed technical-ecological analysis of the combined technologies and to test further options and adaptations that cannot be transferred to practice. The objective is the assessment of greenhouse gas reductions and to evaluate the cost-benefit ratio and to develop an intelligent system operating strategy. Efficiency, constraints and experiences during installation and operation of the systems were documented, so that potential imitators could benefit from it so as to accelerate the activation of further stakeholders for a climate-neutral power supply. In addition, the implemented options are compared and evaluated in a superordinate examination and generalised so they can be transferred to other sites and in particular to industry clusters and are then finally expanded by further options and scenarios. To this end, sample quarters are defined based on industrial areas customary in Germany, which are then virtually equipped with different scenarios and combinations of technology.

Implementations and objectives for the clusters

The main intention for the site in the administrative district of Gifhorn is the implementation of a hydrogen-based energy system, which guarantees a virtually climate-neutral operation of the regional waste management centre with integrated power and heat supply. Through the photovoltaic system that has an electric capacity of 234 kilowatt (kW), the hydrogen storage and the re-electrification, a high degree of self-supply can be achieved with regenerative energy. With this technical set-up, the site positions itself sustainably and future-proof with regard to potential cost increases for the avoidance of CO_2 or for purchases of fossil power and gas. With the implementation of the planned energy system, the following assumptions are to be validated in the project:

- Improvement of the CO_2 balance and reduction of grid power purchases
- Reduction of CO_2 emissions by 39 t to approx. 2 t CO_2/a
- Improvement of the cost/income situation against the background of declining feed-in remunerations for photovoltaics
- Technically and economically optimum solution (It is expected that the power and heat requirement of the building can be covered with highest efficiency (η > 85 %) through the consistent utilisation of all energy flows and the use of a sophisticated energy and performance management system.)
- System benefit (relief of superordinate power grids by not feeding in power during peak hours)
- Perspectival, further application and connection options for instance mobility applications can be used (for instance H_2-operated forklift trucks)

For the industrial area in the Rhine harbour of Karlsruhe the research project MethGrid (funding code: 03EIV045) found that an industrial area is particularly well suited for the use of hydrogen. The provision of power to meet peak demands and the use of waste heat have a large potential to optimise the energy supply, which could be increased in an even more efficient manner precisely by the use of sector-coupling hydrogen technologies. It must be clarified in this connection how an existing cluster that is supplied with methane can be repurposed for the use with hydrogen in ongoing operation. To this end, a flexible mixed operation with fluctuating methane-hydrogen blends must be allowed for during a transition phase. These aspects are to be investigated in the industrial area Rhine harbour of Karlsruhe. In this project, the following objectives are aimed at:

- Improvement of the CO_2 balance: Replacement of a conventional natural gas CHP with an innovative generating plant with H_2 (blend) operation
- Expected reduction of the CO_2 emissions by at least 24 t CO_2/a (at 4.000 full load hours/a)
- System benefit for the relief of local power grids
- Fast implementation of greenhouse gas reduction objectives without the necessity of redesigning complete energy systems

Contact:
Wolfgang Köppel
DVGW-Forschungsstelle am Engler-Bunte-Institut
Engler-Bunte-Ring 1–9
76131 Karlsruhe
E-mail: koeppel@dvgw-ebi.de
Internet: www.dvgw-ebi.de

The hydrogen grid in the living laboratory SmartQuart

by **Dr Sahra Vennemann** (E.ON SE), **Jürgen Hammelmann, Dietmar Ewering, Carsten Stabenau** &
Dr Stefan Stollenwerk (all: Westnetz GmbH)

How renewable energy for heat, power and industry can be intelligently coupled to the mobility sector is demonstrated by the urban quarter in Kaisersesch by means of H_2 technologies. There, a H_2-based microgrid for the entire value-added chain is planned and implemented. Renewable power is converted to green hydrogen in a power-to-gas system, stored and then distributed to users who use the green hydrogen on the spot for the mobility, heat and industrial sector. The necessary infrastructure is to be set up by the end of 2022, so that two years of test operation under real conditions can follow from 2023.

