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PROFESSIONAL DRIVING

Dear Readers!

The debate about the future use of hydrogen is in full swing. At the moment, many different opinions are clashing; after all, the energy industry is also about re-sorting the balance of power. Sometimes, however, it is almost frightening to observe the fierce battles that are being fought, especially in the social media.

During an event in Berlin, Kurt-Christoph von Knobelsdorff, the managing director of the National Organisation for Hydrogen and Fuel Cell Technology (NOW) GmbH, remarked that the discussion had now taken on almost religious characteristics. He spoke of a "radical one-sidedness" that could be found especially on the part of the battery advocates. Among fuel cell fans, no one negates the need for accumulators, says the NOW boss.

Ferry Franz, Director Hydrogen Affairs Europe at Toyota, commented: "In terms of inner cities, small electric vehicles are certainly ahead." However, he further noted to has-to-be's e-mobility internet platform that in the future, hydrogen will definitely be ahead "when it comes to professional driving, transportation, long distance, transport and heavy-duty".

Perhaps this concept of "professional driving" is the decisive element in order to be able to better decide in the future when and where battery or fuel cell-powered vehicles should be used: In the private sector, there are now great and even very affordable offers to be able to travel efficiently and sustainably electrically – with battery cars.

However, the majority of the transport sector in which people drive for work could be covered much more efficiently with hydrogen. Buses, trucks, vans, ships, planes, trains are usually operated commercially. Professionals are at work here, so completely different standards apply than in the private sector.

While private individuals tend to choose their cars according to shape or colour, or according to which brand or performance class they prefer, other values count for professional drivers. Here, the focus is on factors such as economy, efficiency, durability, time savings and range.

Here is a small example: My neighbour is a salesman at a large German supplier company. He is always provided with a fancy, large company car by his employer so that he can travel quickly and comfortably in the field. Now his boss has decided to make the company's own vehicle fleet CO_2-neutral already by 2025. My neighbour thinks it's a great idea and is in favour of this step, but he and many of his colleagues now fear that they will then get battery cars.

Their association is that they then have to take a break for at least 30 minutes every 300 km at the latest (every 150 km in winter), possibly even longer if there is no free charging station. That's why my neighbour is clearly in favour of fuel cell cars and hopes that the H_2 filling station infrastructure will continue to improve by 2025. For his wife, on the other hand, who commutes 50 km a day, he would like to have a battery car that can then be charged with his own photovoltaic plant.

Kurt-Christoph von Knobelsdorff's statement that "the passenger car topic will come back – in five to ten years" fits this example. His estimate is probably based on the assumption that the density of H_2 stations will be so high that field staff will also be able to visit customers with fuel cell passenger cars as soon as a significant number of commercially used vehicles are on the road in Germany, i.e. a significant number of H_2 trucks are driving across the country and FC vans are delivering parcels in the cities.

If a few tech-savvy, well-heeled freaks want to buy a comparatively expensive H_2 car and then drive it on a skiing holiday once a year, let them do it. By then, the others will be able to access a dense network of charging stations with their purely battery-electric driven e-cars or will have long since switched to public transport and will then be sitting in an FC bus or an H_2 train.

Ah yes, the federal electrion in Germany: Which party you voted for is, of course, entirely up to you. For the hydrogen and fuel cell sector, it should ultimately not be so significant who governs in the end, because by now all democratically oriented parties have recognised that "business as usual" does not work. Accordingly, all of them have included hydrogen in their party programmes.

The only question that remains is whether the change, the energy turnaround, will be significant enough to prevent the number of weather extremes from rising even further. ||

Sincerely

Sven Geitmann
H2-international editor

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25 Hydrogen ferry in Schleswig undergoing trials

Source: Gateway49

50 Europe is "Fit for 55" – with hydrogen


Source: EIB

GERMAN-AMERICAN TAKEOVER

Fig.: Dr Massimo Venturi [Source: Eberspächer]

It also works the other way round: While mostly large US corporations take over foreign companies, in this case it is a German company that has bought up ViCTORi, LLC. At the beginning of July, the Eberspächer Group announced that it had acquired 100 per cent of the North American compressor manufacturer from Boulder, Colorado. With this step, the automotive supplier from Esslingen secured access to the worldwide hydrogen and fuel cell market.

ViCTORi, better known as Vairex air systems, develops and produces air compressors that are used, among other things, in fuel cells to supply the cathode side with gas. According to Martin Peters, managing partner of Eberspächer, the compressor is "a key component for the performance of fuel cells and contributes significantly to the efficiency, optimal design and durability of the overall system". He went on to explain: "We are deliberately investing in a market of the future and want to grow purposefully with hydrogen and fuel cell technology." Ski Milburn, who is to remain CEO of Vairex air systems, said: "The planned new products can be introduced faster than would have been possible for us alone." The new President of Vairex will be Dr Massimo Venturi (see photo). ||

On 14 and 15 September 2021, Eberspächer Vairex will present its new product range for fuel cells at the f-cell in Stuttgart.

SUBSIDIES OF PASSENGER CARS

The parliamentary group of Bündnis 90/Die Grünen (Alliance 90/The Greens) has submitted a small question to the federal government on the topic of "Promotion of hydrogen passenger cars". Parliamentarians Cem Özdemir, Oliver Krischer, Matthias Gastel and others wanted to know what results the financial support has produced so far.

The question refers in particular to the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP), which since 2007 has provided many millions of taxpayers' money for the procurement of vehicles, for tax concessions for their operation, for the development of fuelling infrastructure, and for research and development. The parliamentarians' criticism is aimed at the fact that despite various incentives (e.g. eligibility of new cars for the European CO_2 fleet limits or preferential treatment in road traffic via the Electro-mobility Act), the current stock figures of FC passenger cars are still low.

The Federal Ministry of Transport and Digital Infrastructure replied to this question on behalf of the Federal Government that "as of 1 June 2021, 1,261 fuel cell passenger cars were registered in Germany" (see also p. 26) – including 223 units from Mercedes, 540 from Hyundai, 126 from Toyota and 347 from Honda as well as a few other individual units. It goes on to say that according to the National Hydrogen Council, a small share of fuel cell passenger cars is expected by 2030. The National Platform for the Future of Mobility (NPM) also shows a low share, while Ludwig-Bölkow-Systemtechnik GmbH expects significantly higher values. The 90 H_2 filling stations that have been state-subsidised since 2008 have been supported with a total of over 100 million euros. ||

Source:
Federal Government, printed matter 19/30905

NOW NETWORK ATLAS

The Nationale Organisation für Wasserstoff- und Brennstoffzellentechnologie (NOW) GmbH has produced a new overview: During the Supplier Marketplace on 18 August 2021, the Berlin agency presented the "Atlas of Hydrogen Networks in Germany", which is intended to support both regional and nationwide searches for potential partners.

On 29 double pages in landscape format, clusters, energy agencies, innovation centres and loose associations as well as associations and societies in all 16 federal states are listed with name, address and homepage. A rough overview of European associations and networks was also included. ||

GUIDE TO H_2 SAFETY

Safety plays a decisive role when it comes to the topic of hydrogen. However, not because H_2 gas is exceptionally dangerous, but because there are many questions and uncertainties in dealing with this energy storage. For this reason, the HYPOS network has developed a guideline within the framework of the INES project, which summarises safety-related and organisational instructions that enable the safe operation of plants for hydrogen production, transport, storage and utilisation.

For more than three and a half years, the project partners (TÜV SÜD Industrie Service, TU Dresden, Dr.-Ing. Veenker Ingenieurgesellschaft, Otto von Guericke University Magdeburg, Fraunhofer IMWS) analysed and researched all conceivable safety aspects in connection with hydrogen applications. The 133-page paper can thus now – beyond the HYPOS network – act as a guide for future hydrogen projects for many stakeholders.

Project coordinator Dr Hartmut Neumann explained that the focus was on the specific hazards of H_2 technologies and the development of a methodology for an integrative safety assessment of the technical-technological value-added chain of power-to-X technologies. He said: "The guide not only gives users, manufacturers or project developers an initial orientation, but also concrete advice on how to get started with the topic of hydrogen safety at all the value-added stages considered." ||

FES AND SERENERGY ACQUIRED

Fig.: Hans-Peter Fischer [Source: fischer group]

The fischer group is transferring its fuel cell business to Advent Technologies Holdings, Inc. At the end of June 2021, the US FC company announced that, in addition to the assets of German fischer eco solutions GmbH (FES), it was also taking over those of Danish SerEnergy A/S. Advent will pay 15 million euros in cash and 37 million euros in ADN shares for this, and will henceforth be responsible for both the 17 FES employees and 55 SerEnergy employees in Aalborg, Denmark, as well as the 20 in Manila, Philippines.

Dr Vasilis Gregoriou, CEO of Advent Technologies, said: "We are excited about the agreement signed between Advent and the Fischer family, which will integrate some of the world's leading suppliers of high-temperature fuel cells into our company and contribute to our business momentum. [...] Together with the already completed acquisition of UltraCell, this will make Advent a global leader in the production of fuel cell systems for the distributed and off-grid energy market."

Hans-Peter Fischer, managing partner of the fischer group, said: "Our fuel cell business has worked for 15 years to become a leader in off-grid markets. [...] The Fischer family is very excited to partner with Advent in this fast growing market." Morten Sørensen, Research Director at SerEnergy, added: "We consider the potential for synergies between the companies in the group to be very high. SerEnergy's reformed 5 kW methanol fuel cells, our strong development team and existing customer base are the perfect complement to Advent's proprietary technology and product line." ||

DZM STARTS OPERATION

Almost exactly one month before the federal election, Federal Minister of Transport Andreas Scheuer gave the go-ahead for the establishment first of the office and then of the German Centre for Future Mobility (DZM) he is planning in Munich. The kick-off event for this took place on 23 August 2021 in the presence of the Bavarian Minister President Dr Markus Söder and Dieter Reiter, the Lord Mayor of the City of Munich.

According to the BMVI, the DZM is to become "an internationally outstanding centre of mobility research" where "the mobility of tomorrow will be rethought and developed". The content will focus on hydrogen technologies, synthetic fuels, innovative logistics concepts and digital, platform-based mobility concepts. It is also about expanding the production of both electricity-based fuels and advanced biofuels in Germany. The Federal Ministry of Transport and Digital Infrastructure (BMVI) said: "We bundle expertise and promote the exchange between science and industry – application-oriented, future-oriented, user-oriented, internationally at the highest level and visible worldwide." A total of 400 million euros will be invested and around 200 scientists are to be employed.

In addition, other locations are to be involved in various topics and supported with 4.55 million euros. In June 2021, it was announced that the Hamburg Wireless Innovation Competence Center (HAWICC – Funding: 0.25 million euros), the Smart Rail Connectivity Campus research campus (SRCC – funding: 2.3 million) in Annaberg-Buchholz, Saxony, and the Rail Campus OWL (funding: 2.0 million) in Minden, North Rhine-Westphalia, were selected as satellite centres. Another DZM branch is to be located in Karlsruhe, Baden-Württemberg. The planned Hydrogen Innovation and Technology Centre, for which Chemnitz, Duisburg and Pfeffenhausen, Bavaria, are currently bidding in the site allocation procedure, will also be part of the network. The "Behörden-Spiegel" quotes the Federal Government as saying that "due to a lack of knowledge of the locations, the BMVI was unable to carry out a prior examination of the economic efficiency of the project".

In response to a question from the opposition in the parliament as to whether there had been a call for tenders before Munich was chosen as the seat of DZM, the Federal Government replied: "There is no process relevant under procurement law in the determination of the location or an obligation to conduct a competitive procedure. [...] The immediate proximity to the digital test field along the A9 as well as to the International Motor Show were factors in favour of the Munich Metropolitan Region as the location for the headquarters of the German Centre Mobility of the Future." ||

LØKKE HEADS HYDROGEN EUROPE

Fig.: Jon André Løkke [Source: Nel]

The European Hydrogen Association has reorganised itself. In June 2021, Hydrogen Europe announced that Jon André Løkke would henceforth be the Chairman of the Supervisory Board. Løkke succeeds Valerie Bouillon-Delporte, who had held the post since 2017.

Løkke, CEO of Nel Hydrogen since the end of 2015, said: "The time for hydrogen is now. It is of utmost importance to accelerate development, scale up and reduce costs. Good cooperation is essential to achieve this. I hope that I can contribute with my experience and background to support the vision of Hydrogen Europe, as well as the team and the rest of the Executive Board."

Together with Løkke, five other members were elected to the Supervisory Board: Glenn Llewellyn, Airbus; Gerrit Marx, CNH; Melissa Verykios, CEO Helbio; Gunnar Groebler, Salzgitter; Christelle Werquin, France Hydrogène.

