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Innovations made in NRW
Power-to-X

VDMA

Content

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Prof. Dr Andreas Pinkwart
Minister for Economic Affairs, Innovation, Digitalisation and Energy of the State of North Rhine-Westphalia

Business leaders,
members of the business community

Power-to-X technologies have enormous potential, which needs to be put to good use, especially in North Rhine-Westphalia, the industry and energy powerhouse. We are talking about an important milestone along our ambitious path towards turning North Rhine-Westphalia into Europe's most modern climate and eco-friendly industry region.

A key role is set aside for Power-to-X (P2X) in the industrial and energy sector's endeavours to implement the changes made necessary by the energy transition policy, by integrated energy approaches, referred to as "sector coupling" by some, and by low-resource production techniques. Electrical power generated from renewable sources can be used for efficient just-in-time production of non-renewable energy sources and base chemicals. Such technological expertise is crucial to an industry that – whilst continuing to be competitive – needs huge quantities of energy and resources produced in a climate-neutral fashion.

A significant contribution is going to be made by the hydrogen sector which is currently being developed. As state government, we are pushing this forward with a number of instruments, including our hydrogen roadmap and a multitude of action programmes. We want North Rhine-Westphalia to become Germany's leading hydrogen region where applications and technologies are developed for the energy source of the future, a key part of P2X application chains.

Our support for innovation in industry is also coming in the shape of the IN4climate.NRW initiative and the Industrial Innovation Excellence Cluster (SPIN). By developing innovative technologies, NRW can be a trailblazer – as the leading site of P2X facilities and strategies, and thus as a region at the cutting edge of energy transition and climate protection. Since we are so industrialised, our market potential is above the national average.

It is now essential to use the chances and strengthen the innovation and transformation prowess of our businesses.

Yours
Prof. Dr Andreas Pinkwart

© Boge

Wolf D. Meier-Scheuven
Spokesman
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Competence Network

Dear Reader

In all branches of industry, efforts are being made to protect the environment. The mechanical and plant engineering sector is no different. Our branch is a key industry for climate action. As the largest industrial employer and an enabler for scores of other industries, mechanical and plant engineering is an innovation driver that covers all sectors – especially when it comes to climate-friendly technologies.

The climate-neutral industry offers the sector the opportunity to export its solutions worldwide, develop new markets and business models, and strengthen its position as a capable partner in this field as well. At the same time, mechanical and plant engineering is more than just a provider of solutions for new, sustainable energy systems – our sector also uses those solutions itself. Concepts such as "climate neutrality", "green hydrogen", "sector coupling", "CCU/CCS" and "decarbonisation" are hot topics at the moment, as also is "Power-to-X", the subject of this edition of Innovations magazine.

Power-to-X, the production of synthetic fuels on the basis of renewable electricity, is a key element of the energy and transport transition. In this area too, mechanical and plant engineering is a major player. The sector supplies many components that are essential for the successful use of Power-to-X, from the generation of renewable energies, through storage and transport to the users of synthetic fuels.

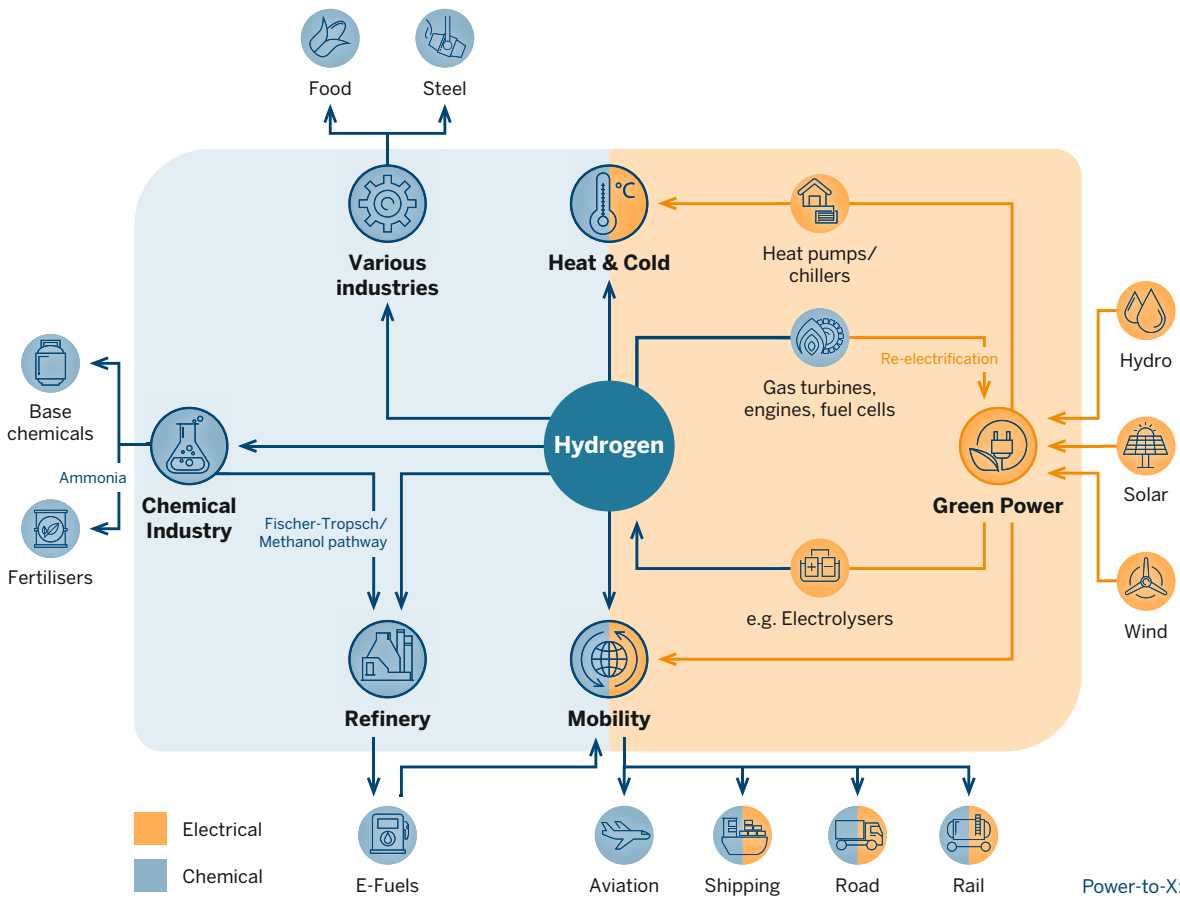
This Innovations magazine presents examples of applications and cutting-edge projects from North Rhine-Westphalia, and discusses some of the potential areas of impact along the value chain for our local industry in implementing Power-to-X solutions.

Fighting climate change is a challenge for society as a whole, and it's a challenge we can only tackle together. In this spirit, make use of our network and benefit from it – for a positive climate future!

Yours
Wolf D. Meier-Scheuven

Mechanical engineering and plant construction: a driver of the energy transformation

As a provider of technology, the mechanical engineering and plant construction industry plays an outstanding role in actually achieving agreed climate targets.

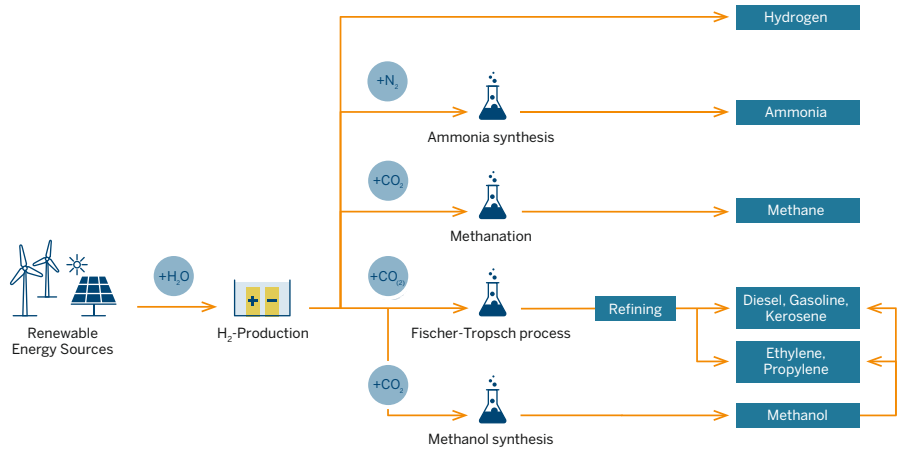


Power-to-X: what is it?

There are always three factors at play at a global, European and national level: further expanding the use of renewables, increasing energy-efficiency, and effective sector integration.

Mechanical engineering makes important contributions in all three areas. Fuels in liquid and gaseous form will be needed for the long term in air, sea and road-based goods transportation, for construction machinery and in agricultural engineering. In all these areas, hydrogen can be used, either directly or following further processing, e.g. in the form of e-fuel. In industrial applications such as the steel industry, for example, production processes can be made climate-neutral through the use of hydrogen. In the energy sector, hydrogen or hydrogen derivatives like synthetic gas can also be used to create flexible, fossil-free power generation systems as buffers for wind and solar power.

Power-to-X, or P2X for short, is a critical component as the key process for producing hydrogen and its derivative products. Without it, global climate protection would be virtually impossi-



Power-to-X: production and products.

ble. Expanding into large-scale hi-tech application opens up excellent opportunities for P2X, the industry, and mechanical engineering as a whole. Rapidly ramping up the international market could benefit SMEs in particular, as providers of P2X technologies and systems. But the crucial factor is whether Germany can now assume a leading technological position for P2X systems and turn it into export success. To make this happen, Germany and/or Europe must quickly ensure the necessary conditions are in place, implement industrial-scale P2X projects and establish a customer market.

Create the conditions and grasp the opportunities

P2X is ready for practical application. Policy-makers have recognised the fact, and Germany's national hydrogen strategy and the European hydrogen strategy in Brussels have set the direction for turning the practical significance of P2X for climate policy into reality. Many other countries have approved their own strategies, or are close to doing so. At a European level, internationally competitive, industrialised P2X production is achievable.

Accordingly, by implementing further P2X projects on an industrial scale, a domestic market can be created within which the technologies can be refined and new value chains established in the area of hydrogen. Currently, P2X products are still too expensive to be able to compete with fossil-based raw materials. But that can quickly change with plants on an industrial scale, lower electricity costs, expanded capacity in the area of renewables and an appropriate administrative policy framework.

To enable a genuine market for P2X to develop, we need fair conditions and market-based rules in place. That includes having as many sectors as possible participate. The partial or total exclusion of individual areas from the use of hydrogen and P2X technologies would be counterproductive, since demand grows with the number of potential applications, and higher production volumes help to keep manufacturing costs down. A relevant price for CO_2 is also important: the mechanical engineering industry is firmly in favour of revenue-neutral CO_2 pricing. More CO_2-intensive primary energy sources should be more expensive than their climate-friendly counterparts. That would also offer a thoroughly market-friendly incentive to make more use of climate-friendly primary energy sources in the future, to use fewer fossil-based raw materials and to emit less CO_2 in all areas of application, from mobility to building use and steel manufacture.