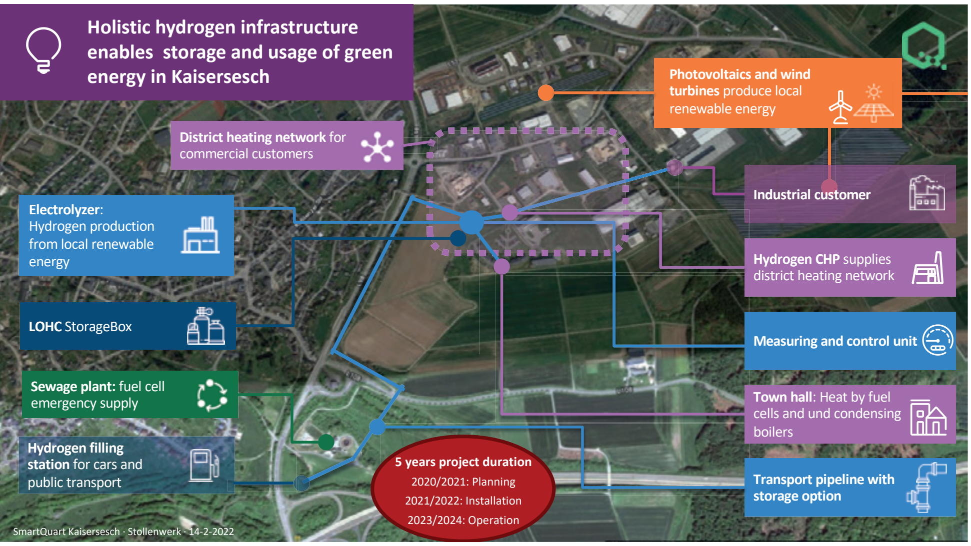
Kaisersesch is one of three urban quarters in the living laboratory of SmartQuart that is funded by the Federal Ministry for Economic Affairs and Climate Action and demonstrates the potential of hydrogen for the energy transition. Behind this project is the idea that hydrogen can be used as a multifunctional storage for renewable energies to link the most important consumption sectors. For the energy carrier to develop its full potential in this regard not only requires the necessary imports, but also the local capacities for renewable energies to be massively expanded on the production side. In addition, both existing gas infrastructures for hydrogen or hydrogen-based fuels must be upgraded and new pure H_2 infrastructures created.

Value-added chain

This is where the project SmartQuart in Kaisersesch comes in. In the association of municipalities, the entire value-added chain from generation, conversion and storage to distribution and utilisation is demonstrated by the development of a H_2 infrastructure. The objective is to integrate regenerative generating plants in the close proximity to keep the added value in the region and to be able to use any excess power where applicable. Currently, several options to purchase power are investigated. Considerations range from the development of own open photovoltaic spaces to purchasing stock exchange electricity with suitable proof of origin. This model could be supplemented by existing photovoltaic roof systems in the region of the association of municipalities that soon no longer qualify for EEG subsidies.

The renewable power will supply the electrolyser as an essential component of the hydrogen infrastructure. The power-to-gas system will achieve a H_2 production rate of 200 standard cubic metres per hour with a power connection capacity of 1,000 kilowatt (kW), which corresponds to a daily production of approx. 400 kg. The generated hydrogen will then fill a transport pipeline that reaches the various ultimate consumers in the territory of the association of municipalities. The pipeline is made of steel, will have a nominal diameter of 250 mm and be dimensioned for a pressure stage of 70 bar. With this, a storage function is to be created that guarantees a consistent supply with hydrogen even during a possible dark doldrum and can thus serve as blueprint for future hydrogen infrastructures.

At the southern end of the pipeline, directly at the exit to Kaisersesch on the motorway A48, a motorway service station with hydrogen filling station that can be supplied by the main pipeline is currently in the planning stages. On the part of the administrative district of Cochem-Zell, which organises the public transport in the region, the conversion of the local bus route 713 to hydrogen is contemplated and this could provide for a basic utilisation of the H_2 filling station. Further projects aim at a hydrogen-based emergency power supply of the neighbouring sewage treatment plant. In addition, the project partner Viessmann will equip the town hall of the association of municipalities at the north eastern end of the transport line with hydrogen fuel cells to provide the base load heat supply and a hydrogen condensing boiler to cover peak loads. A local CHP manufacturer located in the immediate vicinity of the town hall is preparing a green district heating grid for the supply of neighbouring crafts businesses and commercial enterprises on the basis of a hydrogen CHP. For this, an existing natural gas-operated CHP must be converted to hydrogen operation.