Jorgo Chatzimarkakis, former Secretary General and new CEO of Hydrogen Europe (see also his article on p. 50), explained: "Thanks to the leadership of Ms Bouillon-Delporte, the association is now on the right track to underpin the role of hydrogen as the second pillar of the energy turnaround. I welcome Mr Løkke and Mr Schutte [a member of the Supervisory Board since 2019; editor's note], who will jointly lead the association and the board members to realise our vision of driving global carbon neutrality by accelerating the European hydrogen industry." ||

H_2 PIPELINE FOR EASTERN GERMANY

The transmission system operators Gascade Gastransport GmbH and Ontras Gastransport GmbH are planning to set up an eastern German hydrogen hub with doing hydrogen. Within this framework, H_2 production, transport, storage and consumption in Mecklenburg-Western Pomerania, Brandenburg, Berlin, Saxony and Saxony-Anhalt are to be bundled. A regional H_2 pipeline network is to be installed for this purpose by 2026, in which about two-thirds of the existing natural gas infrastructure will be converted and one-third of supplementary H_2 pipelines will be newly built. Christoph von dem Bussche, Managing Director of Gascade, explained: "Together we can initiate the rapid development of a hydrogen economy in eastern Germany. With 475 kilometres of launch network, we can quickly build large H_2 capacity and also expand internationally." Gascade further told H2-international: "Our approach is to build a physical hub. We want to create the transport infrastructure as a link between the production and consumption of hydrogen." ||

Category: Trade fairs | **Author:** Sven Geitmann

IN DIRECT COMPETITION WITH THE F-CELL

Peter Sauber hands over to Landesmesse Stuttgart

A difficult mixture – this is how one could describe the setting of this year's f-cell. Because precisely on 14 September 2021, when the doors opened again for the Fuel Cell Symposium in Stuttgart's Haus der Wirtschaft (House of Economy), the Automechanika also started 200 km to the north. Messe Frankfurt is also focusing on hydrogen this year – as a "game changer for the mobility of the future". Much further north, in Schleswig-Holstein, the three-day Husum Wind Fair began on the same day, where the topic included "hydrogen and climate protection".

Michael Johannes, Vice President Mobility & Logistics at Messe Frankfurt, explained in advance as part of the digital Energy4Mobility talk series with Silke Frank, Managing Director of Mission Hydrogen and former long-time employee of the Peter Sauber Agency: "We created this expert talk series because there will be no mobility turnaround without alternative energies. [...] But we also want to play this topic more strongly at our two trade fairs in Frankfurt, Automechanika and Hypermotion, from 14 to 16 September 2021."

Automechanika is the automotive industry's leading trade fair for equipment, parts, accessories, management & services and this year offers a condensed on-site exhibition as well as on-line presentation and networking opportunities. Hypermotion on the topics of mobility and logistics took place in parallel.

In Stuttgart, the local organiser, Peter Sauber Messen und Kongresse GmbH, hosted around 60 exhibitors who presented their innovations live to visitors under the motto "Energizing Hydrogen Business". In addition, the same number of speakers presented the latest development results and projects during the congress.

In Husum, information on a green hydrogen economy in various regions were provided as early as 13 September, as part of the H2.0 conference there. Two days later, during the Husum Wind trade fair, the watt_2.0 forum followed, also on the topic of hydrogen. ||

PETER SAUBER RETIRES

Fig.: Peter Sauber

In mid-August 2021, Peter Sauber, founder of f-cell and owner of the event agency named after him, announced his intention to gradually withdraw from the active trade fair business. In order to ensure a smooth transition after decades of activity in the event sector, the agency business is to be merged with that of Messe Stuttgart within the next few weeks. Neatly explained: "We bundle our expertise. From 2022, our portfolio will find its home at Messe Stuttgart."

The Peter Sauber Agentur had already cooperated closely with Landesmesse Stuttgart GmbH in 2012 and had moved from the Haus der Wirtschaft (House of Economy) to the Stuttgart trade fair grounds at that time. However, since the symbiosis with Battery+Storage did not bring the hoped-for growth in subsequent years and the FC community preferred a more homely atmosphere, f-cell moved back to the city centre in 2018. The cooperation with the Landesmesse seemed to be over.

However, Peter Sauber now announced: "The complete team will also move to Messe Stuttgart on 1 October 2021, and I am still going to be available as an external consultant for some time." The declared goal is to take "f-cell to the next level as Europe's leading event for hydrogen and fuel cells" at the modern trade fair centre in the heart of Europe. The Canadian sister event, the f-cell+HFC in Vancouver, as well as the international joint booth during the FC Expo in Tokyo, also organised by Sauber, will also change hands.

Category: Policy | **Author:** Sven Geitmann

GREENWASHING IN THE GAS SECTOR?

Comment on the influence of lobby groups

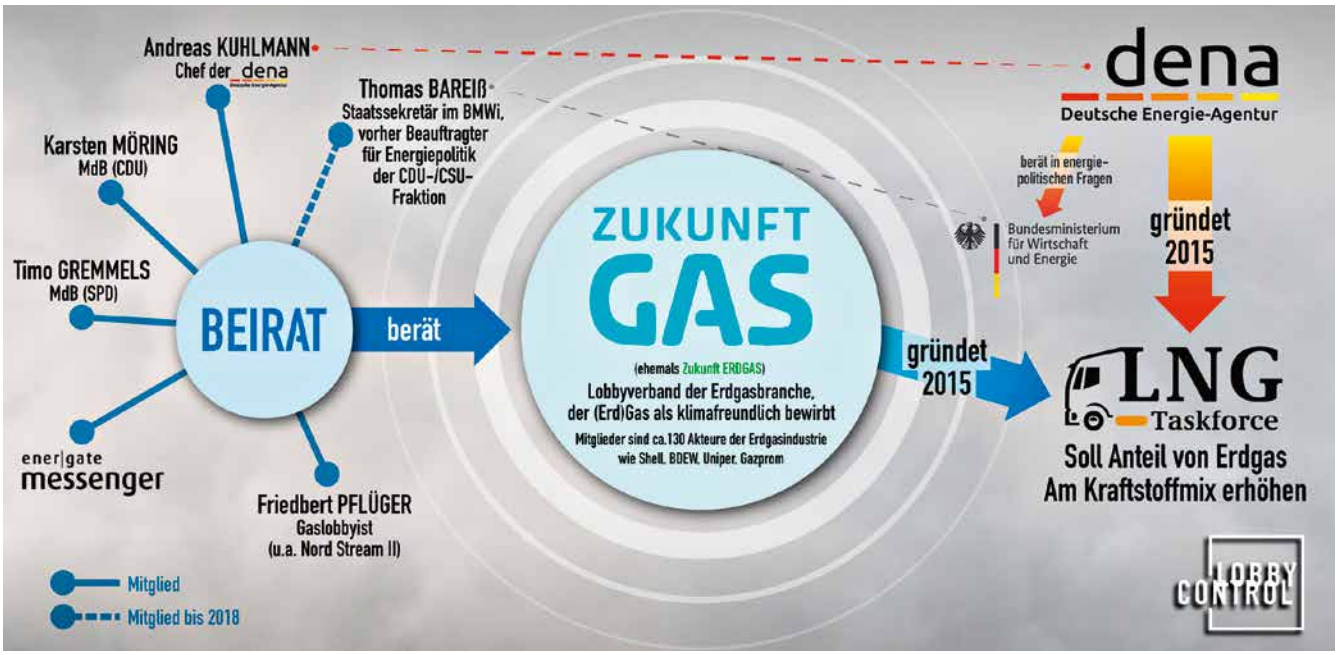

Fig. 1: Connections and forces of influence at Zukunft Gas

Alongside factual reporting, H2-international regularly features commentaries on the current political situation as well as the activities of associations. Such opinion pieces may occasionally leave one or the other reader feeling disgruntled if their view differs, but these articles can also help to make sense of events that may be difficult for outsiders to interpret. Even for people with a different viewpoint, such commentaries help them to form an opinion – in whichever direction. In the light of recent events, H2-international has decided to provide an outline of matters that have attracted comment elsewhere, with the aim of facilitating comprehension for our readers.

First of all, it's important to clarify that this isn't about lobbyist bashing, it's about transparency. Pressure groups play an important role in society. There's a reason why lobbyists are termed a state's fifth estate – alongside legislature, executive, judiciary and the press. Thanks to the expertise of their member companies, these associations possess valuable knowledge that isn't always present within the government apparatus. This expert knowledge can contribute to improving draft bills, so that good legislation results. But as with almost everything, it's a question of striking the right balance. Measured, constructive suggestions for improvement can be helpful; too much influence can be toxic. An added factor is that associations can, as a rule, only offer recommendations. Whether these are accepted by the legislator is another matter.

LOBBYCONTROL CRITICIZES ZUKUNFT GAS I mention this upfront because just recently, the gas sector was targeted by LobbyControl. LobbyControl is an initiative for transparency and democracy and, by its own description, aims to uncover wrongdoing and create transparency to ensure democratic control. An extensive report published by LobbyControl this summer took a close look at the German lobbying group Zukunft Gas. Founded in 2013, this German gas sector association stands accused of watering down Germany's climate policies. The report specifically states: "The German government is being closely advised by a gas industry lobbying group – at the expense of climate protection."

Author Nina Katzemich provides a detailed account of how the lobby group – which was previously known as "Zukunft Erdgas" and currently has over 140 member companies – exercises its influence on Germany's political processes. Based in Cologne, LobbyControl staff member Katzemich has also looked into the various platforms that Zukunft Gas has created. These include Initiative Brennstoffzelle, which refers to itself as a center of fuel cell competence, as well as a task force for liquefied natural gas.

The report states that the task force was set up in 2015 by the German energy agency dena, the German gas and water industries association DVGW and Zukunft Gas – apparently "at the behest of the German transportation ministry." In 2020, this led to various concessions (subsidies, tax incentives, toll exemption) for LNG trucks, even though the German environment agency UBA had only shortly before issued a recommendation not to extend toll exemption for LNG trucks, as the measure was "not really justifiable" for environmental reasons. It further stated that due to the escaping methane, the emissions for LNG were only marginally lower compared to a diesel truck.

TIMM KEHLER
Managing director of the Berlin-based Zukunft Gas is Timm Kehler. Kehler is also spokesman for the Zukunft Gas platform "Initiative Brennstoffzelle," together with Andreas Lücke, who was the CEO of the Federation of the German Heating Industry until September 2021. At the end of 2020, Kehler was additionally appointed president of the Natural & bio Gas Vehicle Association Europe.

Fig. 2: Kehler (left) and Rimkus at the webinar "Spotlight Energiepolitik"

Since 2016, gas lobbyists have been broadcasting the message that climate targets cannot be achieved without gas. This proposition manifested itself in Germany's gas strategy 2030, when economy minister Peter Altmaier attested that Germany's gas demand would increase and called for an expansion of the gas infrastructure. Katzemich believes that Altmaier based his statement on a study by Nord Stream 2, as research by the organization Environmental Action Germany had revealed.

Active members of Zukunft Gas include numerous municipal energy suppliers and utility companies, the energy and water industries association BDEW, as well as companies such as Gazprom, Shell, Uniper and Wintershall Dea.

In relation to hydrogen, LobbyControl criticizes the gas industry's demands for blue hydrogen to be rated carbon neutral – which was indeed achieved in Brussels, but not in Germany as yet. Zukunft Gas therefore continues to press hard for the promotion of hydrogen manufacture from natural gas, whereby the carbon dioxide is captured and then stored underground long term – a process known as CCS. The magic word in all this is "bridging technology," which is applied both to the transition from nuclear energy and coal to gas, as well as from natural gas to green gas, the latter signifying a completely carbon-free energy system.

In connection to this, the gas industry association wants hydrogen to be used as comprehensively as possible – both for transport as well as for the domestic energy supply, while the German Advisory Council on the Environment (see H2-international, August 2021) called for hydrogen to be limited to sectors where there are no available alternatives (such as the chemical, cement, glass and steel industries). Nina Katzemich points out that the German government had in fact recognized this in its hydrogen strategy, but that the gas industry is persisting in its campaign. This currently includes a new series of PR events by Zukunft Gas, which calls for a "full throttle" approach on hydrogen. Similarly, the DVGW recently showcased "hydrogen weeks," during which the advantages of green gas were discussed daily.

TOO CLOSE TO POLICYMAKERS LobbyControl takes a very critical view of the group's name change early this year from Zukunft Erdgas to Zukunft Gas, with the former belying its natural gas industry heritage, and also of the close ties between Germany's political organs and these associations. To cite one example, economy minister Altmaier is also patron of the German gas industry innovation prize, jointly awarded by the BDEW, the DVGW, Zukunft Gas and the energy use association ASUE.

LobbyControl in particular took to task the advisory council of Zukunft Gas. The council meets twice a year and advises the supervisory board as well as the board of directors. Its members include Timo Gremmels and Karsten Möring – both members of parliament who are active on energy and housing issues in their parliamentary parties. Until recently, the advisory council also included Friedbert Pflüger, former parliamentary state secretary to the defense minister, but he was appointed chairman of the supervisory board in July 2021.

LobbyControl disapproves of Pflüger's practice of presenting himself as a scientist when he is in fact lobbying for the gas industry as a partner of the lobbying agency Bingmann Pflüger International. According to Katzemich, this is also why the European Centre for Energy and Resource Security at King's College London, which he had been director of since 2010, distanced itself from him. Also very questionable, say the lobbying critics, are the energy talks regularly held at the Bundestag, to which Pflüger invites people such as former EU commissioner Günther Oettinger, former economy minister Sigmar Gabriel or Kerstin Andreae, managing director of the BDEW.

Another target for scrutiny was Andreas Kuhlmann, chairman of the board at the German energy agency. Thomas Bareiß, chairman of the supervisory board of federally owned company dena is also a parliamentary state secretary to the economy and energy minister, as well as a former member of the Zukunft Gas advisory council. Nina Katzemich argues that this represents a clear conflict of interest, as the boss of a supposedly independent federal agency is providing the lobbying group with access to the German government's legislative process (see "Gas 2030 dialog process"). This has also been heavily criticized by nongovernmental organizations.