The Power-to-X for Applications working group

The VDMA Power-to-X for Applications (P2X4A) working group is the central, cross-industry information, communication and cooperation platform for the P2X community. It is growing quickly, currently with more than 110 members, and brings together all the key stakeholders and players covering everything from developing manufacturing processes to the production of synthetic fuels and raw materials using P2X technologies, and end customers.

Our activities are aimed at encouraging an end-to-end approach to the transformation of energy systems that is open to all technologies, and sharpening an awareness for environmentally friendly energy use and mobility among policy-makers and the public. We firmly believe that P2X offers the most promising method for turning electricity generated from renewables into other forms of energy, and thus exiting the use of fossil primary energy sources such as coal, oil and gas in the long term.

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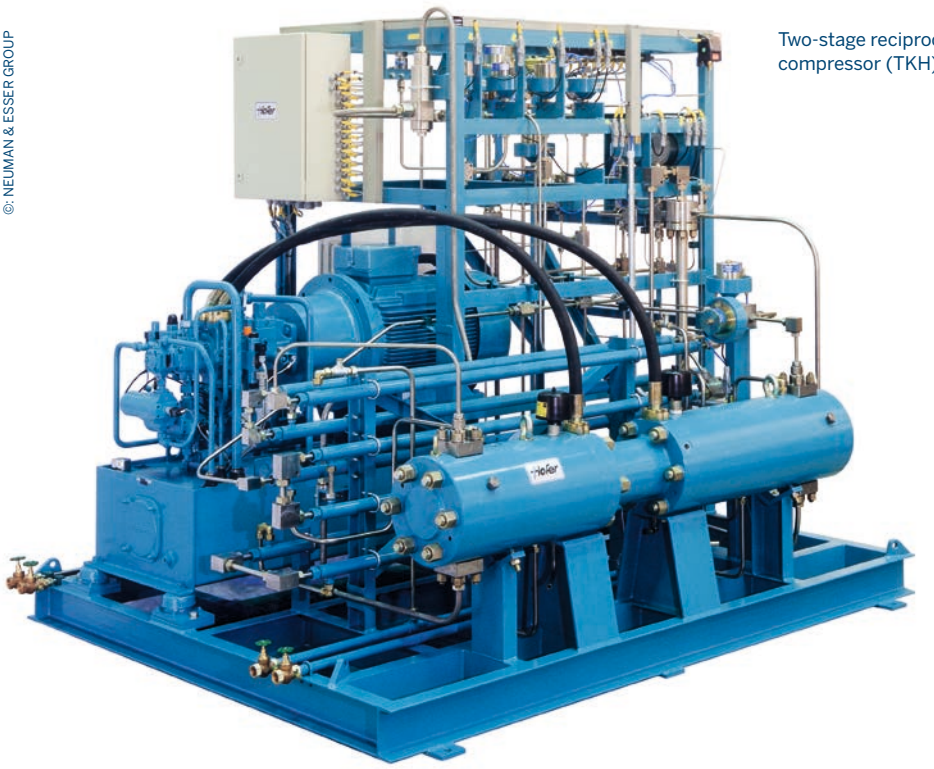
Hydrogen compressors

Compressors are essential whenever hydrogen (H_2) has to be compressed, transported or stored.



Two-stage reciprocating compressor (TKH).

The use of green hydrogen in the context of Power-to-X is a factor of particular interest in the energy market transition. Green hydrogen is generated mainly in electrolysers using the power-to-gas process for use in transportation and industrial processes, and as a means of storing energy. NEUMAN & ESSER GROUP (NEA) has accumulated many references in the areas of mobility (H_2 refuelling stations), industry and electricity generation with fuel cells supplied using this infrastructure.

Compressors for hydrogen infeed

In addition to pipelines constructed especially for hydrogen, which offer a huge energy transport capacity, existing gas pipeline networks are also used to supply hydrogen. Many large gas pipelines have a rated pressure of up to 100 bar, and mostly operate at around 70–85 bar. Smaller regional gas pipelines often operate at 20–30 bar.

With two single-stage diaphragm compressors from HOFER, NEA's premium brand for high-pressure systems, the company plays a part in the plant operated by Schleswig-Holstein Netz in Brunsbüttel, the first to feed green hydrogen into the gas network. Before the hydrogen is fed in, it is tested to ensure purity and humidity requirements are met. Limit values for hydrogen concentration are currently up to ten percent by volume. These measurements are also used to ensure that the calorific value of the resulting gas mixture in the pipeline meets gas specifications. At Brunsbüttel, HOFER diaphragm compressors ensure oil, leak and abrasion-free compression to maintain maximum product purity.

Compressor system in Europe's largest cavern field

Caverns in salt domes also offer vast storage capacity. An average cavern 60 metres wide, 300 metres high and with a filling pressure of 175 bar can store 100 million Nm³ of working gas. In the case of hydrogen, that equates to 300 GWh of energy, which can be used for heating, steel production, mobility, and/or reconversion into electricity. Each cavern storage system consists of several individual caverns.

Since 2008, NEA reciprocating compressors have been successfully used to feed in and withdraw natural gas at the Epe cavern field in Gronau, Westphalia. Together with German gas storage operator Trianel, NEA developed an innovative compressor system design for the second gas storage extension phase. The total volume of working gas in the caverns is 240 million m³. A six-crank, 320-scale compressor with 700 kN connecting rod force was tailor-made to provide a reliable and economical overall system for the cavern field at Epe.

Hydrogen filling

A further method for storing and transporting hydrogen is to fill pressurised containers, which can sometimes be used as bottle batteries or also as tube trailers for transportation.

Two or three-stage dry-running reciprocating compressors (TKH) are used for applications with a filling pressure of 250 bar; pressure storage systems and trailers with a filling pressure of more than 300 bar often use diaphragm compressors that enable completely gas-tight compression (quality 5.0).

The Electricity Generating Authority of Thailand (EGAT) in Lamtakong uses a two-stage diaphragm compressor. EGAT has upgraded a pumped-storage hydroelectric station there, with a peak load of 1,000 MW. To generate electricity, water is fed into turbines located 350 metres below the surface of a reservoir. One element in the upgrade is a PEM electrolyser, which enables the generated electricity to be converted into hydrogen and oxygen. This green hydrogen, which is then stored in bottle batteries, serves as an energy source for a fuel cell system supplying a public learning centre for electricity generation and storage technologies.

H_2 mobility: HOFER is the market leader for compressors in South Korea

Hydrogen is also a major theme in the future of mobility. Fuel cell-powered vehicles fill up with hydrogen in gas form at hydrogen fuel stations. Refuelling in this way requires pressures of up to 1,000 bar, and compression must take place without gas impurities or abrasion. The compressor must also operate without oil and leakage-free. Depending on the required volume flow and the mode of operation, either the TKH or the diaphragm compressor will represent the ideal solution.

With its "Hydrogen Economy Roadmap of Korea", South Korea is working toward 2040 as the target date for producing 6.2 million fuel-cell electric vehicles and replacing 40,000 buses and 80,000 taxis with H_2-powered vehicles, as well as having 30,000 fuel cell-powered goods vehicles in operation. That will put South Korea in a leading position for H_2 mobility, alongside Germany.

For more than 80 years, NEA has been engaged in processes to compress industrial gases, H_2 and H_2 gas mixtures in particular, using API 618-compliant compressor systems. By expanding its portfolio, NEA is supporting the current transformation of the fossil fuel-based oil and gas sector into a sustainable hydrogen industry based on green hydrogen from renewables.

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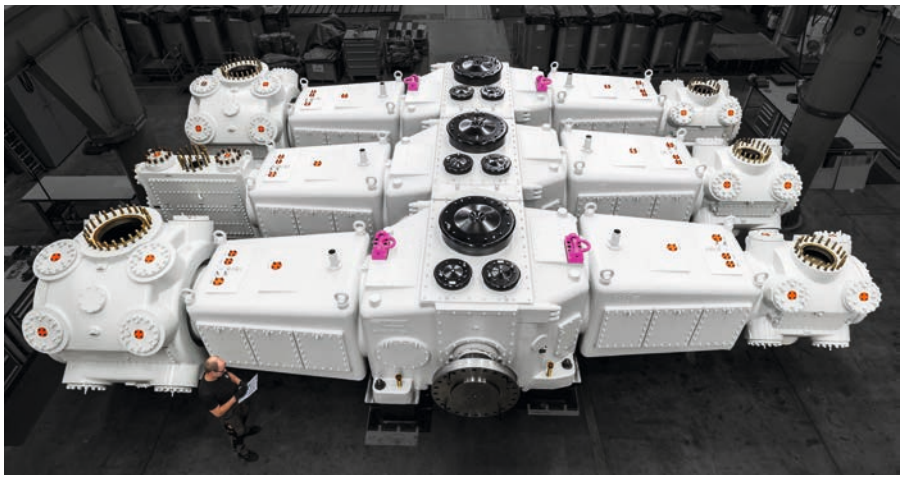


Six-crank reciprocating compressor, horizontal.

Moving into a sustainable future with tkH2steel

Ground-breaking concept for integrating a hydrogen-based direct reduction facility for 1.2 million tonnes of electrical pig iron into an existing iron and steel works – how can more efficient use of capital through innovative plant engineering and construction protect the climate effectively?