Source: Westnetz

Overview hydrogen infrastructure

For the supply of the ultimate consumers, low pressure service lines made of PE and PA12 are planned to test the suitability of different materials and joining techniques. The use of the LOHC technology (liquid organic hydrogen carrier) of the project partner Hydrogenious Technologies will in addition create the possibly to use the hydrogen produced far away from the accessibility of the transport pipe. The Franconian start-up has developed a method by means of which the hydrogen can be chemically stored in an oil and will build such a storage system in Kaisersesch. The bound hydrogen can then be transported by means of trailer to a far away release unit by means of which the hydrogen is reclaimed. For a possible usage option, E.ON supports a study which the responsible Administrative Union Regional Rail Transport Rhineland-Palatinate North has commissioned to investigate the conversion of a train route to the transport of hydrogen.

Storage simulation

For the design of the transport pipeline and to determine potential load profiles for the power-to-gas system, simulations of the microgrid were created on the basis of various purchasing scenarios. To this end, both real operating data and standard load profiles were consulted for all potential consumers. Depending on the purchasing scenario, there are different effects for storage level and degree of filling of the pipeline in the course of the year. If all potential consumers are fully supplied, the storage capacity of the pipeline in the winter months will for longer periods reach the agreed minimum fill level of 10 percent, although the electrolyser is operated at full load. In this case, a prioritisation of the supply must take place. As all potential customers have an existing power supply, the security of supply would not be jeopardised at any time.

Summary

The construction, approval and operation of the infrastructure primarily serves to gain experience with a hydrogen infrastructure including possible end uses. A blueprint for sector coupling in urban quarters and apart from that an optimised use of energy within and between the quarters is to be created.

Within the scope of the project SmartQuart, Kaisersesch will be linked with the two other urban quarters in Bedburg and Essen. The overarching goal: To make the use of fossil energy carriers largely redundant there by means of innovative solutions and products. At SmartQuart, a total of eleven project partners and associated partners are working towards this goal: E.ON (consortium manager), E.ON Energy Solutions, gridX, Hydrogenius LOHC Technologies, RWTH Aachen University, town of Bedburg, town of Essen, Association of Municipalities Kaisersesch, Viessmann, H_2 Mobility and RWE.

Currently, many challenges still have to be overcome in this regard. As power-to-gas is not yet economically viable due to the current general regulatory framework, the underlying potential business models must be drawn up and evaluated on the basis of various conceivable scenarios under the Renewable Energies Act. Furthermore, bodies of rules and regulations and legislation on the injection of hydrogen are partly not yet existent or not consistent. The greatest challenge of this project is therefore not solving the technical tasks, but in fact coping with these normative challenges.

Contact:
Jürgen Hammelmann
Westnetz GmbH
Collingstr. 2
41460 Neuss
E-mail: juergen.hammelmann@westnetz.de
Internet: www.westnetz.de

Verbandsgemeinde Kaisersesch

Bundesministerium für Wirtschaft und Klimaschutz

IMPRINT

Publisher:
DVGW Deutscher Verein des Gas- und Wasserfaches e. V. –
Technisch-wissenschaftlicher Verein
Josef-Wirmer-Str. 1–3, 53123 Bonn
Phone: 0228 9188-5, Fax: 0228 9188-990
E-mail: info@dvgw.de, Internet: www.dvgw.de

Publishing house and distribution:
wvgw Wirtschafts- und Verlagsgesellschaft
Gas und Wasser mbH
Geschäftsführer: Stephan Maul, M.A.
Josef-Wirmer-Str. 3, 53123 Bonn
Phone: 0228 9191-40, Fax: 0228 9191-498
E-mail: info@wvgw.de, Internet: www.wvgw.de