Dena's reports and studies – some of them jointly published with gas technology corporation DBI – are partly supported by energate, a publishing and media company specializing in the energy sector. The chief editor of the company's Berlin office is Christian Seelos, who is also a member of the Zukunft Gas advisory council. When contacted by H2-international, Seelos stated: "There is no direct link. I am on the advisory council of Zukunft Gas as a trade press representative and my role is to monitor the discussion from a public interest point of view. This is an honorary role." Energate is a subsidiary of the conenergy consortium. Conenergy, in turn,

ASUE
Similar to Zukunft Gas, the Association for the Efficient and Environmentally Friendly Use of Energy, ASUE in short, brings together heating technology providers for single-family homes, municipal energy suppliers as well as gas grid operators. The association claims to campaign for an efficient, economical and reliable provision of power, heating and cooling. Its members include the DVGW as well as companies such as E.ON, Gas-Union, Gasag, Ontras, Viessmann and VNG.

is a consultancy and service provider to the energy industry. Its holdings include a 50 percent share in E-world energy & water – the leading trade fair for the gas sector.

Most recently, Zukunft Gas made good use of its close connections to political figures for a new series of talks on energy policy. Staged under the heading "Spotlight Energiepolitik," the events were held during the parliamentary summer break – ahead of federal elections – and featured Zukunft Gas managing director Timm Kehler discussing energy policy issues with different conversation partners. According to Kehler's own statement, the topics he discussed with his guests included "the course to be set on energy and climate policies after the federal election, for example with regard to the passing of the EU package 'Fit for 55,' as well as the direction the new government should take." His first guest on July 27, 2021, was member of parliament for the Social Democratic Party Andreas Rimkus.

When H2-international asked whether policymakers and gas associations were too closely intertwined, Rimkus replied that special interest groups were important and that interconnectedness was good, as long as everything was transparent. During the webinar mentioned above, he said: "It makes sense for politicians and associations to work together. I'm firmly convinced that it's the right thing to do." Kehler agrees that this is "how the system works" and cited the German constitution and the applied practice of interest groups explicitly being invited to join Bundestag committees. When asked about any possible concern that other technologies or interests might get "excluded," for example as a result of economy minister Altmaier appearing as patron at gas industry events, they didn't feel this was a problem as long as everything was done "openly and transparently."

In her conclusion, Katzemich writes: "The gas industry is succeeding in marketing natural gas as a green fuel. It is persistently seeking to ensure that use of its fossil fuel and the associated infrastructure will continue far into the future. The PR lobbying group Zukunft Gas plays a key role in this. The association is framing gas as a green and supposedly carbon-neutral energy source, and is promoting it as a means to achieve the energy transition using highly contentious remarks. Yet the government, especially the economy and energy ministry as well as dena, work very intensively with the association. [...] The closeness between some sections of the German government and Zukunft Gas is unacceptable. A PR lobbying group should not be involved in shaping the government's gas policy." LobbyControl concedes that all stakeholders should be consulted, but demands that the government must listen to its own scientific experts rather than interest-driven industry studies. It is also urging the government to significantly distance itself from lobbying organizations with regard to political decision-making. ||

Source:

LobbyControl, Nina Katzemich: Zukunft Gas: wie ein PR-Lobbyverband der Gasindustrie die deutsche Klimapolitik verwässert, July 21, 2021

"Zukunft Gas is an initiative of Germany's gas industry. It brings together the sector's interests and acts as the industry's voice in the public, political and consumer domain. Together with its members, the initiative champions the potential of gas as an energy source and advocates for the use of the existing gas infrastructure. It also provides information on the opportunities and possibilities that natural gas and green gases such as hydrogen and biogas offer our society. The initiative is funded by leading gas sector companies. Industry associations and heating technology firms support Zukunft Gas as partners."

Zukunft Gas about itself

Category: Policy | **Author:** Sven Geitmann

CURTAIN FALLS FOR THE EnergieAgentur.NRW

NRW.Energy4Climate emerges as new regional body

At the end of 2021 the EnergieAgentur.NRW will close its doors for good. For over 30 years, the energy agency for North Rhine-Westphalia – Germany's most populous state – has been an established part of the energy industry and has played a prominent role in the transition from coal to a renewables-based economy. With offices in Düsseldorf, Wuppertal and Gelsenkirchen, the agency has had a presence in the very heartlands of Germany's energy production. Initially these cities were centers of the fossil fuel industry and in more recent times have shifted their focus increasingly to more sustainable energy sources. The regional agency was also a pioneer in the emerging hydrogen and fuel cell sector and in the early 2000s boasted an extensive network of 40 members, a figure which later rose to almost 600 partner organizations, setting the standard for the nation as a whole.

North Rhine-Westphalia has had a long involvement in the energy sector. Consequently, the state played a central part in the establishment of the European Coal and Steel Community from which the European Union then later evolved. From 1951 onward, this European trading association allowed its members – Belgium, Germany, France, Italy, Luxembourg and the Netherlands – to access coal and steel without having to incur customs duty.

The team, led by director Frank-Michael Baumann, was able to leverage this experience in order to initiate numerous demonstration projects and entice many innovative enterprises to move to the region. This laid the foundations for a transformation of the energy sector long before the term "energy transition" had become common parlance. One particular highlight in the agency's endeavors was the successful staging of the World Hydrogen Energy Conference in 2010 in Essen.

The EnergieAgentur.NRW GmbH, which was formed in 2007 through the merger of the Energieagentur NRW and the Zukunftsenergien NRW regional initiative, assumed the form of a private company that undertook work on behalf of North Rhine-Westphalia. In its mandate, emphasis was placed on neutrality rather than profit. Shares were divided equally between the companies Agiplan, which dealt largely with communication, and EE Energy Engineers, a subsidiary

Fig.: Frank-Michael Baumann (shown here in 2017 at North Rhine-Westphalia's representation in Berlin) took on the directorship of the then Zukunftsenergien NRW regional initiative in 1996. He will enter retirement along with his fellow director Lothar Schneider.

of TÜV Nord, whose remit primarily covered the project business and networks. The agency also collaborated closely with the local chamber of commerce and was financed by both regional and EU funds in a roughly equal split.

PINKWART REMARKS CAUSE ANNOYANCE When questioned about why the current contract was not being extended and the reasoning behind a new energy and climate agency for North Rhine-Westphalia, it was claimed that the state was restructuring its climate action and energy sector initiatives. The region's economy minister Andreas Pinkwart declared in a press statement in May 2021: "This is a mammoth task for which we need professional and sufficiently flexible structures. The regional body NRW.Energy4Climate is a means of resetting the course toward this."

Not long before these remarks were made, Pinkwart had told broadcaster WDR in March: "What we have resolved to do for the next 10 or 20 years here in North Rhine-Westphalia is a real undertaking. And this undertaking requires a powerful organization. And sadly this is something we have not had up until now." However, in an official communication from January 2021 seen by H2-international, Pinkwart had attested that the EnergieAgentur.NRW had "performed extremely successfully for many years" and had a "very high reputation" far beyond North Rhine-Westphalia and acted as an example to the world.

Pinkwart also indicated that the previous contracts could not be extended again "according to current public procurement law" once this had already occurred for 2021. A simple "Business as usual" scenario with the existing staff is therefore not possible, it was claimed. Furthermore, he described the practice of retendering every six years, a process which dates back more than 30 years, as "a temporary measure with shaky underpinnings in terms of its scope and legal basis."

The advantage of the new agency, in the minister's opinion, is that it "can be more directly controlled as a wholly owned regional entity, tasks can be organized more flexibly." He announced that private service providers would also be commissioned in parallel to the work undertaken by the agency.

OVERWHELMING CRITICISM This decision, which was taken by North Rhine-Westphalia's coalition government under Minister President Armin Laschet, garnered vehement criticism from its opponents. Wibke Brems, the Green party's energy expert at the state parliament in Düsseldorf, said: "The energy agency does a very, very good job. I'm sure that the minister is trying to gain more influence over such an agency if he is bringing it closer to the ministry."

Likewise André Stinka, energy spokesman for the Social Democratic Party at the state parliament, explained to WDR: "The energy agency is inconvenient. And it makes it clear to the state government that its claims frequently do not line up with reality. It knows, for example, that when it comes to heating expansion, we are not falling behind because buildings cannot be renovated. And perhaps the minister does not like this assertion." Stinka also told the Welt am Sonntag newspaper: "It doesn't suit the state government that the agency is forever being critical of it."

In addition, the nature of future engagement with the agency's many partner institutions has been left hanging in the balance since it is likely that not all previously established networks will continue going forward. Instead, other offerings and formats may take their place. WDR sums up the situation as follows: "The opposition is outraged, staff frustrated."

> "Instead of repeatedly tendering to external service providers that are required to act within extremely tight legal constraints, it can carry out work flexibly and on a sustained basis – without long-term contractual constraints. Minister Pinkwart: 'When it comes to climate action and the energy transition, the notion of relying exclusively on service contracts that are limited in time and scope does not do justice to the economic and social meaning of climate action. For the vital implementation phase we need strong forces on a solid footing.'"
>
> *Extract from a press release dated May 20, 2021, North Rhine-Westphalia economy ministry*

"The regional initiative IN4climate.NRW remains as a brand under the umbrella of the new regional body. It will continue to focus on climate action and the transformation of North Rhine-Westphalia's industry and bring together experts from academia, business and politics in its role as a think tank and work platform."

NRW.Energy4Climate GmbH

POOR START FOR REICHARDT Heading up the new climate and energy agency will be Ulf C. Reichardt, a business administrator by training and the former director general of Cologne Chamber of Industry and Commerce. According to the regional economy ministry, Reichardt has been making preparations in readiness for the agency's launch since April 2021. Plans are based on the IN4climate.NRW platform that was created in 2018 and would allow the agency to start its operations, based in MedienHafen Düsseldorf and in Gelsenkirchen, in 2022. The NRW.Energy4Climate website (www.energieundklima.nrw) went online in summer 2021.

The decision to appoint the 56-year-old former Thyssen-Krupp manager, who has worked in Cologne since March 2012, to the position of chairman of the agency's board is highly controversial in spite of the fact that the post was publicly advertised and received more than 200 applications. The national chambers association bffk, for instance, reproaches Reichardt for the Cologne chamber "never submitting a legally compliant budget" while he was in charge (see the rulings of Germany's constitutional court dated Jan. 22, 2020) and yet, according to the claims, the chamber paid him a high salary and high bonuses.

In a contrasting take on events, the North Rhine-Westphalia economy ministry referred to Reichardt as one person from a wide field of applicants who was put through a multi-stage selection process overseen by a human resources consultancy. The ministry also highlighted his entrepreneurial approach and his understanding of how to bring together various stakeholders and encourage them to take part in joint projects and investments. In addition, Reichardt had an established and extensive network of contacts within the areas of business, politics and administration which made him an ideal candidate for the post, it said.

FUTURE FOR STAFF UNDECIDED At the end of September 2020, the EnergieAgentur.NRW had 158 members of staff. By summer 2021 its workforce still numbered around 120 people. Since then the core team at EnergieAgentur.NRW GmbH has been let go. The office rental agreements are also due to expire as the year closes out.

Responding to the query that H2-international put to Minister President Laschet about what would happen to the agency's former employees, the state economy ministry stated: "At the very latest since the announcement of our plans in September 2020 the companies behind EnergieAgentur.NRW GmbH have been requested to create new opportunities for their employees. As a private company it is part of its business model to apply for public and private contracts on the open market. In addition, the state of North Rhine-Westphalia has recently put out to tender various contracts that support the state's energy and climate objectives. The supporting companies of the EnergieAgentur.NRW have already been successful in many of these bidding processes."

Some workers will likely either remain or find new employment at EE Energy Engineers, which is led by Frank-Michael Baumann and Andreas Ziolek. Therefore most of the roughly 80 former staff members at EE should be taken care of. However, sources in Düsseldorf indicate that the future of staff working for Agiplan is, for the most part, uncertain. Realistically, the chances of being taken on by the new regional entity are limited since only 20 to 25 jobs are expected to be created there initially. This figure is set to grow to 100 from 2024 at the earliest. However, Janne Hauke, temporary spokeswoman for NRW.Energy4Climate, explained that "some of the in-house expertise at the current EnergieAgentur.NRW and associated jobs" were being retained. Furthermore, "open application processes for various job profiles" are currently ongoing, commented Hauke.

According to its own statement, the EnergieAgentur.NRW is "still in tendering processes for follow-up contracts for the North Rhine-Westphalia economy ministry." It was awarded four out of a total of six tenders – some of which were a joint bid as part of a consortium of service providers. In all, the new state entity as well as supporting service providers commissioned by the state are due to recruit approximately 100 people in the course of this year.

UNPLEASANT PROCESS The responsibility for the closure of the EnergieAgentur.NRW supposedly lies with a report that was ordered by Minister Pinkwart in spring 2020. This report had outlined better policy control options in the event of a change in legal form and the associated direct instruction right. Furthermore, the internet portal energiezukunft.eu reported significantly lower staff costs resulting from remuneration based on a public service pay scale.

Reiner Priggen, chairman of the regional association for renewable energy, told WDR: "Every state government is, of course, entitled to change structures if such a thing occurs them. In my opinion that's quite legitimate. But then you also have to consider the people. They'll go away. And I think such inhumane treatment of people of this skill level simply can't be tolerated."