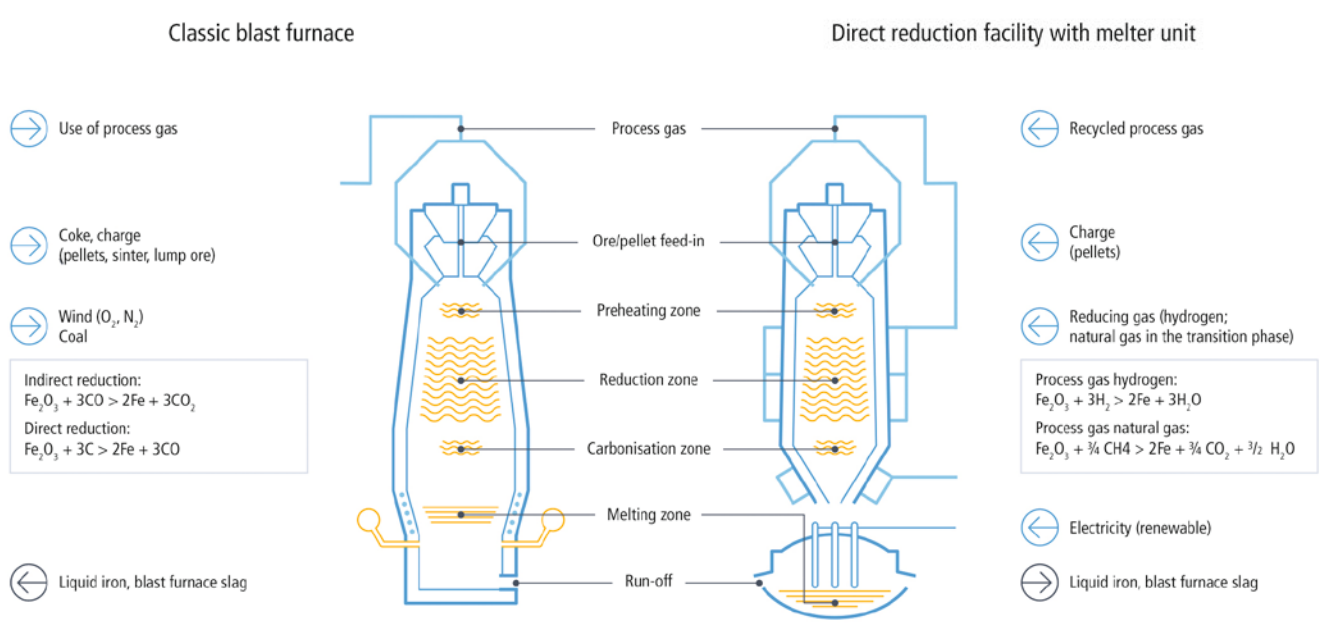
thyssenkrupp Steel Europe (tkSE) is a typical integrated iron and steel works, producing around 10 million tonnes of steel from iron ore per year in Duisburg – and around 20 million tonnes of CO_2. To reduce the iron ore (iron oxide), carbon is used; it separates the oxygen from the iron ore. This ultimately produces carbon dioxide – and a substantial amount of greenhouse gas. This process accounts for almost 80 per cent of the world's steel production, totalling 1.8 billion tonnes annually. thyssenkrupp Steel has a reputation for producing very high-grade steel, and is an important cornerstone of premium value chains in North Rhine-Westphalia, Germany and across Europe.

In the future, thyssenkrupp Steel aims to retain this position, albeit with a significant reduction in climate impact. On the way to greenhouse gas neutrality in 2050, current emission levels are to be cut by 30 per cent by as early as 2030, while at the same time significant quantities of green steel will be made available to customers. So thyssenkrupp Steel is locking in North Rhine-Westphalia's status as a location for industry and safeguarding the related value chains, including their top-quality industrial jobs.

What does the tkH2steel transformation path look like?

The classic route is based on a blast furnace in which iron ore and coke are fed in at the top and air and pulverised coal are injected at the bottom, using the counter-current principle. Heated air, along with the carbon from coke

The core of the transformation:
direct reduction facility with melter unit produces "electrical pig iron"



Comparison of blast furnace and direct reduction facility with melter unit

The tkH2steel concept was unveiled in Duisburg on 28 September 2020 (from left) North Rhine-Westphalia Prime Minister Armin Laschet, Federal Minister of Economic Affairs Peter Altmaier, thyssenkrupp AG's CEO Martina Merz and the chairman of the Executive Board of thyssenkrupp Steel Europe AG, Bernhard Osburg.

and coal, forms reaction gases that rise and reduce the iron ore to iron in the upper furnace. This reduced iron is melted into pig iron in the lower furnace. Through metallurgical treatment in the steelworks, the liquid pig iron can be processed to all qualities and degrees of purity.

To avoid creating greenhouse gases, the carbon has to be replaced by other reducing agents. In the future, this will be green hydrogen, although natural gas may be used in the transition phase. Completely replacing carbon with hydrogen (H_2) as a reducing agent is not possible in a blast furnace, because coke makes a critical contribution to the mechanical stability of the so-called Möller column (iron ore and aggregates) in the furnace.

There are direct reduction facilities (DR facilities) in which the iron ore is reduced according to the same mechanism, but with natural gas instead of coal and coke: ascending natural gas (CH4) separates into H_2 and CO and reduces the iron ore. This makes natural gas an important step in hydrogen metallurgy. In the DR facility, the iron ore is reduced in solid form and is not melted. Traditionally, the DRI (Direct Reduced Iron) produced is melted in electric arc furnaces (EAF) where (for metallurgical reasons) only a portion of the current range of grades is produced. For example, the products crucial for the energy transition and climate protection, such as electrical sheets as the basis for electrification, have hitherto been reserved for the blast furnace route.

This poses two challenges for the process: firstly, to completely eliminate carbon, you need DR facilities that work not only with natural gas, but also with 100 per cent H_2. At the same time, the DR system represents only the upper furnace of the blast furnace; the lower furnace and the liquid pig iron to produce all grades of steel are absent.

The innovative approach of thyssenkrupp Steel involves coupling the DR facility with a new type of downstream melter. This melter unit takes over the function of the lower furnace, meaning that liquid "electrical pig iron" that is fully equivalent in technological terms – but with much lower CO_2 emissions – is produced, which can be used as usual in steelworks. So the existing steel grades can still be produced, and the value chains can continue to be supplied without interruption.

Where are the obstacles?

This transformation, as outlined, is a huge challenge. Hydrogen has not previously been used in continuous industrial operation, nor has such a melter been operated in the steel industry. However, smaller variants are standard in non-ferrous metallurgy.

The integration of the new system into an existing plant infrastructure in a way that is technologically and economically viable is also a challenge, but at the same time a great opportunity for plant engineering and construction. In this way, the transformation of the steel industry can be moved forward with innovative approaches.

The capital requirement is substantial. In addition to investment worth billions, it is in particular the ongoing operating costs that will be higher, for years to come, than with the classic blast furnace route. But corresponding funding programmes and regulatory frameworks can make this future a reality in North Rhine-Westphalia today. That was the message from Federal Economic Affairs Minister Peter Altmaier and NRW Prime Minister Armin Laschet during their visit to Duisburg on 28 September 2020, when this cutting-edge concept for tkH2steel was unveiled.

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Hydrogen, ammonia and synthetic methane for an environmentally and climate-friendly route into the future

Our mobility and our energy supply are on the brink of far-reaching change. Energy sources that are clean, preferably C-free, but at least CO_2-neutral, are essential for an environmentally and climate-friendly energy environment. The hydrogen and fuel cell centre ZBT is responding to the technological challenges involved in producing and using these energy sources.

Electrolysis systems and components for hydrogen refuelling stations are trialled at the hydrogen test site at the ZBT.

Our energy environment is changing. We will be switching from fossil energy carriers to synthetic fuels produced from renewable sources. A range of process routes with many possible products can be summarised under the term "Power to X": ZBT is developing the technologies for hydrogen production, for the production of methane and for the synthesis and conversion of ammonia. These substances can be used as fuels in mobility, as raw materials in industry and for generating electricity and heat.

Electrolysis on an industrial scale

Electrolysis of water to oxygen (O_2) and hydrogen (H_2) is a process that has been known for decades. However, operating with fluctuating, renewably generated electrical energy poses new challenges for the technology. In the application scenarios currently being discussed, investment costs, efficiency, stability and maintenance outlay are key assessment criteria on the basis of which suitable technologies are selected. In the Carbon2Chem® project, an experimental area for a range of electrolysis technologies was set up at ZBT with funding from the BMBF (Germany's Federal Ministry of Education and Research). An alkaline, a PEM and an SOEC system were installed, with the aim of determining valuation parameters in dynamic operation. The electro-

lysis systems provide pure hydrogen (5.0) within a pressure range between 10 and 35 bar.

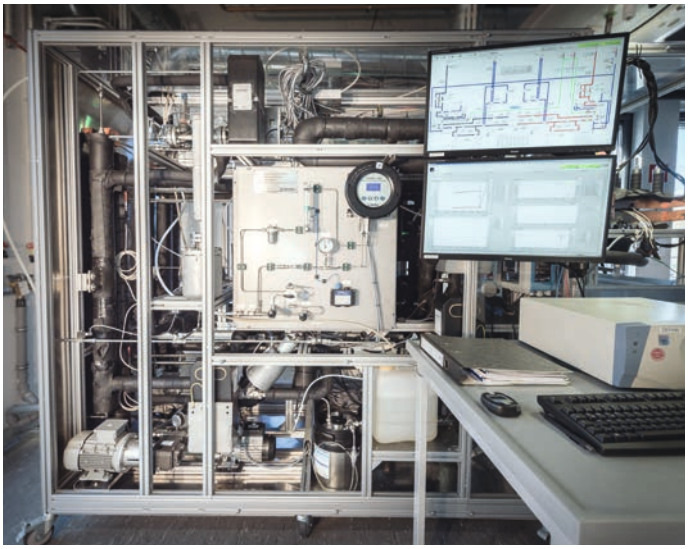
Testing the infrastructure of the refuelling stations

Hydrogen as a fuel for mobility requires the development of an extensive network of refuelling stations. There are currently 85 refuelling stations in operation in Germany. However, the delivery of hydrogen at these refuelling stations is still energy-intensive and the equipment setup is complex. With the aim of developing and testing optimised processes and components, as well as innovative refuelling station concepts, in the "H2TestOpt" project funded by the BMWi (Germany's Federal Ministry for Economic Affairs and Energy) a test platform for hydrogen refuelling stations has been designed and built.

The test site incorporates, among other things, 480, 500 and 900 bar storage cells of different tank types, a compressor for compression to the pressure level or for booster refuelling, and various pre-cooling systems. In addition, there are two dispensers, each delivering hydrogen at 350 and 700 bar, a control room and a testing room for the qualification of components such as valves, sensors, etc.

Synthetic methane

Alongside the use of pure hydrogen, methane produced from renewable sources will also play a major role in the energy system of the future. Reasons for this are the continued use of existing infrastructures and end-user technologies, as well as the transition to a more flexible array of increasingly renewable energy systems. On behalf of the state of North Rhine-Westphalia, ZBT is researching the production of methane from hydrogen and carbon dioxide in a specially developed demonstration plant at the Virtual Institute – Electricity to Gas and Heat. The plant, which uses the catalytic methanation process and produces a feed-in natural gas substitute (SNG), is operated under realistic load profiles to develop and technically implement optimisation approaches to increase system flexibility, robustness and service life.



©: Nadine van der Schoot, ZBT GmbH

Testing of electrolysis stacks in the ZBT laboratory.

Ammonia as a carbon-free energy source

Ammonia is in the frame as a carbon-free source of large quantities of hydrogen, and has great potential as fuel for applications with a high energy requirement. The focus is moving to mobile applications such as shipping and aviation, and stationary applications for electricity and heat supply. Hydrogen production from ammonia plays a key role in the operation of fuel cells, engines and gas turbines. In the "NH3toH2" project, an ammonia cracker for generating a hydrogen-rich gas mixture for use in stationary fuel cell systems is being further developed with funding from the state of North Rhine-Westphalia and the EU.

The projects presented here give a little insight into the diversity of the technologies that will have to be used in the future for converting our system of energy and raw materials. The extent to which mechanical and plant engineering can participate in this transformation ranges from supplying specific production machines to the construction of complex generating units and conversion facilities for hydrogen, methane, ammonia and other energy sources and products. As an independent research institute, ZBT acts as a know-how provider in this field, capably supporting the industry in developing new products, processes and services.