Editor:
Prof. Dr. Gerald Linke

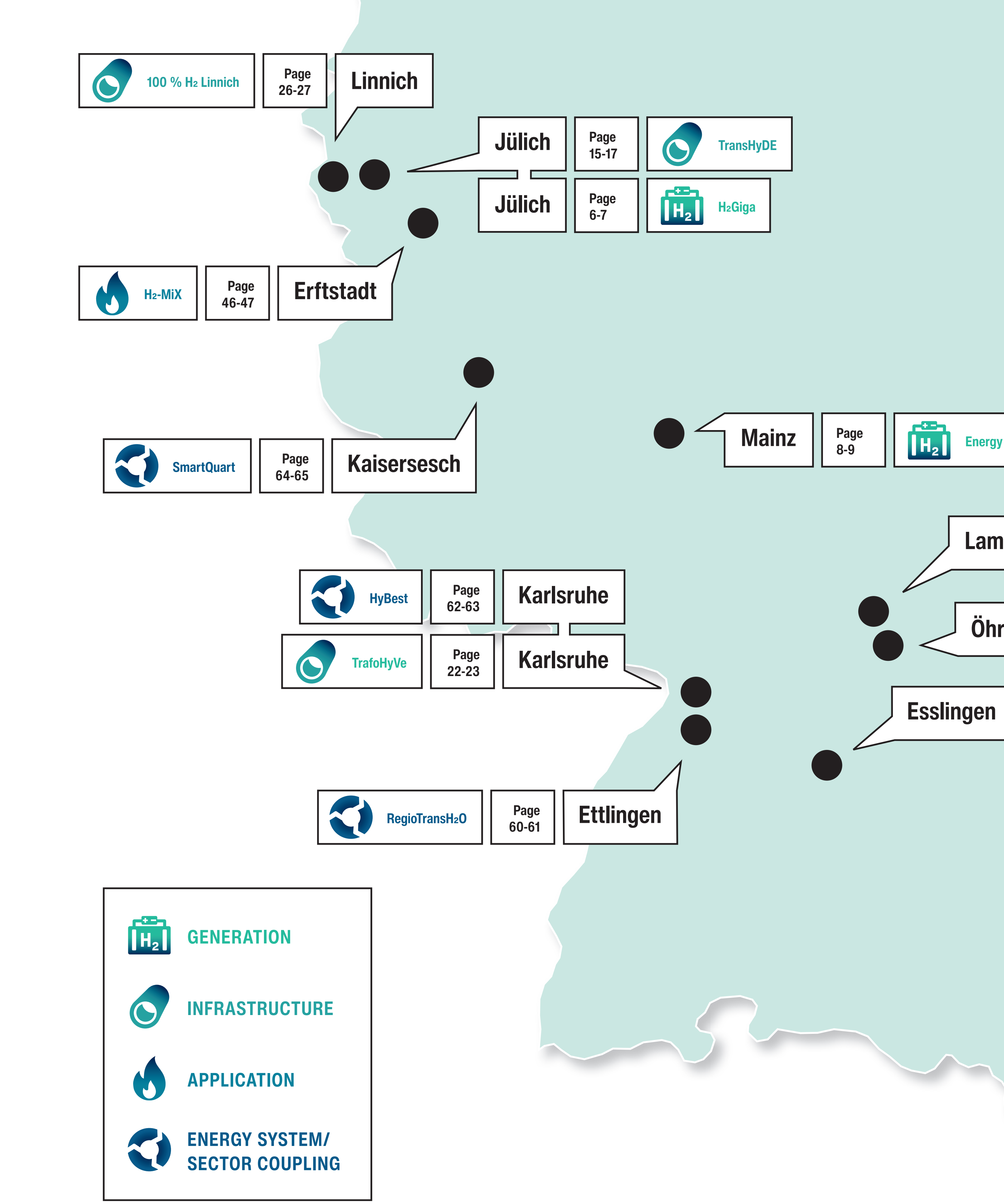
Main editorial office:
Marcel Pannes (responsible)
Phone: 0228 9191-451

Editorial staff:
Martin Schramm, Eike Bode, Dr. Stefan Gehrmann,
Janosch Rommelfanger, Frank Gröschl, Dr. Stefanie Schwarz