On the whole, it can be said that following the initial outcry – the Bielefeld climate alliance amassed over 14,300 signatures by the beginning of August 2021 in a petition to keep the old agency – things have calmed down to a degree, since some of those affected can indeed expect improvements insofar as temporary contracts will be replaced by permanent ones. However, those who have lost their jobs and are facing an uncertain future have more to be upset about than just the process. ||

"We were informed of the decision by the economy minister Prof. Pinkwart at the end of September 2020 and are of course disappointed and saddened that, after 31 years, the work cannot carry on in its current form. [...] A basis for the decision was a report on the possible continuation of an energy agency. We were aware that a report of this nature was being prepared. The ministry previously obtained such a report from the same Berlin consultancy prior to the new tenders at the time in 2010 and 2015 – albeit in those instances with different recommendations; namely the continuation of the EnergieAgentur.NRW with the conditions that have prevailed since 1990. [...] The North Rhine-Westphalia economy ministry has communicated to us that the new ERDF program of the EU does not permit further financing of an EnergieAgentur.NRW."

Uwe H. Burghardt, press spokesman for EnergieAgentur.NRW

Category: Policy | **Interview Partner:** Rainer Baake

CARBON NEUTRALITY CAN'T BE ACHIEVED WITHOUT HYDROGEN

Interview with Rainer Baake, director of the Climate Neutrality Foundation

Fig.: Rainer Baake [Source: Climate Neutrality Foundation]

For years, Rainer Baake was seen as one of the staunchest skeptics of hydrogen and fuel cell technology. During his tenure as state secretary at the German economy and energy ministry (2014 to 2018) and the environment ministry (1998 to 2005) he acquired a reputation for blocking hydrogen schemes – with some projects getting as far as his desk but not much further. However, for the past few months he's been sending out rather different signals, especially since his appointment as director of the Climate Neutrality Foundation in July 2020. H2-international has taken this opportunity to talk to him about the foundation's recently published hydrogen study and about his new approach – which, he argues, isn't really that new.

H2-international: Mr. Baake, after more than 30 years in environmental policymaking, is it fitting to describe you as part of the bedrock of the renewable energy sector?
Baake: Bedrock sounds rather too static for my liking.

You were one of the first full-time Green Party politicians employed in environmental administration. In 2002, you helped shape the law to phase out nuclear energy and are sometimes referred to as the "manager of the energy transition." What kept you motivated over the years?
Together with many others, I worked to remove the dangers of nuclear energy and to build a modern, climate-friendly energy industry.

In 2018, you asked to be dismissed from your position as state secretary at the economy and energy ministry. Why?
The agreements on climate protection formed by the grand coalition were not ambitious enough to meet the challenges.

What does your new role at the Climate Neutrality Foundation entail?
Better climate protection requires scientifically substantiated schemes – instruments that enable us to reach specific targets – as well as a dialog among stakeholders. This is what the Climate Neutrality Foundation wants to help achieve.

How did you come to this role? Were you invited or did you actively apply for the job?
I was invited.

Up until a few years ago, you weren't a great fan of hydrogen – to put it mildly. Some exponents of the hydrogen sector used to describe you as a stumbling block or hurdle that was difficult to overcome. For a long time, you were in favor of an all-electric world, in other words complete electrification of the energy sector, including the expansion of the power line network. Today you seem a little more open minded in relation to hydrogen. Is that a correct observation?
The observation is wrong. Carbon neutrality can't be achieved without hydrogen. We need it in particular as a storage medium in the electricity sector and as a feedstock in industry. The dispute was and still is over whether we should also use hydrogen in areas where the direct use of electricity is significantly more efficient – for example in heating systems and cars. In a competitive economy, everyone is welcome to choose the costlier option at their own expense, but if you're asking for state subsidies, you have to expect questions about efficiency.

What caused you to realize that the energy transition can't be achieved entirely without gas?
Please have a read on the internet; I have held this view for many years now. And I would also like to remind you that carbon-neutral hydrogen is produced using electricity from renewable resources. In a carbon-neutral world, electricity is the all-pervading energy source.

Looking back, would you say it was a good thing that the hydrogen supporters remained so insistent?
Well, the hydrogen advocates aren't a homogeneous group. There are some supporters who want to use hydrogen where there is no better alternative. And there are some that want to use hydrogen – or hydrogen-based synthetic fuel – to continue operating old combustion technologies. The second group wants the world to believe the fairytale that cheap hydrogen will be globally available in the near future. The government should deploy subsidies in a targeted manner, instead of broadly scattering its resources about, as it currently does.

In May 2021, your foundation published the study "Hydrogen Strategy 2.0: How to accelerate the market ramp-up. A programmatic proposal." Please provide a brief overview of the core propositions.
As you've just rightly cited, we need to accelerate the process. To reach the new climate target, we foresee a hydrogen requirement of 60 terawatt-hours in 2030. We have proposed specific key points for further development of the hydrogen strategy – to ensure the necessary amounts are in actual fact produced, transported to the consumers and used in the right places. The production of carbon-neutral hydrogen will

require significant government funding, at least for the foreseeable future. Leaders will have to set priorities – at present these are industry, electricity production and long-distance transport. A robust certification system is essential if we want to achieve effective greenhouse gas reductions and ensure the efficient use of public funds. And as hydrogen will be traded across borders, we need a European solution. Where possible, the existing natural gas networks should be converted to hydrogen networks. We need an initial long-distance transmission network and, in the longer term, an interlinked EU-wide long-distance network, so we can connect to favorable locations such as the Iberian Peninsula.

Why did you commission the Freiburg-based Oeko-Institut with compiling the study? Dr. Felix Christian Matthes, the research coordinator of the institute's energy and climate division isn't exactly known for being a hydrogen supporter.

Evidently, nothing is as hard to dismantle as a solid preconception. I strongly recommend everyone reads his report. We have published it on our website.

The Oeko-Institut has stated that hydrogen is not the key to transforming the transport and heating sectors. Of course, supporters of hydrogen vehicles and fuel cell heating appliances are particularly critical of such comments. Where do you stand in this dispute?

In a market economy, everyone is entitled to use carbon-neutral hydrogen at their own cost, even for applications where more efficient and cheaper solutions exist. In the end, the customer decides. I'm not suggesting the government should restrict the application areas, but the use of limited public funding should be target-driven.

The team in Freiburg also asserts that hydrogen is a comparatively expensive option for climate protection and should therefore be consumed sparingly, like Champagne. Do you share this opinion?

Without subsidies, the price for carbon dioxide would need to be at EUR 350 per metric ton to achieve cost parity between hydrogen and natural gas. Currently, the carbon dioxide price in EU emissions trading is at around EUR 50 per metric ton. Innovations and industrial production will lower the costs, but I don't know a single operator who will be using carbon-neutral hydrogen in the foreseeable future without significant public aid.

So overall, you do now see hydrogen as an important factor in the energy transition. Am I correct in saying this?

If you cross out the word "now," then the answer is Yes.

Have you made peace with the key players in the hydrogen community? Are you already conversing with its exponents or are you open to dialog?

I am constantly engaged in exchanges with those who want to produce and use hydrogen. I agree with many of them, with some there is still dissent. The important thing is that we listen to each other and that we understand the other's position. The energy transition is a process of exploration – nobody has the complete truth.

What, in your opinion, are currently the energy sector's most important areas for improvement which the new German government should address?

The electricity sector plays a key role. We must decarbonize it as quickly as possible, which in particular means bringing the coal phaseout forward to 2030 and massively expanding renewable energies. If the additional electricity required for electric cars, heat pumps and hydrogen comes from coal- or natural gas-fired plants, then all we're doing is shifting the emissions – which won't help us achieve climate targets.

Will you continue looking into the possibilities hydrogen offers? What role do you feel hydrogen will play on the path to carbon neutrality – which of course is what you want to achieve?

Hydrogen is a key technology on the path to carbon neutrality.

In your opinion, will reaching carbon neutrality by 2045 be enough to keep to the two-degrees target?

In the joint report by Prognos, the Oeko-Institut and the Wuppertal Institute, we suggested achieving carbon neutrality by 2045 because it would save the atmosphere from the additional burden of close to 1 billion metric tons of carbon dioxide. If other countries meet their Paris Agreement obligations too, we still stand a chance of averting the worst form of climate catastrophe. The fact that we are already in the middle of climate change has just recently been highlighted by the devastating floods.

Thank you very much for your time and for answering my questions.

Interviewer: Sven Geitmann

Reference(s)

Climate Neutrality Foundation, Hydrogen Strategy 2.0: How to accelerate the market ramp-up. A programmatic proposal, 2021 (in German)

Category: Energy storage | **Author:** Maximilian Pfennig

PtX ATLAS SHOWS WORLDWIDE POTENTIAL

Hydrogen exports only viable in liquid form

Many regions of the world can be considered prime locations for the production of green hydrogen and renewably manufactured synthetic fuels. How much actual potential each area has to offer, though, has now been revealed in detail in the first-ever global power-to-x atlas. The assessment of each site's technical and economic potential is based on extensive analysis, for example the availability of land and the weather conditions. Other factors taken into consideration include local water supplies, ecological issues, investment security and transport costs.

Great hope rests on green hydrogen as a means of producing synthetic fuels. The expectation is that these energy carriers will replace their fossil-based counterparts in industry, transport and other sectors. As in many other countries, Germany attaches a high degree of importance to these power-to-x fuels in its climate policies.

But where could carbon-neutral fuels be sustainably made? How much could be produced and at what cost? And how would the costs be affected by transporting those fuels? The answer to these questions is something that the PtX atlas drawn up by the Fraunhofer Institute for Energy Economics and Energy System Technology IEE makes crystal clear.

The focus of the study is on locations outside the European economic area. For example, the map allows interested parties to call up relevant PtX sites along with their achievable full load hours and possible outputs, the production costs for various power-to-x fuels as well as the costs of their transportation to Europe.

The PtX atlas came about as part of the DeVKopSys project supported by the German environment ministry. The aim of the project is to scientifically examine development pathways in the transport sector that would be compatible with the climate objectives of the German government, while also taking into account other sectors of the energy system.

SUFFICIENT SUPPLIES The result shows that, while applying strict sustainability criteria for the site analysis, a total of around 109,000 terawatt-hours of liquid green hydrogen or 87,000 terawatt-hours of synthetic fuels can be produced each year in the long term outside of Europe. These synthetically produced fuels are also known as synfuels or power to liquids – PtLs for short. Only some of this potential, however, can be realistically exploited – among the reasons being that some locations do not offer adequate security for investment or they lack the necessary infrastructure.

Yet even if these factors are taken into consideration, the remaining potential to be tapped is still 69,100 terawatt-hours of hydrogen or 57,000 terawatt-hours of synfuels a year. By way of comparison, the global aviation industry will need at least 6,700 terawatt-hours in 2050; for international shipping the figure is 4,500 terawatt-hours of PtL.

If the achievable quantities are scaled down to Germany's current share as a proportion of the world's population, there would be 770 terawatt-hours of hydrogen or 640 terawatt-hours of PtL available.

TRANSPORT: A KEY COST FACTOR In calculating the economic potential of individual locations, researchers factored in the costs of generating electricity from renewables and the efficiency of power-to-x processes as well as peripheral, storage and transport costs. Areas with favorable wind conditions for power generation, particularly when combined with photovoltaics, proved to have the lowest production costs. In locations with scarcer wind resources, the power-to-x production costs using photovoltaics-based systems are, by contrast, higher. Yet even when it comes to hydrogen, the costs of conveying it to Germany are, depending on the site, a significant factor and in some cases this overcompensates for any differences between locations.

The atlas also shows that it is often more cost-effective to manufacture fuels such as PtL for the European market at the place where the green hydrogen is also produced, rather than relying on imported hydrogen in Europe. These synfuels are much cheaper to transport and, if these locations deploy air capture technology, they can obtain carbon dioxide for wider use. The reason behind this is that to transport hydrogen over long distances requires an enormous input of energy and expense to turn it into liquid form. Another consideration is the boil-off of liquefied gases which causes losses during transportation.

HYDROGEN FROM NORTH AFRICA The nations and regions which could be in the running to supply Europe need to be considered on a case-by-case basis. Countries with a high level of production potential and favorable socioeconomic conditions such as the USA and Australia could deliver large quantities of power-to-x fuels. Nevertheless, domestic demand, especially in the US, is predicted to be substantial which would reduce the potential for exports. Plus, the large distances involved would make it economically unfeasible to transport green hydrogen to Europe from these particular countries.