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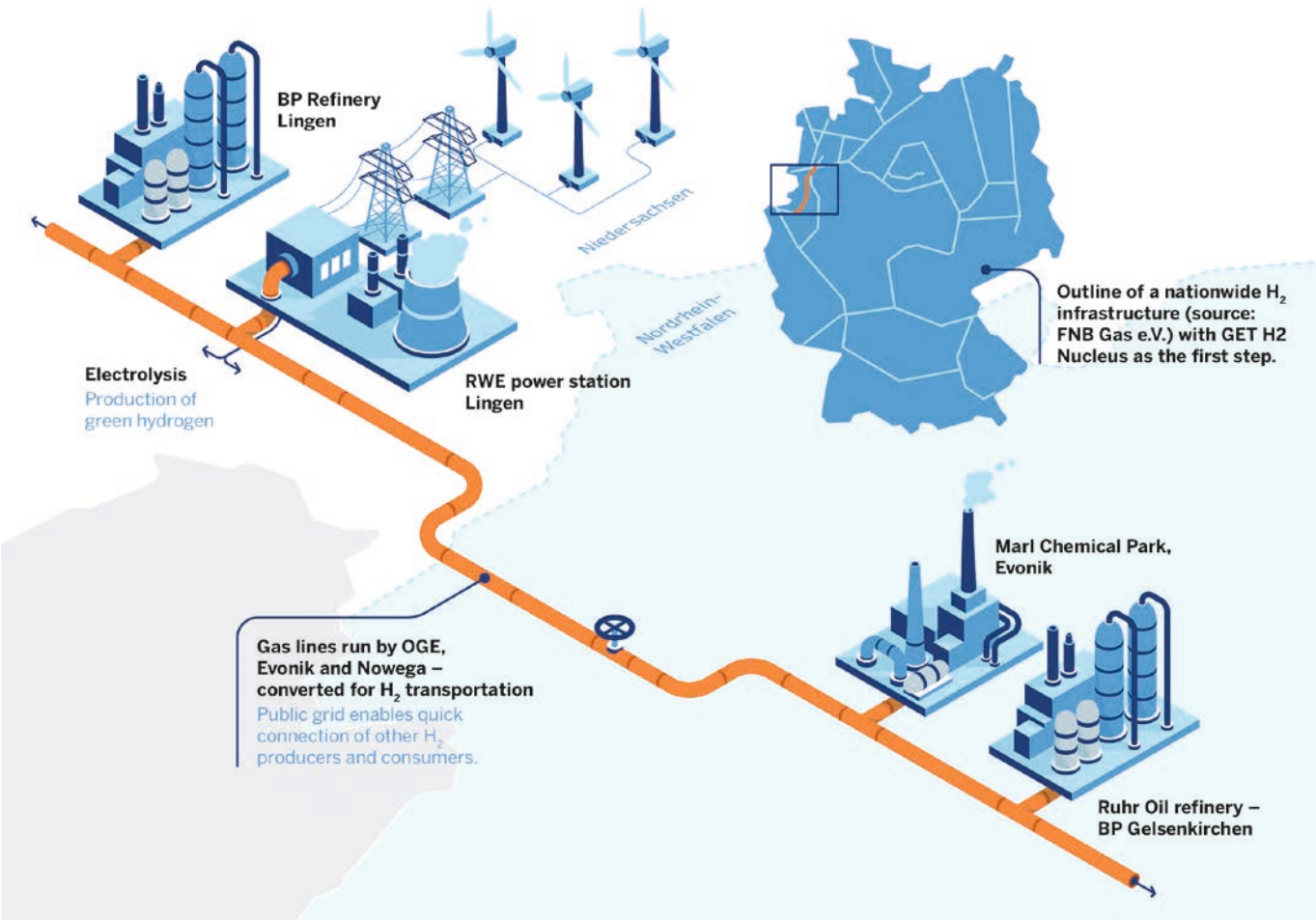
Green light for the hydrogen industry in Germany

Essen-based long-distance natural gas pipeline network operator Open Grid Europe GmbH (OGE) has already begun contributing to the success of the energy market transition with its innovative hydrogen solutions and projects.



Outline of nationwide H_2 infrastructure with GET H2 Nucleus as the first step.

Hydrogen is the key to the success of the energy transition. If that wasn't clear before, it is now, with the passing of the German government's National Hydrogen Strategy. But anyone wanting to produce (green) hydrogen reliably and in the required industrial volumes will need the necessary wind and solar power to do it. That means the expansion of renewables needs to pick up the pace again at a domestic level.

In detail, the German government expects hydrogen requirements in the order of 90 to 110 TWh by 2030. That means generation facilities with a total capacity of up to 5 GW will be needed in Germany by 2030, including the necessary offshore and onshore power generation systems. A further 5 GW will be added by 2035 if possible, or by 2040

at the latest. To cover import requirements, partnerships at a European and international level will also be established to create a hydrogen value chain.

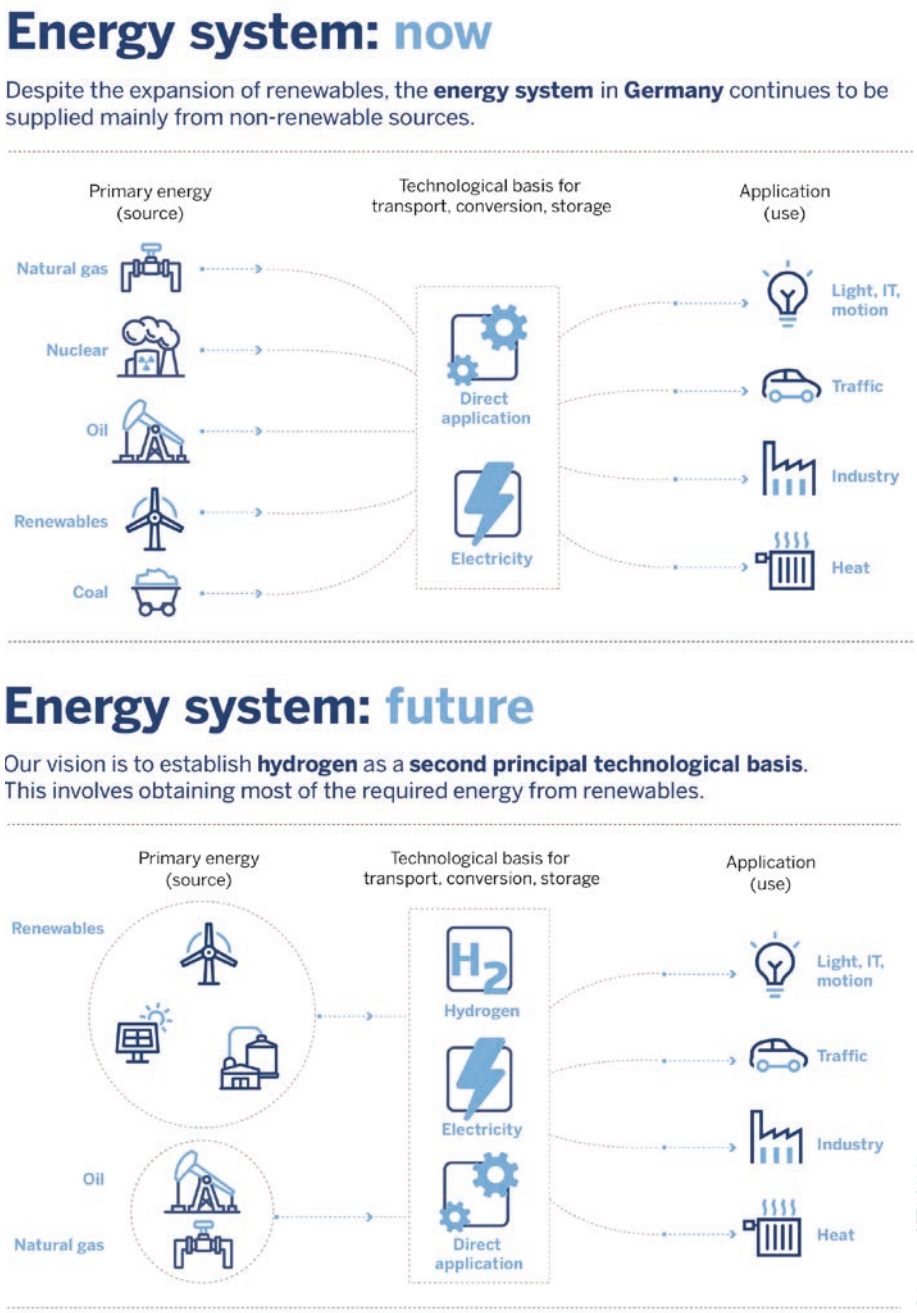
Powerful hydrogen infrastructure

One example of a project in this area is the GET H2 Nucleus. The project partners – BP, Evonik, Nowega, OGE and RWE Generation – want to work together to develop the first publicly accessible hydrogen infrastructure. The GET H2 Nucleus project provides a link between the generation of green hydrogen and industrial customers in Lower Saxony and North Rhine-Westphalia. The first H_2 network in the regulated sector with non-discriminatory access and transparent prices will be a network about 130 kilometres long between Lingen and Gelsenkirchen. Non-discriminatory access means all market players are treated equally. The green hydrogen will be generated using wind power in Lingen, Lower Saxony. To achieve this, an electrolysis plant with a capacity of more than 100 MW will be put in place at the RWE power plant location in Lingen.

The key factor here is that elements in the value chain are not considered in isolation but are dealt with as a whole. Production, transport and consumption are considered as a unit, and are planned and implemented accordingly.

Transport and storage in existing infrastructure

The value chain principle is broken down into four sections:



Status quo and future of the energy systems in Germany.

1. Green hydrogen is generated from wind power at the RWE power station location in Lingen, Lower Saxony, using an electrolyser with a generating capacity of more than 100 MW. There is potential for expansion depending on consumer requirements.
2. Existing gas lines belonging to Evonik, Nowega and OGE will be converted to transport 100-percent hydrogen. Evonik will also construct some new lines.
3. The hydrogen will be transported via this infrastructure, with a total length of 130 kilometres, to the

chemical facilities and refineries in Lingen, Marl and Gelsenkirchen.

4. The green hydrogen is used in production processes. The result is a substantial decrease in CO_2 emissions.

GET H2 Nucleus – the first step in a nationwide hydrogen network

GET H2 Nucleus is creating the foundation for a reliable and sustainable hydrogen industry in Germany by bringing together continuous generation of green hydrogen at an industrial scale, transportation and storage using existing infrastructure, and continuous sales to industrial buyers. The production of green hydrogen and supply to customers should be in progress by as early as 2023.