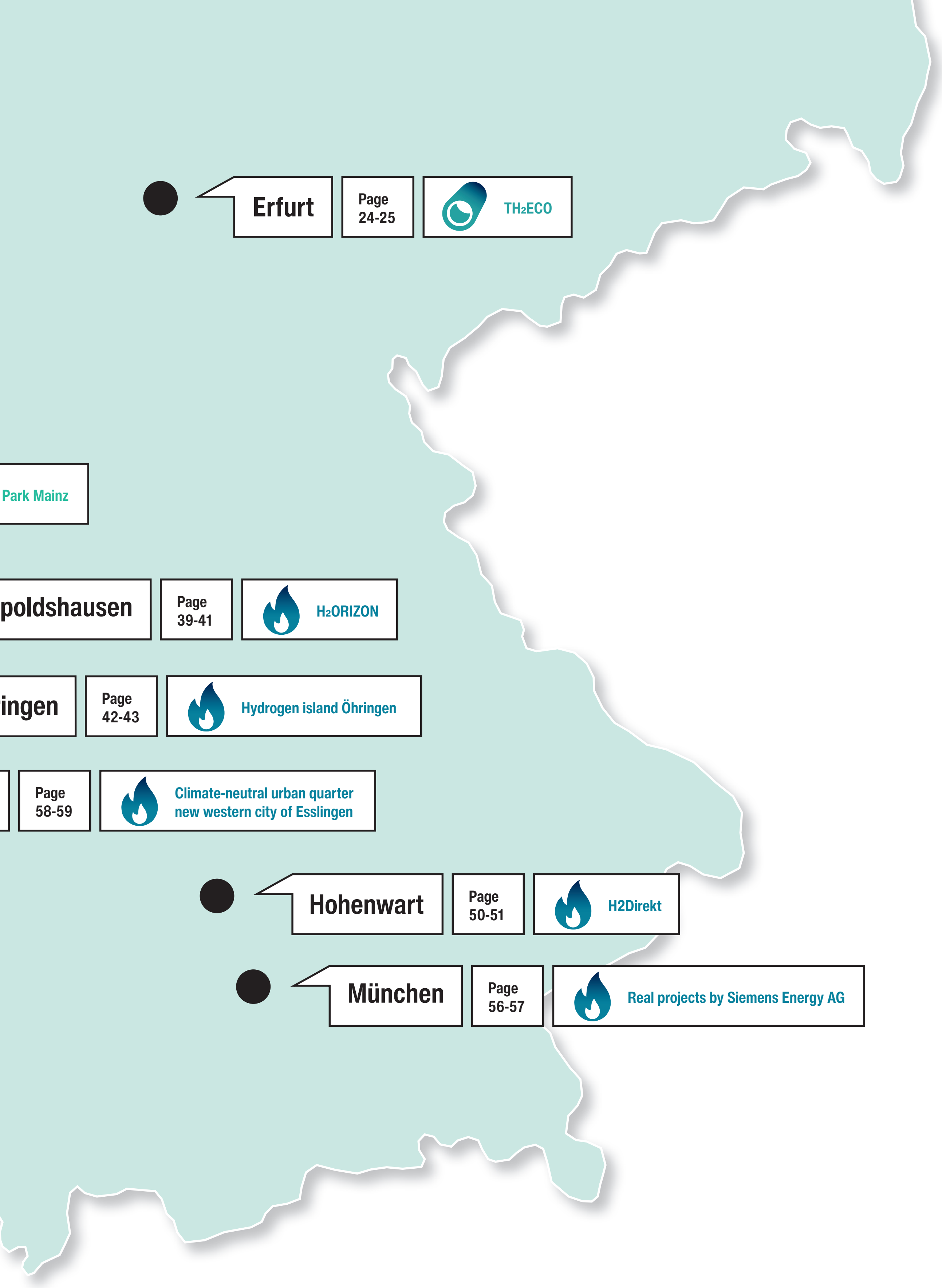
Editorial assistant:
Alexandra Thies, Phone: 0228 9191-443

Layout and typesetting:
Andrea Willers, wvgw

Picture credits:
kartoxjm/fotolia.com (Deutschlandkarte), Linde GmbH (S. 5)



100 % H2 Linnich
Page 26-27
Linnich
Jülich
Page 15-17
TransHyDE
Jülich
Page 6-7
H2Giga
H2-MiX
Page 46-47
Erftstadt
Mainz
Page 8-9
Energy
SmartQuart
Page 64-65
Kaisersesch
Lam
HyBest
Page 62-63
Karlsruhe
Öhr
TrafoHyVe
Page 22-23
Karlsruhe
Esslingen
RegioTransH2O
Page 60-61
Ettlingen
GENERATION
INFRASTRUCTURE
APPLICATION
ENERGY SYSTEM/
SECTOR COUPLING



Erfurt
Page 24-25
TH2ECO
Park Mainz
poldshausen
Page 39-41
H2ORIZON
ingen
Page 42-43
Hydrogen island Öhringen
Page 58-59
Climate-neutral urban quarter new western city of Esslingen
Hohenwart
Page 50-51
H2Direkt
München
Page 56-57
Real projects by Siemens Energy AG

DVGW energie | wasser-praxis konkret

More information on this topic can be found at

www.dvgw.de