The scenario plays out differently when it comes to less far-flung locations, for instance in North Africa. From this geographical region it would be relatively inexpensive for hydrogen to be piped to Europe. That said, the politically stable nations of Morocco and Tunisia are only able to produce 814

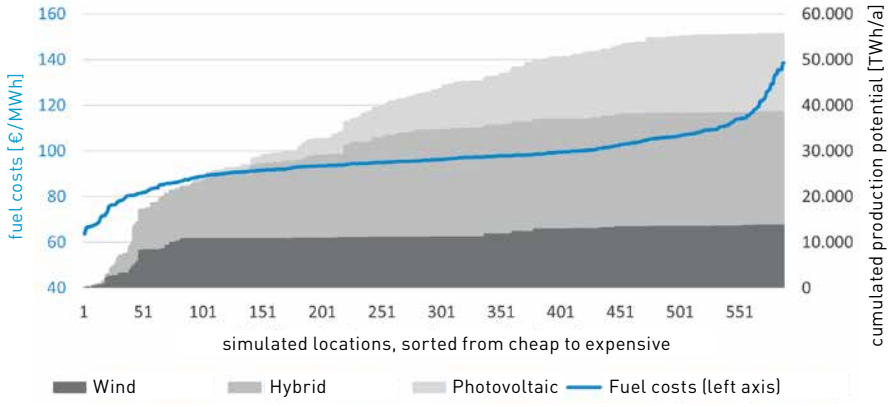

Fig. 2: Production costs and cumulative manufacturing potential of international coastal locations investigated in relation to the production of liquid hydrogen using low-temperature PEM electrolysis in 2050

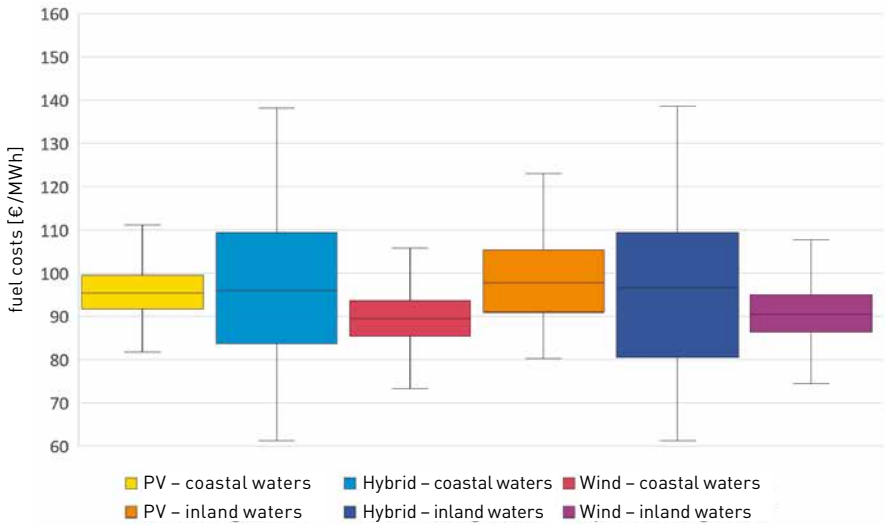

Fig. 3: Production cost ranges for the manufacture of liquefied hydrogen (using PEM or SOEC electrolysis) in 2050. Outliers (in the upper and lower 2.5-percent quantile) are not taken into account.

terawatt-hours of hydrogen. The potential in Egypt, Libya and Algeria is much greater, estimated at 8,638 terawatt-hours. However the socioeconomic conditions are much worse in these locations. Consequently, the investment risks are much higher which can also push up the costs of financing.

FUEL-BY-FUEL RESULTS In order for hydrogen to be brought to Germany from far afield, it needs to be liquefied and transported by ship. The average production costs for liquefied hydrogen in 2050 lie between EUR 64 and EUR 153 per megawatt-hour depending on the country concerned. If you add on the transportation costs, for example from Argentina, the import costs work out at EUR 112 per megawatt-hour. The bottom price for importing liquefied hydrogen to Germany is EUR 82 per megawatt-hour from Mauritania. Hence, it is not financially prudent to bring in imports of hydrogen from far-off countries such as Australia. On the other hand, the potential for imports via pipeline from areas including North Africa has its limits.

For synthetic natural gas (SNG), the same rules apply as for hydrogen in that the gas must undergo an energy-intensive liquefaction process before it can be transported by cargo vessel. And yet the potential for imports via pipeline is limited. The average production costs for liquefied SNG range between EUR 87 and EUR 195 per megawatt-hour, placing it at a similar level to Fischer-Tropsch fuels and methanol, albeit with pricier shipping costs.

PtL energy carriers such as Fischer-Tropsch fuels and methanol can be produced at average cost and range between EUR 86 and EUR 190 per megawatt-hour. In this case the cheapest locations are those with excellent wind conditions, although regions with high levels of solar irradiation, like Chile, can also be attractive even if it has little to offer in the way of wind resources. The lower cost limit for such locations is EUR 112 per megawatt-hour for PtL – the same figure as for SNG.

CONCLUSION The analyses to assess the degree of potential take into account tough sustainability criteria when appraising a site (among them, water supplies, infrastructure, absence of nature reserves or forests, absence of competition with agricultural land) as well as socioeconomic factors including social (e.g., satisfaction, health), political (e.g., rule of law, climate goals, corruption) and economic criteria. If these factors are taken into consideration, the realizable potential outside of Europe still amounts to 69,100 terawatt-hours of hydrogen or 57,000 terawatt-hours of PtLs a year.

Even in power-to-x export regions, the use of renewably generated electricity for PtX is in competition with the decarbonization of local power generation, for instance the early shutdown of coal-fired power plants, which would bring about a much greater carbon dioxide saving. The worldwide potential for renewable energies is extremely high, and the limiting factor is not the availability of suitable land; rather it's the maximum possible speed of renewables expansion. This becomes clear if you look at what has historically been the low proportion of global power generation contributed by wind and solar.

As well as exploring import options, Europe should endeavor to build up its own hydrogen production capabilities. This is where offshore could come in: Due in part to the lack of grid connection options, there is an opportunity for early expansion of offshore capabilities explicitly for the purposes of hydrogen manufacturing. As a result, gaseous hydrogen could be efficiently supplied to industrial users e.g., in the steel industry, or in the energy sector for fueling new gas turbines. Here we see a more competitive position in comparison to PtX import prices. For efficiency reasons, hydrogen that is produced in Europe lends itself to transportation via pipeline in the form of a gas while beyond European borders the preference is to import PtL by ship. ||

→ https://devkopsys.de/ptx-atlas

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Category: Energy storage | **Author:** Sven Geitmann

HYDROGEN RECOVERY FROM OLD WIND TURBINE BLADES

Havelstoff – hydrogen from the Havel region

Fig. 1: A copious amount of trash is readily available [Source: Shutterstock]

Producing high-purity hydrogen from the blades of decommissioned wind turbines is a most ingenious idea. If this can be scaled up successfully, it would solve a number of challenges in one fell swoop: For one thing, it would save the effort of shredding, recycling or otherwise disposing of old blades. Instead their composite material could be usefully reclaimed. Secondly, it would open up an additional hydrogen source to help satisfy the rapidly rising demand for hydrogen. And thirdly, the process would result in an extremely clean form of carbon dioxide that could be used in various branches of industry. But before any of that is possible, a whole range of issues must first be overcome.

Richter Recycling sees great potential for salvaging material from wind power plants that have been withdrawn from service. In 2019, the waste disposal business, located in the Berlin/Brandenburg metropolitan region, took specific steps to make this idea a reality. Christian Gerstädt, lawyer and legal advisor to the German company, told H2-international that Richter Recycling began a collaboration with Plagazi from southern Sweden 2 years ago and to that end acquired a 30-acre (12-hectare) plot of land in the Premnitz Industrial Park (IPP).

It is here – at the site of a viscose manufacturing plant that was demolished in 2016 – that hydrogen could be produced in years to come. Almost in anticipation of this development, Gerstädt founded Neue Energien Premnitz in early 2015, a business he runs as company director.

ROTOR BLADE RECYCLING Franz Richter, director of Richter Recycling, plans to use old rotor blades as the starting material for the hydrogen recovery process. These consist of a carbon composite material that is built to withstand the stresses and strains that wind turbines have to endure, including ultraviolet radiation, the weather, temperature variations and vibrations. When a turbine is dismantled, however, this material is then considered, in Gerstädt's words, "nothing more than non-recyclable waste."

Because the first wind plants to be constructed under Germany's renewable energy law EEG at the turn of the millennium are nearing 20 years of service, these plants are due to be scrapped in the months and years ahead. This then raises the question of what to do with them. The entire German wind sector is facing the challenge of finding suitable routes for disposing of or reusing this equipment to avoid the creation of huge scrap heaps, as has already happened in North America. Up until now, waste of this type has often been exported to Asia.

The timing is therefore apt. A fact which is also not lost on Plagazi SE. The Båstad-based enterprise promises a patented plasmalysis process that is capable of vaporizing the composite materials. According to the company, this procedure calls for very high amounts of energy but a large proportion of the thermal energy needed is basically supplied within the material itself. As a result, much less electrical energy is required in comparison to electrolysis, said Gerstädt.

The advantage of plasmalysis, Gerstädt added, is that the starting material is heated to extreme temperatures which divides it into its constituent parts. The molecules of complex carbon compounds are split and can then be separated or recombined. This allows C_mH_n compounds to produce both pure, liquid CO_2 and large quantities of H_2. Using this procedure, any pollutants arising are bound in a glass-like slag and are therefore comparatively easy to dispose of. Alternatively the byproduct can be reused in road construction, Gerstädt noted.

In Plagazi's view, its processing method is carbon negative in environmental terms: Up until now, the carbon that was used to manufacture the enormous turbine blades has not been offset anywhere. The carbon dioxide that is produced during plasmalysis can be kept in circulation and utilized for industrial purposes. In the food processing or chemical industries, for example, this means that carbon dioxide does not need to be manufactured separately using energy-intensive techniques and consequently the overall result is a carbon saving.

The Swedish enterprise has started the ball rolling in several locations, among them North America. Torsten Granberg, Plagazi director, reported at the end of June 2021 that Plagazi has been carrying out treatment tests on wind turbine blades in a plasma gasification plant in the USA, working with its technology partner InEnTec. Nevertheless, the treatment process is only being tested on a laboratory scale and is not being put through its paces in continuous operation. Granberg explained that if the blades are simply scrapped and piled up in landfill sites they will stay there forever since they cannot be decomposed or other-

Fig. 2: Torsten Granberg [Source: Plagazi]

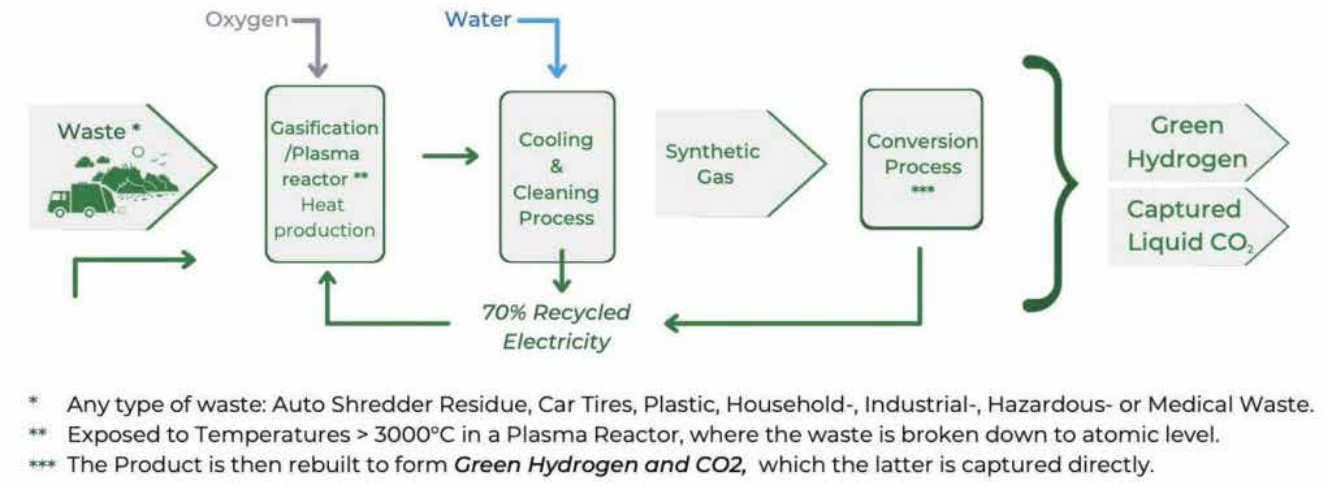

Fig. 3: The Plagazi process [Source: Plagazi]

wise broken down naturally. He estimates that 14,000 wind turbine blades will be taken out of service in Europe by the year 2023, the equivalent of between 40,000 metric tons and 60,000 metric tons.

PLANS FOR PLASMALYSIS PLANT IN PREMNITZ The German town of Premnitz, which also submitted a bid in early 2021 to become the location of the proposed hydrogen research center (see H2-international, August 2021), also already appears to be familiar with this idea. The prospect of Plagazi investing around EUR 70 million in the area has purportedly generated much interest in its Brandenburg locality. Rüdiger Hage, director of project management company IPG Infrastruktur- und Projektentwicklungsgesellschaft, is already looking forward to its arrival: "The high financial outlay by the town of Premnitz, LEG and the state of Brandenburg has been worth it. Vacant industrial land will now be repurposed in a forward-thinking way." (LEG stands for Landesentwicklungsgesellschaft für Städtebau, Wohnen und Verkehr des Landes Brandenburg – the state development company which is now in liquidation.)

However, before the plant can go into operation as hoped in 2023, the parties involved still need to complete checks on the subsidy framework. For instance, it's still not clear which "color label" will be given to hydrogen made in this way and therefore whether this production procedure can be financially supported under Germany's national hydrogen strategy.

Would the hydrogen be classified as green because it makes no use of fossil fuels? Or would it be gray since it could be likened to a byproduct of the chemical industry? Or perhaps it would need to be given a new color entirely? The answer to this question is important as the national hydrogen strategy currently treats green hydrogen preferentially when it comes to funding. Yet according to the current definition, hydrogen gas is only specified as green when it has been manufactured using renewables by means of electrolysis.