Initial steps are already in place, for example preparing the construction site and technical planning for the 100 MW electrolysis plant in Lingen, the feasibility study for construction of a hydrogen feed-in station, preparing the initial measures to convert existing natural gas pipelines for hydrogen use, and the submission of a TÜV study for the first of the pipelines to be converted. Consideration is already being given to the next steps: linking up existing cavern storage systems, additional H_2 generation facilities, and additional customers.

A further positive aspect is that the project is part of a nationwide initiative in Germany known as GET H2. The initiative is conceived as a platform for businesses, institutions, trade and professional associations, and administrations. The partners – currently 40 in total – aim to build up a nationwide H_2 infrastructure, and they all want to support the regulatory changes needed in this regard.

Elenor and Optimus

The use of a mobile compressor is an innovative technology within the natural gas transport industry that makes a sustainable contribution to environmental protection and to the responsible use of primary energy. Mobile pipeline compressors prevent natural gas losses and climate-damaging methane emissions.

During maintenance and repair work on natural gas transport pipelines, as well as during the construction of new connections and network expansion measures, the respective pipeline sections often have to be taken out of service. This is usually done by shutting off a pipeline section by closing the main shut-off valves. The affected section is then pressure-relieved and completely degassed. This results in the release of large quantities of gas (methane) into the atmosphere.

The use of a mobile pipeline compressor makes it possible to transfer the gas content from the affected barrier section to an adjacent section. This prevents not only the loss of the unused gas but also the release of the climate gas. The pressure is reduced to minimum residual pressures. In this way, up to 95 percent of the gas is secured for further use and the climate is protected. A mobile pipeline compressor can be used individually or in a highly efficient parallel operation.

Carolin Kielhorn
Press spokesperson
Open Grid Europe GmbH
Essen
www.oge.net

The mobile compressors “Elenor” and “Optimus” in use.

Power-to-X offers new perspectives

How electricity-based synthetic fuels (e-fuels) can serve as energy storage systems and build bridges to a climate-friendly system, while simultaneously allowing the use of proven technologies and existing infrastructures as part of a cost-efficient overall system.

Although the proportion of renewables included in Germany's overall power consumption in 2019 grew to about 42.6 per cent (243 TWh_{el}), and will continue to increase, the ability to store renewables, especially in the form of long-term energy storage systems, will play an important part in countering temporary gaps in supply caused by the highly volatile nature of electrical energy from wind and solar sources, and in contributing to grid services.

There is still the question of how it will be possible to reliably and affordably obtain 85.3 per cent of total primary energy requirements from climate-friendly sources by 2050, given that only about 14.7 per cent is currently (2019) covered by renewables. Comprehesive and rapid electrification presupposes an extensive expansion of renewables and electricity grids, in addition to purely electrical applications in all sectors. This is highly unlikely, however. Even just the necessary expansion of the power networks would probably take at least 15 years, taking the north-south connections in Germany as an example. The necessary societal acceptance is another question again.

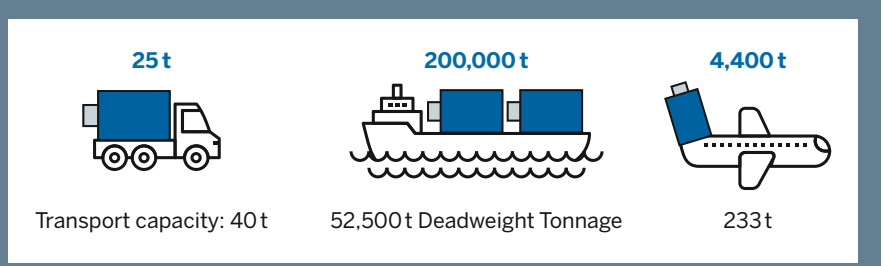
Electricity generated from renewables – wind, solar power or biomass – is used to split water into oxygen (O_2) and hydrogen (H_2) through electrolysis. H_2 can be used as fuel, or it can be converted in a further stage involving carbon dioxide (CO_2) obtained from other industrial, biogenic processes, or ambient air, into synthetic fuels like methane, methanol, petrol or kerosene.

Production in Germany currently involves only small volumes in the order of 1,000 tonnes per year in pilot projects such as the one in progress in Werlte in the north of the country, for example. The process requires large-scale industrial facilities.

Use existing infrastructure

Existing underground caverns and natural gas networks can be used for hydrogen or methane. The Ruhr District and the Leuna-Bitterfeld-Wolfen region have hydrogen transport networks in place to supply the local chemical industry facilities. In the Netherlands, Gasunie NV aims to use decommissioned gas pipelines for hydrogen, a fast and cost-efficient contribution to the large-scale hydrogen industry. Using these pipelines is particularly beneficial in the case of pure hydrogen. Adding it to natural gas is an option but because of fluctuating calorific values this could lead to problems in industrial manufacturing processes, for example.

Where there are no gas pipelines and no opportunities for conversion, an extensive system of new hydrogen pipelines will be required to ensure comprehensive supplies of hydrogen. These days, if new gas pipelines are built or existing gas pipelines are overhauled, they are often prepared at the same time for future use with hydrogen.



Why electrification of long-distance and heavy goods transport is difficult: the pictogram shows that a 40-tonne goods vehicle (range 3,000 km), a cargo vessel (deadweight tonnage 52,500 tonnes, 5,000 containers, range 48,000 km) or a long-haul aircraft (310 passengers, take-off weight 233 tonnes) would need batteries weighing between 25 and 200,000 tonnes.

Use potentials offered by waste

Combination with existing thermal waste treatment in the context of Power-to-X (P2X) is another option that offers major potential for investment, especially since about 50 per cent of the waste is biogenic.

The waste industry in Germany employs about 267,000 people, and its total revenue is in the order of EUR 70 billion. Accounting for more than 30 per cent of the entire circular economy in Germany and with revenue of about EUR 24.5 billion in 2016, North Rhine-Westphalia is the country's most important region in terms of the circular economy. The potential for investment in a sustainable circular economy here is huge.

What others are doing

Existing gas-fired power stations, which remain important in terms of ensuring a sustainable and reliable energy supply, can already be converted from gas to hydrogen with minimum investment. In the Dutch H2M project, for example, Mitsubishi Power is involved in converting gas turbines at the 1,300 MW Magnum gas-fired power plant to 30 per cent hydrogen by 2025, and to 100 per cent hydrogen in subsequent stages.

When it comes to converting from gas to hydrogen operation, it must be remembered that hydrogen and gas have different combustion properties. That means there is a need for adapted combustion systems capable of flexibly burning mixtures of gas and hydrogen as completely as possible, with no flashback and with very low nitrogen oxide emissions. A high overall efficiency rating for gas turbines and power stations, long component service life, ease of maintenance and minimal conversion costs are other important prerequisites for commercial success.

The Regional Greenhouse Gas Initiative in the USA has given rise to projects such as Advanced Clean Energy Storage in Utah, which will involve storing green hydrogen in up to 70 salt caverns. One cavern can store enough hydrogen to generate up to 100 GWh of electricity, and long-term energy storage for a period of months is also possible.

Starting in 2025, Mitsubishi Power – also in Utah – will convert the Intermountain Power Agency's coal-fired power station to natural gas, and then to 100 per cent hydrogen in stages to provide a climate-friendly energy supply with a capacity of up to 840 MW.

To ensure comprehensive coverage in Europe in the medium term, blue hydrogen will be used alongside green hydrogen, given its availability and the fact its production costs are as much as to 40 per cent lower (AURORA Study 2020). This creates incentives to establish a hydrogen infrastructure that can subsequently be used by green hydrogen, with staged increases to 100 per cent.

Complex energy systems demand digitalisation: Once gathered, data is analysed using artificial intelligence to optimise the way generation, storage and consumption work together. Tomoni™ is one such digital solution. It's part of the Hydaptive™ Standard Flexibility Package from Mitsubishi Power, and is intended for use in large-scale projects for the Danskammer Energy (New York) and EmberClear (Ohio) power stations.

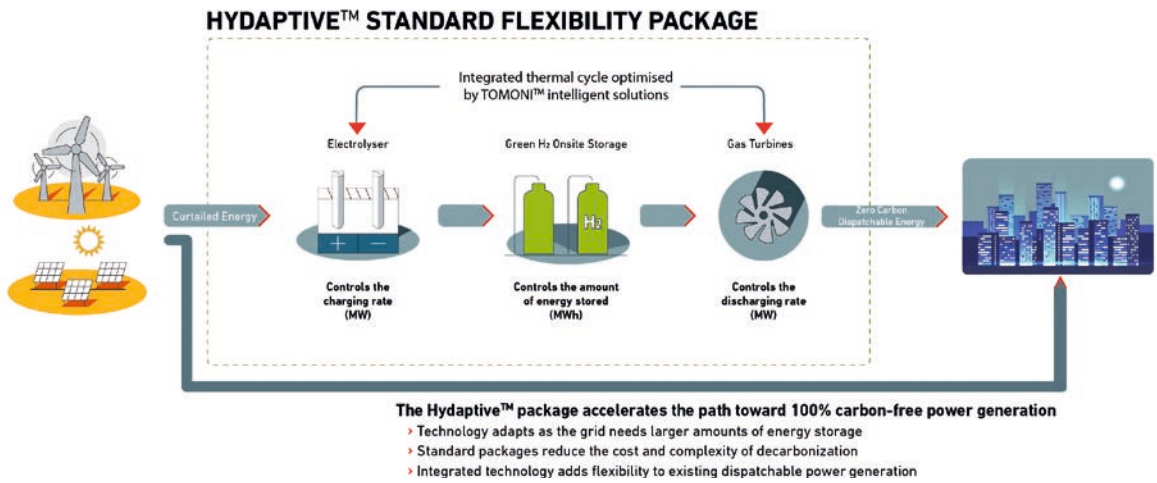
Carbon capture technology to supply the necessary CO_2 is already available, like that supplied by Mitsubishi Heavy Industries in Petra Nova (Texas), with a capacity of almost 5,000 tonnes per day, making it the world's largest commercial system of its kind.

Demo CCU system as part of the ALIGN CCUS project in Niederaussem.

©: ALIGN CCUS

Energy and climate-friendly Europe

Intensive efforts are being made at an international level to make material use of carbon dioxide, such as the ALIGN-CCUS (Accelerating Low-Carbon Industrial Growth through Carbon Capture Use and Storage) project, which ran until November 2020 and involved 30 industrial firms and research institutes from five countries. At Niederaussem, for example, a complete



Hydaptive™ Standard Flexibility Package from Mitsubishi Power.

CCU chain was constructed, one of its goals being to produce dimethyl ether. This can be used to replace diesel and LPG, and can serve as a precursor for olefin and kerosene synthesis.

It is unlikely that Europe will be able to cover its primary energy needs with climate-friendly resources and without importing renewables in the form of e-fuels, transported via pipelines and ships. With a global market volume for e-fuels of up to 41,000 TWh, according to World Energy Council Germany (2018), there could be a need for electrolysis to cover as much as 6,000 GW. Forbes Magazine estimates that even just the US market for hydrogen will be worth up to USD 170 billion by 2050.

Learn from "first-of-its-kind" facilities

Power-to-X opens up opportunities for the mechanical engineering and plant construction industry: there will be a need for electrolysers, pipelines, valves, new materials, compressors, expanders, reactors, gas and steam turbines, heat exchangers, fuel cells, pumps, heat pumps, electrical systems, electronics, controllers, containers, and much more besides. Key technologies like CO_2 separation, electrolysis, purification and synthesis processes, and storage and transportation options are already available in many cases.

But in combination, these elements often produce "first-of-its-kind" P2X facilities involving elevated technical and commercial risks, which contribute to the "Lessons Learned" process. Before an e-fuel can be used, it must be determined whether it satisfies current permit specifications. If not, the regulations should be adapted as early as possible. Lifecycle analyses are required, since financial assessment criteria for CO_2 emissions impact on cost-efficiency and competitiveness.

P2X needs security of planning and investment, reliable regulatory conditions, long-term cost-efficiency, low power costs (e.g. low electricity procurement costs for electrolysers), appropriate financing frameworks and acceptance from society. Major projects like those in the USA and the Netherlands can serve as blueprints for turning Germany into a successful, sustainable business location.

A region like North Rhine-Westphalia can prepare for the future with P2X. And regional businesses have an opportunity to play their part in global value chains.

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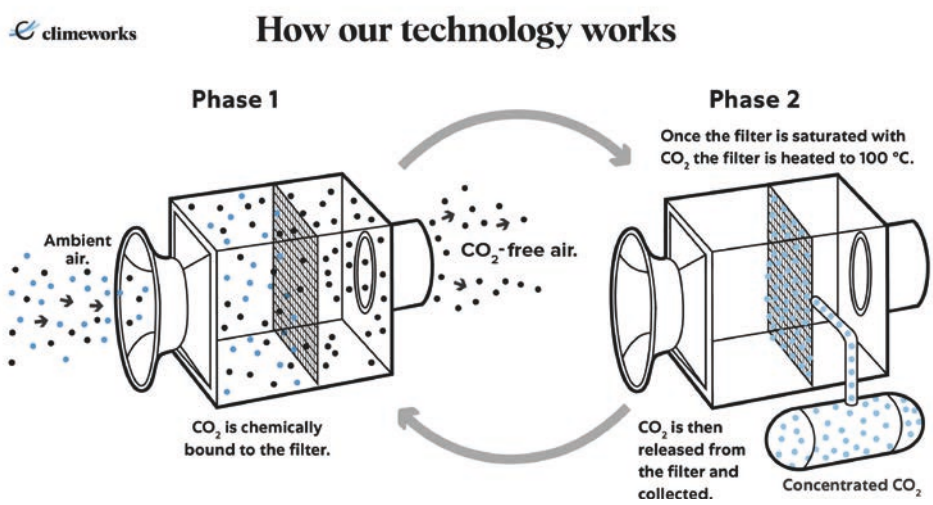
Renewable fuels from air and water

With more and more discussions about the energy transition these days, and CO_2 emissions continuing to increase around the world, it seems too good to be true: producing synthetic, renewable fuels from nothing but air and water. Diesel, petrol, kerosene, sourced directly from ambient air. The underlying process is known as direct air capture (DAC) – in other words, drawing CO_2 directly from the air.



This diagram shows the DAC process in simplified form. It always involves an adsorption and a desorption phase, which alternate on a cyclical basis.

From outside, DAC systems look like large ventilation systems, but there's more to them than that. Behind the large fans is a special filter material (sorbent), which is capable of capturing even the smallest volumes of CO_2 from the air. Even if the greenhouse gas CO_2 has the greatest impact on climate change, it makes up only a very small part of the ambient air, at about 0.04 per cent by volume.

Four steps to turn air and water into fuel

As part of the "Power-to-X" (P2X) project by the Copernicus Institute, a consortium of several companies brought together all necessary process steps in one single location with a compact plant in early 2019.

The DAC system first captures the CO_2 from the air: during the first, or "adsorption", phase, the ambient air is sucked in through the DAC machine. The CO_2 sticks to the surface of the filter material. The second, or "desorption", phase begins as soon as the filter is saturated with CO_2. The chamber is closed and an underpressure is generated. At the same time, the chamber is heated to about 100° C, enabling the CO_2 to release from the filter material again, at which point it can be gathered, stored, and re-used. Because CO_2 is distributed fairly evenly throughout the atmosphere around the world, the DAC process can theoretically be used in any location.

The second stage involves high-temperature co-electrolysis (Sunfire GmbH), which breaks down the CO_2 to produce carbon monoxide and simultaneously splits the water molecules to release hydrogen. The result is a synthesis gas, which forms the basis for a huge range of processes in the chemical industry. In the third stage, the synthesis gas is converted in a microstructured reactor into long-chain hydrocarbons. The long-chain hydrocarbons created in the Fischer-Tropsch process form the raw materials for fuels. In the fourth stage,

the quality of the fuel is optimised using hydrocracking to produce the target products – kerosene, diesel and petrol, and to improve yield.

Although only ten litres per day were produced using the plant developed by the project partners in the first phase of the Copernicus project, this is expected to be scaled to 200 litres per day in the current, second phase. After that, pre-industrial demonstration systems in the megawatt range are expected to deliver significant volumes of fuel. It should be possible to achieve efficiency ratings in the order of 60 per cent. That means 60 per cent of the green power used in the process would be stored in the fuel as chemical energy.

CO_2-neutral and CO_2-negative applications

Climeworks AG, established in 2009 as a spin-off from ETH Zürich, now has more than 120 employees and focuses mainly on two areas. Its wholly owned subsidiary Climeworks Deutschland GmbH, based in Cologne, mainly looks after the CO_2-neutral applications.

- **CO_2-neutral applications:**
  After capturing the CO_2 directly from the atmosphere and using it as described above, the CO_2 is released back into the atmosphere and can once again be captured (a closed carbon cycle). One example of an application for this would be the aviation sector, since – for long-haul flights at least – there are no genuine alternatives to renewable, synthetic fuels.
- **CO_2-negative applications:**
  The second field is known as carbon dioxide removal (CDR). In this case, in Iceland, for example, the CO_2 is pumped into underground basalt rock layers together with water. Here, the CO_2 turns into stone itself, which permanently and safely removes it from the atmosphere. Thus, the CO_2 is taken out of the atmosphere and moved below the earth's surface, a process known as direct air capture and storage, or DACS. In the future, this method could be used to remove significant volumes of CO_2 from the atmosphere to stop climate change, and even reverse it. In contrast, fossil carbon capture and storage (CCS), which is widely discussed, could only achieve carbon neutrality at best: although new CO_2 originating from the earth is trapped, none is actually removed from the atmosphere.

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André Bechem
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©: Climeworks

The direct air capture plant in Hinwil, Switzerland, was the first commercial facility of its kind in the world.

©: kit

All four process stages involving the partner entities Climeworks, Sunfire, Ineratec and Kit are brought together in a single system in this container.

High temperature-resistant – gas-tight – ultra-compact

The "energy transition" requires a raft of new processes for energy conversion and uses, such as Power-to-X (P2X). This calls for the development and implementation of innovative solutions for equipment and plant engineering.

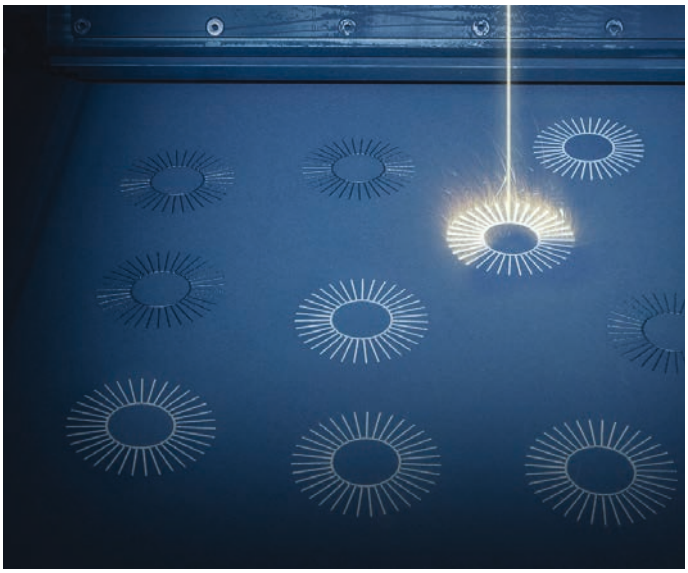
The use of excess electricity and renewable energy as P2X in industrial processes and mobile applications requires new system concepts – most often, concepts with very high equipment demands in terms of overall size, resistance to high temperatures and operational safety. The defined heating and cooling of media in recuperators is a widely used and crucial step in many processes. For particularly challenging heat transfer applications, Hülsenbusch Apparatebau GmbH & Co. KG has developed a compact, high temperature-resistant and gas-tight high-performance recuperator.

In many cases, the proposed P2X applications necessitate the development and manufacture of new systems and equipment. With P2X, as with conventional systems, the defined heating and cooling of gaseous and liquid media is necessary at many points. The increased use of hydrogen entails very high demands on operational safety. Leaks and weaknesses in gas-tightness must be eliminated to avoid the possibility of fires, explosions or other hazards. Leaks also reduce system efficiency and mean the input energy is not used optimally. Gas-tightness must also be guaranteed even at very high temperatures and pressure levels. There are also stringent requirements for the compact design of equipment in mobile applications. The spaces available are restricted, and the equipment needs to be as lightweight as possible. So the recuperators must have very high power densities to transfer large heat flows, while still being lightweight and small.

The role of recuperators

Recuperators have been used for decades for heat transfer in many systems and processes. Different types of recuperator with specific characteristics,

New high-performance recuperator: same level of performance, 25 times smaller in size.



© Hülsenbusch

Production in a 3D printer using selective laser melting.

such as tube bundle, plate and heat pipe recuperators, have been developed for the wide range of operating conditions. As the most basic type of construction, tube bundle recuperators are predominantly used in industry. Due to their robust construction, they have a high level of operational safety and take up a lot of space. In comparison, plate recuperators require less space. But because of their small wall thickness and the often crucial welded joints, they come with a higher risk of leakage, at least in high-temperature use.

To achieve a high level of energy efficiency in P2X systems, especially in hydrogen and fuel cell applications and mobile use, innovative recuperators with better performance values are needed. As part of developing hydrogen reformer units for decentralised power supply on board ships, Hülsenbusch Apparatebau and partners have developed a new high-performance recuperator. This model offers a host of technical improvements, such as high temperature-resistance up to 1,000 °C while maintaining full gas-tightness, and a very compact design. The unit achieves specific performance values of up to 8 MW/m^3 – 25 times higher than with conventional tube bundle recuperators. They retain the same high level of operational safety.