Robert Bock, director of Bock Handelsvertretung and Plagazi's representative in Germany, has been traveling back and forth between Germany and Brussels for many months in order to hold talks and campaign for refuse-derived hydrogen. In his opinion, plasmalysis gas is technically green since, at the end of the day, it represents a form of recycling as part of a sustainable energy sector.

Bock informed H2-international that the Plagazi process has a "smaller carbon footprint than electrolyzers." While electrolysis needs 50 kilowatt-hours of electricity and 9 liters of pure water to make 1 kilogram of hydrogen, he explained that the requirement for plasmalysis is just 10 kilowatt-hours of electrical power. That's in addition to the thermal energy supplied by the material itself and brackish water).

PRODUCTION OF "HAVELSTOFF" This is all some way off. Initially, Richter Recycling wants to shift its production from Geltow in the Schwielowsee municipality to Premnitz, a move that will create 40 local jobs. It then plans to use its new location for the construction of the first plasmalysis plant in Europe, in partnership with Plagazi. This will enable Havelstoff, a company still in the set-up stage, to process 45,000 metric tons of waste, including wood impregnated with plastic. The end product: up to 6,000 metric tons of high-purity hydrogen a year which has been dubbed "Havelstoff" – named for the nearby Havel River and the German word for hydrogen (Wasserstoff).

A great deal of interest surrounds this process. That's why Stefan Kaufmann, German commissioner for hydrogen technologies, along with Brandenburg's economy minister Jörg Steinbach, paid a visit to Premnitz in April 2021 to see the practice for themselves. Robert Bock used the meeting with Kaufmann to express his criticism that both Germany's national hydrogen strategy and the European Union's IPCEI allocation procedure significantly favor large corporations. Small- and medium-sized enterprises hardly got a look-in, he said, due to the high level of bureaucracy when it comes to subsidy schemes. ||

PLASMALYSIS

In this high-temperature technique, the starting materials are heated up to 3,000 °C. More precisely, the material is vaporized. In principle this is like trash incineration, just with much more energy, according to company lawyer Gerstädt. The plasmalysis process, otherwise known as plasma gasification, from which Plagazi® derives its name, is similar to electrolysis but "instead of taking electrical energy, we take thermal energy to split the molecules and then join them together in a new way," he explained. He added: "We release the hydrogen molecules from the moisture and the input materials, hence we need hardly any water." This method ensures that "carbon dioxide is not discharged uncontrollably into the atmosphere." Rather, the carbon dioxide can "be reused in greenhouses." A strong proponent of the technology, Gerstädt summed up: "Our process is carbon negative which means it's better than carbon neutral."

Category: Energy storage | **Author:** Niels Hendrik Petersen

VISIONS FOR HELIGOLAND

Electrolytic green hydrogen from offshore wind

Fig. 1: AquaPortus – Heligoland's southern port with planned extension [Source: AquaVentus Association]

Heligoland could, in future, become the new focal point for offshore hydrogen from the North Sea. The remote German island occupies a strategic central position in the German Bight and has excellent port infrastructure, making it ideally placed for a proposed hydrogen hub and liquid carrier supply chain. Under the multipart AquaVentus scheme, initiatives will be rolled out that incorporate the entire hydrogen value chain, including transportation to the mainland.

Green hydrogen from offshore wind is set to create opportunities in Heligoland in years to come. That's according to plans outlined by the 65 international parties involved in the AquaVentus project. Participants include large corporations such as RWE, Shell, Gasunie and Equinor, as well as the Institute for Climate Protection, Energy and Mobility (IKEM), which is based in Germany. The fossil fuel sector, in particular, sees the project as a means of securing the future of the industry for the long term.

Inspiration for the name AquaVentus can be traced back to the first German offshore wind farm AlphaVentus which went online in 2010 and is situated off the coast of the East Frisian island of Borkum. The AquaVentus Association was founded 10 years later, in mid-2020, and has grown steadily ever since. Even Heligoland's local authority can be counted among the members of the scheme. "The continuous growth in the number of international organizations from relevant fields shows that AquaVentus, along with its vision, has become a blueprint for green hydrogen production via offshore wind electrolysis," Jörg Singer, chairman of the AquaVentus Association, was pleased to state. An industrial engineer by training and now also Heligoland's mayor, Singer had previously worked on projects in China and the US before returning to the island. The sheer scale of the AquaVentus initiative, however, is still likely to be new territory for him.

To understand the four subprojects that make up the North Sea scheme, it helps to have some knowledge of Latin, given their names: AquaPrimus, AquaPortus, AquaDuctus and AquaSector. In addition, the proposals include hydrogen-based power units for various types of marine vessels – a project known by the moniker AquaNavis – and a research platform called AquaCampus.

Kicking off the scheme will be, as the name suggests, AquaPrimus. This early-stage pilot project initially envisages two offshore hydrogen wind turbines in the waters off the rocky island's coast. In this case, the electrolyzer will be positioned at the base of the turbine. The two pilot installations, with a generating capacity of 14 megawatts, will later be connected via the AquaDuctus pipeline to the offshore test site AquaCampus located in the southern area of Heligoland. Test operation is expected to start in 2025. The trial will last one year and form part of preparations for wider-scale rollout. When the two 14-megawatt turbines start regular operations, they will supply Heligoland with hydrogen. Spokeswoman Benita Stalmann explained that in the longer term, it is yet to be decided whether green hydrogen from the proposed AquaSector wind farm, with 300-megawatt electrolyzer capacity, will be produced decentrally in this same way or if it will encompass a centralized solution involving an electrolyzer platform within the farm. Both options are currently under consideration.

300-MEGAWATT ELECTROLYZER Two feasibility studies have been commissioned thus far for the AquaDuctus and AquaSector subprojects. In the case of the latter, RWE, Shell, Gasunie and Equinor are backing investigations into the first large-scale offshore hydrogen park. According to the proposals, the AquaSector scheme will see the installation of around 300 megawatts of electrolyzer capacity. That's enough to produce up to 20,000 metric tons of offshore green hydrogen a year. This requires an adequate supply of renewable electricity. By way of comparison, transmission system operator Tennet puts the figure for installed offshore wind generating capacity in German areas of the North and Baltic seas at approximately 7.8 gigawatts at the end of 2020.

In Germany, wind power at sea has an increasingly important role to play in the transformation of the country's energy landscape. In the first half of 2021, the amount of wind

energy carried by the transmission system operator from the North Sea to land was roughly 9.7 terawatt-hours. This saw the proportion of North Sea power in the overall wind energy mix rising to 16.6 percent. This is still 6.6 percent more than in the first half of 2020. For the energy transition as a whole, however, significantly greater amounts of green electricity will be needed than the German economy minister Peter Altmaier has hitherto admitted. Indeed, since his initial announcement he has increased the expected 2030 requirement from 590 terawatt-hours to 645 terawatt-hours and then to 665 terawatt-hours. Yet many experts as well as Germany's federation for renewable energy associations BEE estimate that this figure is still far too low.

From 2028, the intention is for the first quantities of green hydrogen to be transported to Heligoland's southern port via the AquaDuctus pipeline. The corporate groups involved believe that this part of the scheme will demonstrate that hydrogen production at sea is an efficient, cost-effective and sustainable means for Germany to manufacture green hydrogen.

The project partners also see the AquaSector initiative as a way of testing the water prior to instigating the more far-reaching aspects of the AquaVentus vision: namely, plans to install up to 10 gigawatts of electrolyzer capacity by 2035 in order to convey up to 1 million metric tons of hydrogen each year via an extended supply line to the German mainland. Compared to the previous transmission of wind-generated electricity, there would be clear economic benefits to producing hydrogen at sea and pumping it to shore, it is claimed.

The partners cite the ability of one pipeline to do the job of five high-voltage direct current lines. Without the pipeline, these HVDC power cables would have to be installed to ensure the electricity was conveyed with the minimum of loss. By contrast, a hydrogen pipeline represents "by far the most cost-effective option for transporting large amounts of energy over more than 400 kilometers (250 miles)," it was explained in a project presentation.

MORE SITES NEEDED IN THE NORTH SEA Nevertheless, in order to realize the project in its entirety, changes will still be required to the site development plan and maritime planning policy: According to the AquaVentus Association, there is still a need to find large and additional offshore sites to facilitate the production of green hydrogen using wind power. The current area of the North Sea (SEN-1) designated for this type of hydrogen production at present only permits the construction of 300 megawatts. Only through an alteration of maritime planning policy will it be possible for a hydrogen transportation pipeline to be built, thus allowing integration with gas infrastructure as part of network expansion works, AquaVentus has stated. The consortium is putting forward its preferred concept of an "integrated hybrid grid system at sea." This would comprise combined hydrogen production using energy from the project's own wind turbines in addition to power from surrounding wind farms.

Without funding from the government and the European Union, however, this objective would not be achievable. Several individual AquaVentus initiatives have therefore already received backing: AquaDuctus and AquaPrimus, for example, netted grants in May 2021 from the German economy ministry and transportation ministry as part of the German IPCEI selection procedure, in other words for programs that are of significant European interest. Two AquaVentus projects are being supported by the German education ministry within its model hydrogen projects scheme. In addition, AquaPrimus forms part of the H2Mare model hydrogen project and – together with AquaDuctus and AquaPortus – are part of the TRansHyDE model hydrogen project.

Fig. 2: Plan for an LOHC production facility on Heligoland [Source: AquaVentus Association]

DIRECT USE ON THE ISLAND The AquaPortus project will see Heligoland's southern port being equipped with infrastructure capable of handling liquid organic hydrogen carriers, or LOHCs, in addition to measures being taken to decarbonize the island as a whole. When hydrogen is stored in the form of an LOHC, waste heat is produced that can then be used to supply the island. Process heat from the proposed electrolyzer is due to be utilized in the same way. It is also suggested that a ferry service could be run on green hydrogen in the future. As a result of the plans to upgrade the port, Heligoland is set to become a gateway for an LOHC supply chain for industrial users in the coastal region or even a hub for a European-wide hydrogen pipeline network which could be later established in partnership with neighboring countries.

It is also conceivable that the island scheme could work with and connect to the GET H2 initiative. Germany's first publicly accessible hydrogen grid is expected to start supplying increasing amounts of green hydrogen to industrial enterprises in Lower Saxony and North Rhine-Westphalia from the end of 2022. The companies involved include BP, Evonik, Nowega, OGE and RWE Generation. According to the plans, a 100-megawatt electrolyzer plant in the town of Lingen in Lower Saxony, run by RWE Generation and operating on renewable electricity, will be deployed for the production of hydrogen. However, forecasts suggest that this will not be enough to cover demand. Hydrogen gas from the North Sea could therefore also be a useful supplement.

If offshore supplies are brought in, the hydrogen will largely be transported via existing gas pipelines belonging to the transmission system operators Nowega and OGE to industrial consumers such as refineries and chemical plants in Lingen, Marl and Gelsenkirchen.

Plans to set up a liquefied natural gas terminal in Wilhelmshaven appear to be off the cards, meaning that the site could continue to be used for green hydrogen gas. This is something recognized by Lower Saxony's environment minister – Social Democratic Party member Olaf Lies. In his view, the site for the terminal can stay and green hydrogen can be handled in Wilhelmshaven instead of LNG. A development that would fit rather nicely with the visions for Heligoland. ||

Fig. 1: Yara, with its production facility in Brunsbüttel, is among the world's largest ammonia producers

Category: Energy storage | **Author:** Eva Augsten

GREEN AMMONIA NEEDS GREEN HYDROGEN

The role of ammonia in tomorrow's energy industry

While hydrogen is indeed a versatile energy carrier, the transportation of large quantities over long distances remains a challenge. One solution could be green ammonia as it can be conveyed and stored in a more manageable way than hydrogen.

Ammonia boasts a number of positive attributes that have the potential to make it an important carrier of energy. The advantages include not just its chemical and physical properties (see box), but also infrastructure. For no other chemical in the world is produced in such immense quantities as ammonia. Therefore the technology required for ammonia manufacture and transportation does not have to scaled up laboriously as the necessary facilities are already well established in large corporations.

According to the International Energy Agency (IEA), around 31 megatons of hydrogen were needed for ammonia production in 2019. Consequently, ammonia manufacturing ranks second in terms of the biggest hydrogen consumers, right after refineries – and this particular use of hydrogen has increased significantly in the last few years. Both fertilizers and other derived products are experiencing growing demand.

Ammonia production is also top of the list when it comes to energy input and carbon dioxide emissions, coming in first place for chemicals. Any company considering making green ammonia, must first find a way to produce the required hydrogen in a sustainable manner. Up until now, hydrogen has generally been created using fossil-based hydrocarbons, usually in the form of natural gas. If the 31 million tons of hydrogen described by the IEA is to be manufactured using renewable energy via electrolysis, then roughly 140 terawatt-hours would be necessary at an input of 4.5 kilowatt-hours of electrical energy per kilogram. By way of comparison, the entire European Union generated approximately 417 terawatt-hours of wind power in 2019.

Ammonia is produced almost exclusively via the Haber-Bosch process. Developed over 100 years ago, this procedure made it possible to convert atmospheric nitrogen to ammonia for the very first time. Since then, the process has also been used as a low-cost method of fertilizer manufacture which has resulted in a considerable increase in agricultural yields – albeit not without ecological side effects.