Enhancing performance by effective optimisation

These performance values are achieved through the use of thermally and fluidically optimised tube bundles produced by 3D printing (SLM). The flow is precisely directed around and within the tubes, to achieve a very high level of heat transfer. The specific heating surface is also increased, thanks to built-in components. The flow throughout the entire recuperator is evenly distributed by additional built-in components so that the heating surface in the recuperator is fully utilised. These measures are carefully tailored to one another, and are only possible in this form thanks to the precise production of the components using a 3D printer. All in all, they contribute to the exceptional efficiency of the high-performance recuperator.

In addition to producing hydrogen in the reformer module, this high-performance recuperator is also suitable for many other challenging applications. For example, when heating and cooling explosive and flammable gases, plate recuperators of the same size can be substituted, and at the same time the risk of leaks can be significantly reduced. This is achieved through the sturdy construction of individual components of the new high-performance recuperator, and the robust welded connections with sufficient material thickness. 3D printing-compatible construction and high-quality manufacture using 3D printing also guarantee the high level of safety of these systems. The optimised overall construction minimises thermal energy expansion and stress on the welding seams. With this new high-performance recuperator, a host of new P2X system applications with low space demands and high safety requirements is now viable.

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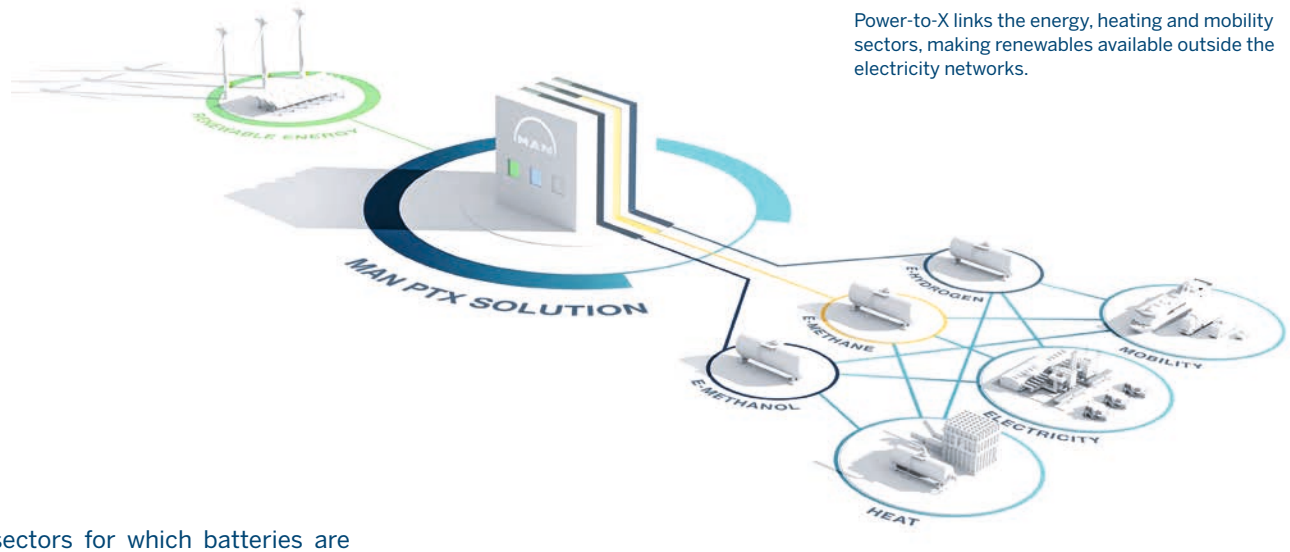
Can North Rhine-Westphalia become a Power-to-X pioneer?

Power-to-X, green hydrogen and the climate-neutral fuels derived from hydrogen will play a crucial part in the transition to a climate-neutral future – that's what all experts in economics, politics and industry all agree about.



Power-to-X links the energy, heating and mobility sectors, making renewables available outside the electricity networks.

In all sectors for which batteries are not an option for technical reasons, such as industry, building heating, and sea transportation, "e-fuels" have the potential to move away from generating emissions that harm the climate.

In the long term, a global market for e-fuels will take shape and offer opportunities in terms of industrial policy for technology manufacturers and producers. Currently, the German mechanical engineering and plant construction industry enjoys a world-leading position in the development of Power-to-X (P2X) processes. After many years of research and development and successful pilot projects, specialists such as MAN Energy Solutions at the Oberhausen site have long been ready to build industrially scaled plants.

MAN is a pioneer in P2X technology in Germany, and as early as 2013 it put a methanation plant into operation for the first – and, at 6 MW, for a long time the largest – Power-to-Gas facility in Europe. So far, the e-gas plant run by Audi AG in Werlte has been able to supply 1,500 gas-powered vehicles per year with climate-neutral fuel.

Since 2013, MAN has rigorously developed its P2X technology to the point where it can now offer turnkey plants with a capacity of 50 MW or higher. A plant of this nature can produce 14,500 tonnes of synthetic natural gas (SNG) per year. That would be enough for 470 gas-powered local transport buses to each travel 60,000 kilometres, on a totally carbon-neutral basis.

Power-to-X needs industrial scaling

Even though Power-to-X has long been technically possible, e-fuels are still not universally available on the market. While the hydrogen strategies recently submitted by the German government and the European Union are highly promising, the current overall regulatory framework continues to hinder urgently needed efforts to ramp up the market for synthetic fuels.

If Germany's mechanical engineering and plant construction industry is to maintain its advantage, however, we

Audi AG's e-gas plant in Werlte provides 1,500 gas-powered vehicles a year with climate-neutral fuel. At the heart of the plant is a methanation reactor from MAN.

need Power-to-X facilities at an industrial scale right now. Industrially strong regions like North Rhine-Westphalia are ideally suited to prove themselves as technology pioneers and to develop in a climate-neutral manner as a strong business location

North Rhine-Westphalia: pilot region for Power-to-X

Three factors are critical when selecting a location to construct a P2X facility: electricity from renewables to generate green hydrogen using electrolysis; a source of CO_2 to convert green hydrogen into synthetic natural gas; and lastly, customers for climate-neutral fuels. North Rhine-Westphalia meets all three of these prerequisites.

- **Renewables continue their advance**
  With its focus on energy, North Rhine-Westphalia is rigorously driving forward the expansion of renewables: In total, the state generated 23,304 GWh of electricity using wind and solar systems in 2019. It has strong ambitions: by 2030, the state government aims to have doubled the proportion of renewables in the electricity mix.

- **North Rhine-Westphalia: a trail-blazer in the circular carbon economy**
  CO_2 is needed to produce synthetic natural gas using green hydrogen. To avoid the need for costly and labour-intensive transportation, the source of the CO_2 should be in the immediate vicinity of the P2X plant. For example, the 16 waste-to-energy plants in North Rhine-Westphalia could be ideal suppliers. These represent about a quarter of the facilities in Germany, and each emits enough CO_2 to feed P2X plants with a capacity of about 800 MW. Emissions from industrial processes would also be suitable.

- **Many fields of application**
  Nowhere else in Germany has a concentration of industry as dense as North Rhine-Westphalia. CO_2-neutral energy sources are needed en masse in the medium term, whether to make processes in the steel manufacturing and chemical industries carbon-neutral or to open up vitally needed opportunities for decarbonisation for inland shipping on the Rhine. For public passenger transport, too, e-fuels have something to offer in providing carbon-neutral transport for millions of commuters.

North Rhine-Westphalia was once the heart of the European coal industry. No other federal state had to undergo greater structural change to reinvent and assert itself as a state-of-the-art location for industry. Power-to-X is one way for the state to continue to grow and enjoy a leading position as a green industrial location into the future.

Holger Kube
Head of Business Development
MAN Energy Solutions SE
Oberhausen
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MAN Energy Solutions now offers turnkey Power-to-X plants with a capacity of 50 MW and higher.

Clean combustion with hydrogen burners

As a fuel, hydrogen can be burned and produce virtually no pollutants in the process. No greenhouse gases are released. Porous burner technology can help achieve zero-emission operation. But there are also ways to reduce the emissions. Solar air collectors are an effective means of doing this.

©: GoGaS

Low-CO_2 building with solar air collector, which efficiently converts solar energy into heat via the medium of air.

P2X is one of the core technologies in the drive to reduce global CO_2 emissions. In the first step, electricity from renewable sources is used to break down water into hydrogen and oxygen in an electrolyser. The hydrogen can be directly converted back into energy in suitable hydrogen burners.

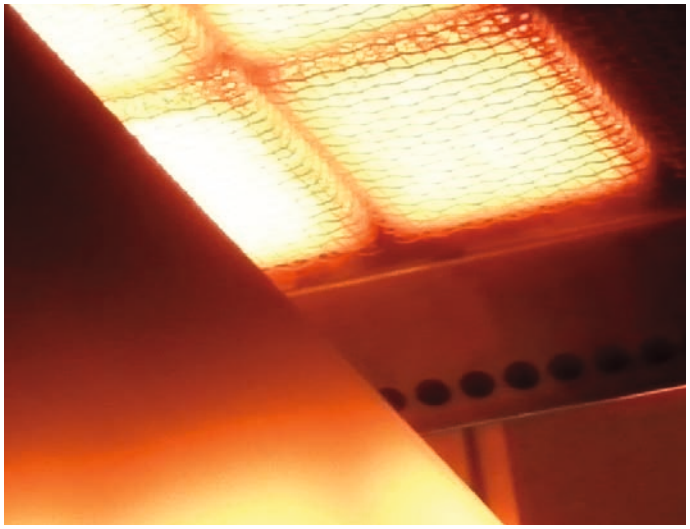
Dortmund-based thermal engineering specialist GoGaS Goch GmbH & Co. KG has developed a hydrogen burner that enables extremely clean combustion using porous burner technology. The process takes place in a porous ceramic foam, with each pore in the foam being a separate reaction cell. Apart from water, the only combustion products are trace amounts of nitrogen oxides. A hydrogen burner has more than twice the heat transfer coefficient of a natural gas burner – so the heating process takes only half as long. This technology can already be utilised in making steelworks largely CO_2-neutral. But it's not just heating or forming processes in the steel sector that can be made sustainable and climate-friendly using this method.

Technology for fuel independence

Another ZIM (the German government's Central Innovation Programme for SMEs) research project, partnering with KIT (Karlsruhe Institute of Technology), is working on a "switchable" burner that can work with natural gas and with hydrogen. This new technology means the burner doesn't rely on one particular fuel.

This new type of burner technology is also the focus of the EU's ECCO research project. The ECCO project is working on making the coil-coating process much more sustainable. The coil-coating method is used in most industrial steel and alloy production, and involves large-scale industrial facilities and a high level of primary energy consumption. As part of the ECCO project, the energy requirement will be reduced by about 80 per cent and CO_2 emissions by about 65 per cent, and the space required by the new technology will be cut by 50 per cent. In 2021, a pilot plant will go into production-scale operation at the project's rolling mill technology partner, Globus SRL, in Italy. The objective is to test the new process on a production scale and verify that there is no loss of quality compared to today's recognised processes. The new procedure should thus be "respectable" and accepted.