The Haber-Bosch process represents the critical last step in the ammonia production workflow. In this particular method, nitrogen reacts with hydrogen – usually under high pressure and employing an iron-based catalyst.

$$N_2 + 3\,H_2 \rightarrow 2\,NH_3$$

This is an exothermic reaction. In other words, it releases energy. The process also takes place under high thermodynamic loads (150 bar to 350 bar, 400 °C to 500 °C). Temperatures of this magnitude are required in order to break the bond between the two nitrogen molecules. Because of the specific conditions required, ammonia is normally only produced in large industrial complexes, which explains why it is usually large chemical and energy companies alongside research institutes that take part in projects to produce green ammonia.

The level of energy input needed for the industrial production of ammonia using the Haber-Bosch method is dependent on the technology and raw materials. The minimum requirement when using hydrogen sourced from hydrocar-

bons is put at just under 6 megawatt-hours per ton of ammonia. In practice, values of up to 13 megawatt-hours are commonplace. If the Haber-Bosch procedure is coupled with a "green" upstream process, i.e., the use of renewable energy for nitrogen extraction from the air and hydrogen production via electrolysis, the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB estimates that the energy needed would be between 10 megawatt-hours and 15 megawatt-hours per ton of ammonia.

GREEN AMMONIA – NOTHING NEW The idea of harnessing renewable energy to make ammonia is nothing new. Lénárd-István Csepei, who is in charge of the Chemical Catalysts research area at IGB, has identified a range of related projects across the globe:

The first large-scale project took shape shortly after the construction of the Aswan Dam in Egypt. The electrolyzer, with a 156-megawatt capacity, was for a long time the biggest in the world and supplied hydrogen for the production of green ammonia. It would still have been one of the largest even today if it had not been replaced by a petrochemical hydrogen manufacturing plant in 2019. In 1962, the Peruvian city of Cusco also became the base for a substantial ammonia-producing operation, churning out 10,000 tons a year of green ammonia in a plant powered by hydroelectricity. According to the Ammonia Energy Association, in 2020 it was the only remaining commercial facility of that generation which was still in operation.

Csepei has prepared an economic analysis using real data that looks at green and gray hydrogen production: If the gas price for fossil-based hydrogen production is USD 34 per megawatt-hour or the electricity price is USD 36 per megawatt-hour, ammonia can be offered at USD 350 per ton. Currently the market price for 1 ton lies between USD 300 and USD 400.
In Kwekwe, Zimbabwe, hydroelectric power was employed initially, with an electricity price of USD 50 per megawatt-hour. But as this resulted in costs of almost USD 500/ton of ammonia – too high to compete with fossil-based alternatives – the plant was switched over to traditional energy sources.

This example shows that conditions can change. In some parts of the globe, power generated from wind and solar resources is now already much lower than EUR 36 per megawatt-hour. And of course fossil fuel prices are well known, too, for their fluctuating nature. Green hydrogen production is particularly affordable in South America, Mexico, the US, India, the United Arab Emirates and Australia, found Csepei during his research.

ELUSIVE FLEXIBILITY Many green visions for the future rely on hydrogen as a storage medium for ever cheaper yet more erratic electricity supplies from wind and solar energy. Indeed, flexible electrolyzer operation is a challenge that numerous commercial concerns and academic institutions are busy tackling. PEM electrolyzers, which are capable of ramping up to their full load within seconds or minutes, are still relatively expensive. Alkaline electrolyzers are a proven industrial technology that is both robust and economical. However, they take several hours to reach their full load following a cold start.

Yet even this type of electrolyzer can be considered relatively dynamic when compared with the Haber-Bosch process which takes around a day to be stepped up from minimum to maximum. In addition to this, a constant base load of roughly 20 percent to 30 percent is required. Plant concepts that enable both dynamic and economical operation are only just now starting to enter the trial stage.

BLUE AMMONIA FOR JAPAN The great advantage of ammonia is that it can be used as an energy carrier in a variety of applications. Current research projects are particularly focusing on its use in shipping as well as its deployment in remote areas e.g., mobile phone masts. In 2021, Japan (see H2-international, August 2021) initiated a project that aims to test the cofiring of up to 20 percent ammonia in large-scale power plants.

Japan's intention to increase its ammonia imports is evident in many areas. The economy ministers of Japan and the United Arab Emirates (UAE) signaled their agreement to cooperate in this regard in January 2021. Among the parties involved is the state oil company of the Emirate of Abu Dhabi – ADNOC – which back in May announced its plans for blue ammonia production in the industrial port city of Ruwais. Development work is already underway. ADNOC already produces 300,000 tons a year of ammonia at its Ruwais production site and this figure is now set to rise to 1 million tons.

Ammonia is labeled "blue" when it is made by conventional means with subsequent capturing of the carbon dioxide. This is a process in which ADNOC also claims to have experience. The company operates the first fully commercialized facility for carbon capture, removing 800,000 tons of carbon dioxide from UAE's steel manufacturing industry each year.

Japan is planning to obtain ammonia from a wide range of sources. In fall 2020, the Saudi oil concern Aramco supplied it with approximately 40 tons of blue ammonia by ship. According to the company, this was the first delivery of its kind in the world. Russia is also getting in on the action. A consortium including the Irkutsk Oil Corporation and the large Japanese trading company ITOCHU is proposing to establish an ammonia value chain in Eastern Siberia. The ammonia will then be carried to Japan by train and ship.

This does not mean we can close the door on the era of fossil fuels just yet. Aramco and IOC intend to use the carbon dioxide resulting from ammonia production for enhanced oil recovery – a technique for forcing oil from the ground that cannot otherwise be extracted by primary or secondary recovery methods. In Aramco's case, the carbon dioxide will also be used to manufacture methanol.

The following overview of existing ammonia processes is a generalized summary of the latest developments and is not necessarily exhaustive.

PROPERTIES

Ammonia is composed of around 82 percent nitrogen by mass; the remaining 18 percent is made up of hydrogen. Under normal conditions (20 °C and 1 bar), ammonia take the form of a gas. This is in contrast to hydrogen which is a liquid at normal pressure and a temperature of -33 °C – or alternatively at an ambient temperature of 20 °C and a pressure of 9 bar. Similar to liquefied petroleum gas, ammonia can be easily transported in large containers if the walls are of an adequate thickness. Liquid ammonia has an energy density of 4.25 kilowatt-hours per liter.

The colorless gas does, however, have some unpleasant characteristics: It is an irritant and in high doses can lead to suffocation. Due to its pungent smell, however, even small amounts are usually detected. Since ammonia does not contain carbon dioxide, no carbon is emitted upon combustion. Once the hydrogen has been separated, the resulting nitrogen can simply be released into the atmosphere.

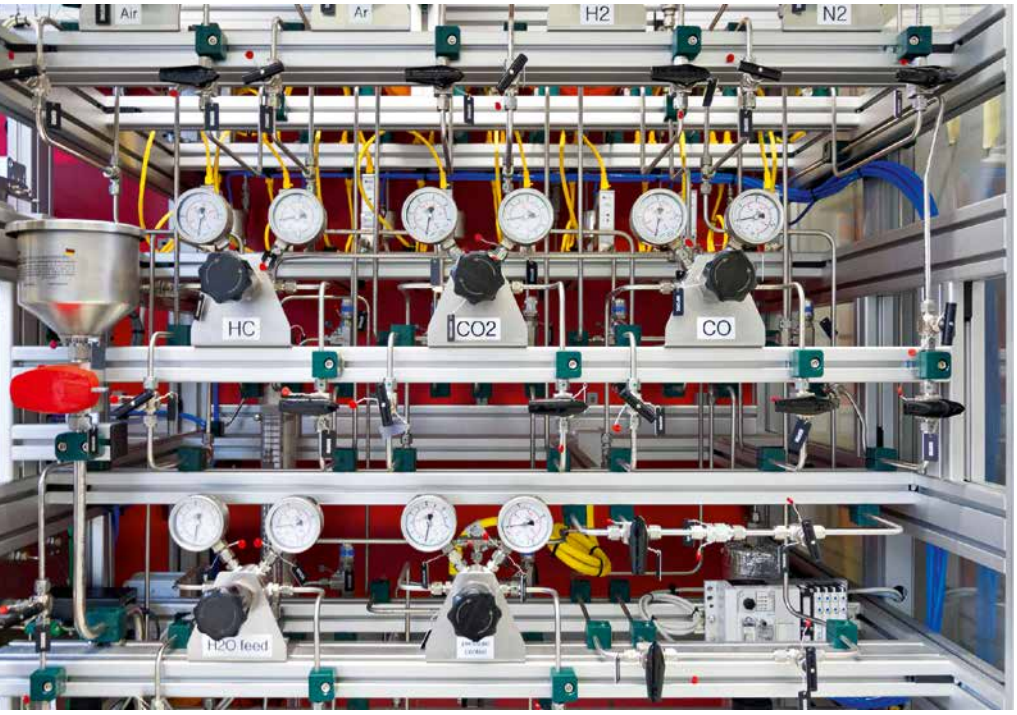

Fig. 2: Screening station in the lab for methanol and ammonia synthesis [Source: IGB BioCat]

US CORPORATIONS TAKE FIRST STEPS According to the company's own reports, fertilizer manufacturer CF Industries has ambitions to become the operator of the first production facility for green ammonia in the United States. CF Industries claims the plant, located at its existing site in Donaldsville in the state of Louisiana, is the world's largest ammonia factory with an annual production of more than 4 million tons. A small proportion of its capacity will now be dedicated to the production of green ammonia. Plans forecast that construction of the 20-megawatt alkaline electrolyzer from ThyssenKrupp will commence before the close of 2021. A volume of 20,000 tons of green ammonia will then be produced from 2023 onward. A press release calls the new electrolyzer the first step in the company's endeavor to reduce its carbon dioxide emissions by a quarter by 2030 and to eliminate them altogether by 2050.

In southeastern Michigan, the Canadian ammonia manufacturer AmmPower opened a "production and development plant" at the beginning of August. This reportedly prepares the way for the second phase of commercialization. It is now expected that a team of engineers and scientists will test out new catalysts and production methods for green ammonia synthesis. AmmPower is also planning to develop processes for cracking ammonia in order to release the hydrogen contained within. As a result, the company would be in a position to use ammonia as a transport medium, enabling it to sell hydrogen at its final destination.

MORE SELF-SUFFICIENCY FOR BRAZIL In Brazil, plans are afoot in the state of Espírito Santo to start green ammonia production. Porto Central, a joint venture company of regional enterprises, has its intentions set on establishing a new industrial port of the same name. The site lies to the north of Rio de Janeiro in the Southeastern region of Brazil – home to around a half of the population and where two thirds of the nation's gross domestic product originates. The manufacture of ammonia is just one part of the wide-ranging project.

Porto Central has signed a memorandum of understanding with Vancouver-based AmmPower covering both ammonia production and logistics. The agreement states that ammonia will be used in various forms for different purposes, including regional energy supply, shipping fuel, hydrogen transportation and fertilizer production. It is worth noting that a large quantity of fertilizer has had to be imported up until now, a figure that AmmPower puts at 90 percent. Nevertheless, the companies involved decline to pinpoint production volumes or a schedule for the works.

ARABIAN OIL STATES GO GREEN By contrast, the oil-producing countries of the Middle East are happy to quote ambitious figures: The manufacturer of industrial gases Air Products, the Saudi energy group ACWA Power and Neom are proposing to sink a total of USD 5 billion into green ammonia production, with financial contributions divided equally between the three parties. Neom – a futuristic metropolis that is being designed from scratch in an area of northwestern Saudi Arabia bordering the Red Sea – also lends its name to the joint venture company (see H2-international, August 2021). The new plant is to supply 1.2 million tons of green ammonia each year. Over 4 gigawatts of wind and solar power will also be incorporated into the project. The scheme is aiming to make 650 tons of hydrogen a day using ThyssenKrupp electrolyzers. The extraction of atmospheric nitrogen will use Air Products technology while the manufacture of ammonia will rely on equipment provided by Haldor Topsoe. Operations are due to commence in 2025.

In KIZAD in the Emirate of Abu Dhabi, an engineering trial is due to take place that will investigate the possibility of integrating the manufacture of green hydrogen and green ammonia using solar energy. The Emirati company Helios Industry has awarded the contract for the trial to ThyssenKrupp. The first stage will see electrolysis on a multimegawatt scale as well as ammonia production of 20,000 tons a year. In the next stage, production volumes will be ramped up to 200,000 tons. According to the proposals, energy for the electrolysis of 40,000 tons of hydrogen in the second stage will be sourced from a solar farm with a peak capacity of 800 megawatts. Helios envisages that the total amount invested in the project will come to USD 1 billion.

GREEN AMMONIA FROM DOWN UNDER In Bell Bay in Tasmania, Australia's most southerly state, two feasibility studies are currently underway. The Australian company Fortescue Future Industries (FFI) and the Japanese IHI Corporation, together with its subsidiary IHI Engineering Australia, concluded an agreement in May 2021 to set up a supply chain for green ammonia. The chemical produced will subsequently be used for blending into existing power generation in Japan. Plans foresee a 250-megawatt electrolyzer capacity and ammonia production of 250,000 tons per year which will be both exported and used locally.

In addition to the IHI collaboration, FFI has a range of other hydrogen projects ongoing, for example the export of

liquid hydrogen to Japan, the reextraction of hydrogen from ammonia with the help of membrane technology as well as a host of different mobility projects. FFI is also sounding out sites for renewable hydrogen production on other continents.