In addition, the burners can be used not only for process heating, but also in dark radiators as radiant heating for factory buildings. The question remains as to whether hydrogen is too valuable as an energy source to be used in its pure form for heating.



©: GoGaS

Steel belt dryer with porous burner, offering a higher energy density and accelerating heat transfer into the conveyor material without impairing product quality.

CO_2-neutral buildings

If we take P2X a step further, the next level is the reaction of hydrogen with environmental CO_2. Here, again using renewable electricity, methane – essentially natural gas – is produced. The methane generated in this way is CO_2-neutral, which means that in contrast to fossil fuels, no additional CO_2 is emitted during combustion.

In the building services engineering sector, it is possible to create buildings that are completely CO_2-neutral in operation. These sustainable buildings are fully planned and implemented by companies such as GoGaS. The prerequisite is that the building envelope is designed from the outset to be energy-efficient. By means of solar air collectors, a renewable base load is integrated into the building.

Depending on usage, this could amount to between 25 and more than 50 per cent of the building's total annual energy requirement.

The solar air collectors use the exterior wall of a building as a solar panel. Ambient air is drawn in through a specially designed, perforated plate. The outside air channelled into the building, preheated by the sun's rays, can reach a maximum of 45° Celsius above the surrounding air temperature. This means that in winter when the outside temperature is –5°, air at +40° is routed into the building, with no need to use fossil fuels. HVLS (High Volume Low Speed) fans prevent the formation of heat cushions below the interior ceiling of the building, saving even more energy.

Solar air collectors and HVLS fans can be readily retrofitted into existing buildings as part of energy rehabilitation schemes. Peak electricity load can be covered either by photovoltaic units on the roof in conjunction with heat pumps, or using our patented condensing technology for dark radiators. Previously, the waste gases from combustion were released into the environment at 200° Celsius. With modern condensing technology, this temperature can be brought down to 30°–40°. What's more, CO_2-neutral natural gas from P2X is used. The use of natural gas from P2X makes the entire process CO_2-neutral, as the CO_2 produced during combustion was taken from the atmosphere beforehand when the CH_4 molecule was formed.

Climate protection needs shorter approval times

It would be desirable for policy-making to adapt to the pace of innovation in the SME sector. The electrolyser as the starting point for P2X technology is subject to regulatory approval under Germany's Federal Immission Control Act (BImSchG). Under that legislation, approval periods are currently running at two to five years. For effective climate protection, the time from beginning of the planning phase to building hand-over must be significantly reduced!

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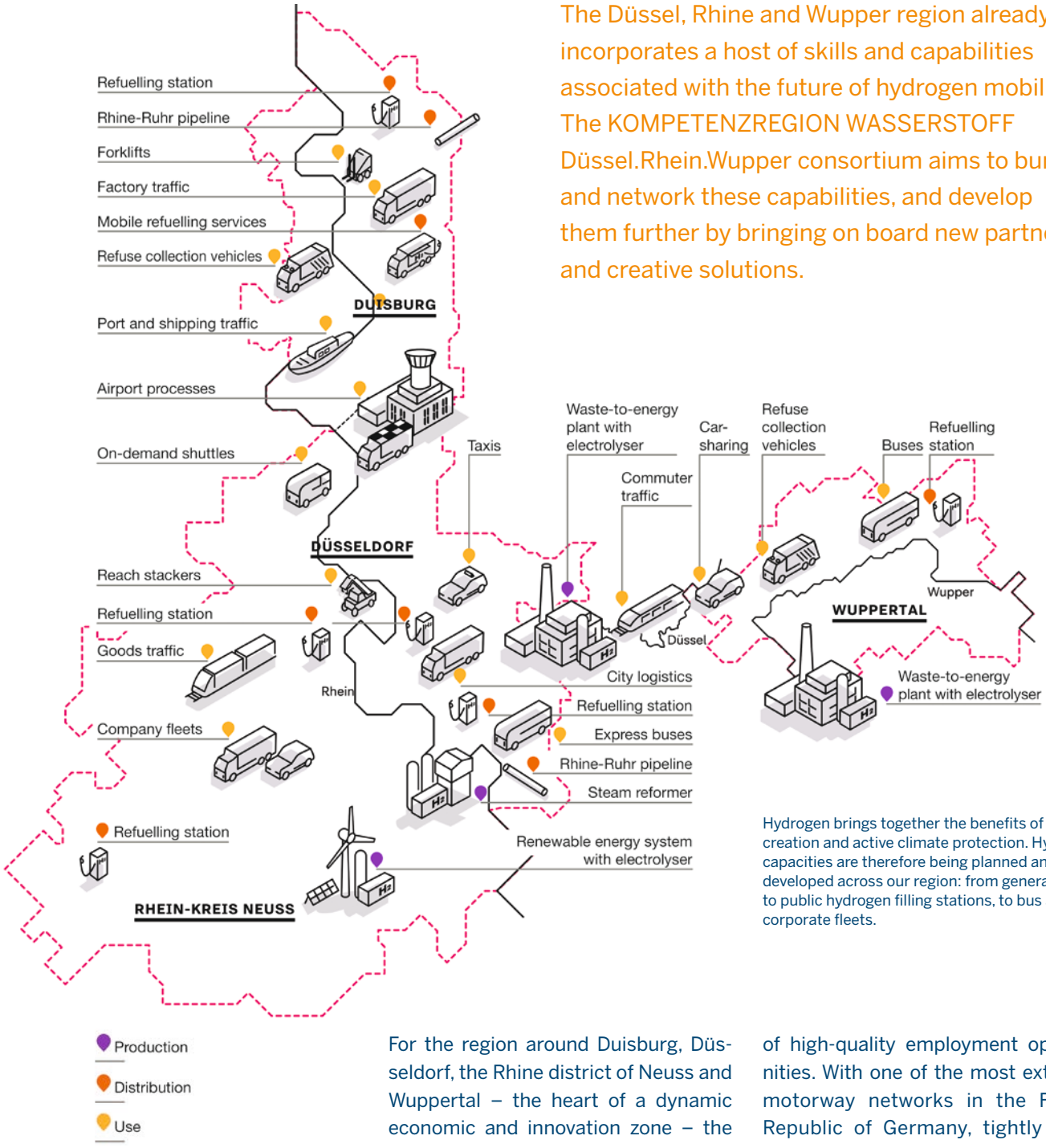
Here.Today.H2

The Düssel, Rhine and Wupper region already incorporates a host of skills and capabilities associated with the future of hydrogen mobility. The KOMPETENZREGION WASSERSTOFF Düssel.Rhein.Wupper consortium aims to bundle and network these capabilities, and develop them further by bringing on board new partners and creative solutions.



Hydrogen brings together the benefits of value creation and active climate protection. Hydrogen capacities are therefore being planned and developed across our region: from generation to public hydrogen filling stations, to bus and corporate fleets.

For the region around Duisburg, Düsseldorf, the Rhine district of Neuss and Wuppertal – the heart of a dynamic economic and innovation zone – the future will bring new tasks and challenges. This densely populated region is home to scores of world-class small, medium-sized and large enterprises, and so it offers a wide range of high-quality employment opportunities. With one of the most extensive motorway networks in the Federal Republic of Germany, tightly timed rail services and Duisburg-Ruhrort as Europe's biggest inland port, the region is also a major international transport and logistics hub.

Solution: local H_2 economy

But this unique location also faces major challenges. An above-average traffic load is having an adverse effect on the environment and quality of life in the region. There is also a need to find new responses to the challenges of structural change – despite all the region's achievements on global markets.

The creation of a local H_2 economy can provide answers here. This is demonstrated by a detailed concept which the cities of Düsseldorf, Wuppertal, Duisburg and the Rhine district of Neuss have worked out in collaboration with utility companies Stadtwerke Düsseldorf and Wuppertaler Stadtwerke, and Air Liquide.

The result: across the various application classes (passenger car, sprinter, light and heavy commercial vehicles, and buses), close to 1,500 hydrogen-powered vehicles could be on the road in the region by 2025, rising to around 6,000 by 2030. A sourcing cluster to leverage this potential was set up while the concept was still being developed. Ten fuel cell-powered buses are already in operation in Wuppertal, with plans to enlarge the fleet to 20 vehicles over the coming year. From the autumn of this year, the first fuel cell-powered truck will also be on the road in the model region – operated by Düsseldorf logistics company ABC-Logistik.

The region also has potential in producing hydrogen. A minimum of six megawatts of electrolysis capacity at six waste-to-energy plants forms the backbone of hydrogen production. By 2030, 130 megawatts of installed renewable capacity will no longer be covered by the compensation scheme under Germany's Renewable Energy Sources Act (EEG) in the region and, via electrolysis, can be put to meaningful use in terms of climate policy and economic considerations. Waste-to-energy plants and renewable energy systems can generate more than 5,000 tonnes of hydrogen per annum by 2030 – equivalent to over 90 per cent of the region's hydrogen demand in the mobility sector. To unlock this potential from renewable energy systems and waste-to-energy plants, a production cluster was set up.

In terms of climate policy, fuel cell mobility has a major role to play. The use of hydrogen within the region's transport sector could potentially cut CO_2 by around 750,000 tonnes between 2025 and 2035.

The competition

The "Kompetenzregion Wasserstoff Düssel.Rhein.Wupper" has been established as part of a funding competition run by the North Rhine-Westphalia Ministry of Economic Affairs and Energy. The competition aimed to find the "Model municipality/region for hydrogen mobility in NRW". The funding competition was designed as a two-stage competition process.

Concept outlines were submitted in November 2018. In addition to the region around Düsseldorf, winners in the first round were Steinfurt and H2Rheinland (Cologne including Brühl, Hürth and Wesseling, the Rheinisch-Bergische-Kreis and the Rhein-Sieg-Kreis). In the second stage of the competition, the Kompetenzregion Wasserstoff Düssel.Rhein.Wupper group emerged as the winner.

Success through cooperation

Close contact and communication with those actively involved in the field has always been a central tenet of work in the Kompetenzregion. The creation of a hydrogen ecosystem will not work without cooperation. In this spirit, in addition to the consortium itself, more than 50 companies have taken part and, as associated project partners, brought their ideas and specific projects into the concept.

This creates an open environment in which users and producers, municipalities and companies join together to shape the future of mobility, for their mutual benefit. Having won the competition, the parties involved now have additional motivation to implement the projects outlined in the concept – in line with their motto "Hier.Heute.H2" (Here.Today.H2).

The exchange of experience will also be expanded to take in Steinfurt and Cologne. The subject of hydrogen requires a wide array of collaborators – this applies in equal measure to hydrogen generation, and to its use and distribution. Together, these groups are working on bringing H_2 applications to road, rail and waterways. They are also looking for other companies and institutions within the region that have relevant projects and ideas to contribute. The creation of networks and the sharing of knowledge is an investment that has already paid off for the stakeholders in the Kompetenzregion Wasserstoff Düssel.Rhein.Wupper.

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