Back in November 2020, Origin Energy announced the start of a feasibility study for Bell Bay. The trial, which will involve an electrolyzer capacity of 500 megawatts and a production volume of 420,000 tons of green ammonia, is projected to cost AUD 3.2 million – half of which is being funded by the Tasmanian government. The study is due to report its findings in December 2021. If the outcome is positive, production could start in the mid-2020s, Origin Energy has indicated.

EUROPE FOCUSES ON DEVELOPMENT When it comes to green ammonia, the world's major chemical corporations are primarily engaged in projects in geographical areas which boast favorable conditions for wind and solar power generation. Nevertheless, ambitious plans are also being put forward in Europe. The relatively young German enterprise Hy2gen, which was founded in 2015 in Wiesbaden and became a public company in 2017, has its sights set on playing a leading role in the production of hydrogen and e-fuels. This is reflected in the language it uses, describing itself as a "game-changer" and "rising star." Its plans include the construction of a plant for green ammonia production in Norway. The Hy2SAUDA project will create 260 megawatts of electrolyzer capacity, powered by renewable electricity, that will enable the production of 208,000 tons of ammonia annually.

According to Hy2gen, the company has projects in progress in various countries that total more than 11 gigawatts of electrolyzer capacity and 1.5 million tons of carbon-free hydrogen. In this year alone, the company is seeking to bring in at least EUR 200 million from investors in order to facilitate the construction of six plants.

In West Jutland, Denmark, three organizations are involved in the innovative REDDAP project. Skovgaard Invest, Vestas and Topsoe have plans to build what they call the world's first dynamic green ammonia plant in the form of a demonstration project. Under the scheme, power generation from wind and solar sources will be directly connected to the electrolyzer unit. What's more, the ammonia production itself will have the capability to adapt to the fluctuating energy supply. It is expected that this will circumvent the cost of interim energy storage in batteries or in the form of hydrogen. The flexible manufacture of hydrogen, including the control system, will come under the remit of Vestas while Topsoe will be responsible for the ammonia facility.

The electricity being supplied to the plant will come from six existing Vestas wind turbines offering a combined generating capacity of 12 megawatts. A further 50 megawatts of capacity will be provided by new solar arrays. The end goal is to produce 5,000 tons of green ammonia each year starting in 2023. The hydrogen production facility will be built at 10 megawatts. A large proportion of the power generated will therefore be fed into the public electricity grid. The Danish government is backing the project to the tune of around EUR 11 million.

One project which particularly stands out due to its engineering complexity is Campfire. This scheme sets out to develop a membrane process that will make decentralized ammonia manufacturing financially viable – for example by enabling production to be directly coupled to wind or solar power plants. The mode of operation is twofold: On the one hand a solid oxide electrolyzer firstly extracts hydrogen from water vapor. On the other hand a membrane allows the hydrogen to come into contact with nitrogen and a catalyst, causing them to react to form ammonia. In contrast to conventional Haber-Bosch synthesis, this process occurs at much lower pressures. This makes it comparatively easy to scale to various levels, making it also suitable for smaller applications. It could take some time, however, before this method becomes a real alternative. In the meantime, the team continues to work on the membrane process. The next stage will be a pilot plant at the Leibniz Institute for Plasma Science and Technology in Greifswald, Germany (see H2-international, July 2019).

The BioCat branch of Fraunhofer IGB is currently researching the production of green ammonia at a laboratory scale (see fig. 2). The intention is to be able to make a kilogram of green ammonia per hour here in the first half of 2023 under industrial conditions. A funding application to allow this to happen has already been submitted. Based in the city of Straubing, IGB BioCat supports the institute's wider aim of conducting applied research. Examples of the engineering challenges being investigated are catalyst development and process development. In addition, the IGB BioCat compiles technical and technical-economic studies and carries out market research into specific technologies.

An overview of the opportunities presented by green ammonia and associated projects will appear in the February 2022 edition of H2-international. ||

AUTONOMOUS FC BOAT FOR THE SCHLEI

In the old brick shed of a former schnapps factory, the inventor couple Stefanie and Lars Holger Engelhard have designed their tugboat and built a prototype. On 7 August 2021, the christening of this prototype of an electrically driven catamaran took place in the presence of Dr Bernd Buchholz, the Minister of Economic Affairs of Schleswig-Holstein. Starting in spring 2023, the ZeroOne could chauffeur excursionists from Schleswig's city harbour across the Schlei River to the UNESCO World Heritage Site of the Viking Museum in Haithabu, or so the plan goes. Another two years later, the hybrid boat designed for up to twelve people could then be travelling autonomously, i.e. without a driver.

The ZeroOne is powered by two 6 kW electric motors. Two battery packs with 13.5 kWh each are on board as power storage, along with a fuel cell that is used as a range extender. Minister Buchholz stated on the occasion of the christening: "For Schleswig-Holstein as a technology location, the development of emission-free ship propulsion systems – coupled with concepts for autonomous mobility – is increasingly becoming a trademark that makes us known far beyond the state's borders."

Fig.: The prototype initially measures 3.2 m, later the ZeroOne is to be 12 m long [Source: Gateway49]

In June 2021, the start-up Unleash Future Boats presented the twelve-metre-long concept boat during the Greentech Festival in Berlin together with technology partner Würth Elektronik. The two men in their late thirties, who come from Bavaria and were previously employed in automotive companies, receive further support from both the state of Schleswig-Holstein and the federal government, as well as from the Port of Duisburg.

Lars Engelhard, Managing Director of Unleash Future Boats GmbH, explained "We are planning a technology transfer from automotive to maritime mobility and thus want to change shipping to become sustainable. [...] Due to the low water levels, the logistics industry will have to rely more on small boats in the future, and these can be operated in an economically sensible way, especially through autonomous systems. Our tugboats are also an attractive concept for cities that want to make inner-city transport more sustainable." According to him, several regions and metropolises from home and abroad have already expressed interest in the tugboats. ||

1 MILLION ELECTRIC VEHICLES ACCOMPLISHED

Just in time for the federal election, the responsible federal ministries announced that the federal government had "reached a decisive milestone with one million e-cars on German roads". To be honest, the second headline of the press release says: "More than 50 per cent of these electric vehicles are purely battery-powered." Almost half are hybrid vehicles.

The target of 1 million electric vehicles by 2020 was set more than ten years ago. On 25 November 2008, the then Federal Minister of Transport, Wolfgang Tiefensee, together with the then Federal Minister of the Environment, Sigmar Gabriel, had presented the plans for a cleaner, electricity-driven future during the National Strategy Conference on Electro-mobility in Berlin. A joint press release from the Federal Transport, Economics and Environment Ministries stated at the time: "By 2020, there should already be one million electric vehicles that can be charged from the power grid and so-called plug-in hybrid vehicles on German roads."

Prof. Henning Kagermann, the chairman of the steering committee of the National Platform for Electro-mobility (NPE) had then spoken of a "calculable success story" in May 2011 and declared: "It's clear to everyone: Electro-mobility will prevail." At the time, he assumed that with state funding there could be around 100,000 electric vehicles in Germany by 2014 and then one million by 2020. Against the backdrop of an initially very slow increase in the number of units, the federal government has since withdrawn the target because numerous experts and the media had assumed that the target figures would be missed by a much greater margin.

In July 2021, the Federal Economics Minister Peter Altmaier now stated: "Our transport will be irreversibly converted to renewable energies." He also announced that the "innovation bonus for the purchase of an e-car will be extended until the end of 2025". Looking to the future, Federal Transport Minister Andreas Scheuer explained: "However, to achieve the climate targets by 2030, we need to become even more ambitious: 14 million e-vehicles by 2030 must be the new target, experts say."

Federal Environment Minister Svenja Schulze said: "Electric vehicles are the most efficient climate-friendly option in the passenger car sector, because they bring the energy used onto the road without detours. Switching to an electric car saves money on top of that. In the long term, charging with electricity is cheaper than filling up at the fuel pump. And the maintenance costs of an electric car are much lower than those of a combustion engine. Last but not least, electric vehicles cause less noise and harmful exhaust fumes, thus increasing the quality of life in our cities." ||

BEV AND PLUG-IN

According to the report of the Federal Motor Transport Authority (KBA) on the number of vehicles, there were 309,083 electric passenger cars (BEV) and 1,004,089 hybrid passenger cars (of which plug-in hybrid vehicles: 279,861) in Germany on 01/01/2021. From January to June 2021, around 314,000 BEVs and plug-in vehicles were added, so that in July/August the mark of 1 million electric vehicles (pure battery-electric and plug-in hybrids) was exceeded.

The stock of hydrogen-powered passenger cars, such as the Hyundai Nexo (see picture) or the Toyota Mirai, stood at 808 at the beginning of the year.

Category: Electric transportation | **Authors:** Doris Wittneben, Lukas Haase

TAPPING REGIONAL POTENTIAL

Hydrogen Regions series: HyPerformer H2Rivers and H2Rhein-Neckar

Fig.: Map showing locations where hydrogen will be produced, distributed or deployed [Source: H2Rivers/H2Rhein-Neckar]

The metropolitan region of Rhine-Neckar and the central Neckar area in Germany are set to become a showcase for the future of fuel cell mobility. As part of an innovative strategy covering hydrogen production, distribution and transportation as well as various mobility applications, plans will seek to exploit synergies between H2Rivers – a HyPerformer project – and the H2Rhein-Neckar program in Baden-Württemberg.

Both projects intend to create a climate-friendly mobility system with the aim of increasing decarbonization efforts as well as curbing transport-related noise and pollution within the towns, cities, districts and communities of the relevant regions. Key elements in the implementation plan are local hydrogen manufacturing in regional proximity to hydrogen consumers and the renewables-based production of hydrogen according to CertifyHy criteria. The plan outlines the exploration of two different production pathways for hydrogen: The metropolitan region, on the one hand, is adopting centralized, industrial-scale hydrogen manufacture within the chemical industry – a scalable option that connects industry and mobility sectors. The central Neckar area, on the other hand, is looking to follow a decentralized pathway with demand-responsive localized production using renewable energies that can be replicated in other areas.

RHINE-NECKAR METROPOLITAN REGION Geographically, the Rhine-Neckar metropolitan region is located at the meeting point of three German states: Baden-Württemberg, Hesse and Rhineland-Palatinate. With a population numbering 2.4 million, it's one of Germany's leading economic areas. Global players such as BASF, SAP, HeidelbergCement and Freudenberg along with medium-sized businesses and startups are headquartered here and account for a market capitalization of EUR 196 billion.

Rhine-Neckar is a hot spot for early-stage businesses: The conurbations of Heidelberg, Mannheim and Ludwigshafen alone are home to over a dozen business incubators. Commercial focal points are the chemical and automotive industries, mechanical and plant engineering, biotechnology, IT as well as cultural and creative sectors. The area also provides a base for leading research in medical technology, health and life sciences and for a thriving further education sector with a wide offering of courses. All these factors combine to make this location the ideal place to connect the dots between industry, academia, society and politics.

Its central European position and first-rate infrastructure mean that the region enjoys excellent international connections: from its location on the Rhine River – Europe's most important waterway – to its rail links and digital infrastructure as well as its connection to Europe's extensive energy networks. In 2005, a treaty signed by the states of Baden-Württemberg, Hesse and Rhineland-Palatinate laid the political foundations for a joint regional development effort, an arrangement which is now benefiting the H2Rivers project.

An academic study carried out in 2019 was able to demonstrate that the Rhine-Neckar metropolitan region has a great deal to gain from establishing hydrogen infrastructure in the mobility sector, reducing local emissions and bolstering value creation in the region.

Prior to this in 2018, the Rhine-Neckar metropolitan region applied to the European Union for funding for to become a European H2Valley and achieved an admirable second place. On that occasion the award went to the HEAVENN project in Groningen in the Netherlands. Having already progressed through the EU

application process, however, meant that the Rhine-Neckar region already had a fully fledged implementation plan. After some modifications to make it suitable for the mobility sector, the region was able to bid successfully for HyPerformer status under the scheme administered by the German transportation ministry. As a consequence, the H2Rivers project received a grant to the tune of EUR 20 million in recognition of the pioneering initiative's national significance.

The project is backed by a consortium of 18 partner organizations with hydrogen expertise and is able to build upon a political willingness to create clean public transportation. The scheme can also take advantage from having the chemical engineering center of Ludwigshafen on its doorstep.

In addition to the government-funded H2Rivers, the state of Baden-Württemberg also provides the stage for another hydrogen project in the metropolitan region: The regional government, as well as supporting the H2Rivers program, is extending it further by creating a regional lighthouse project for fuel cell mobility in the Rhine-Neckar region. These activities run in parallel as part of the H2Rhein-Neckar project and will receive EUR 16.5 million of assistance from the Automotive Industry Strategic Dialog.

Combined investment in the two projects amounts to just shy of EUR 100 million – equivalent to the level of investment in the H2Valley scheme in Groningen. The result is a unique demonstration project that makes it possible to integrate hydrogen and fuel cell technology into day-to-day life.

H2RIVERS As the winning project in the top HyLand category, H2Rivers impressed the competition judges with its ready-to-roll concept. Its overarching objectives are to integrate renewable hydrogen in the transport sector and thereby accelerate the market ramp-up of hydrogen and fuel cell technologies, all the while ensuring climate-friendly hydrogen production.

It is hoped that, through strengthening regional value creation and encouraging regional innovation, the Rhine-Neckar metropolitan region and the central Neckar area will also be able to benefit from the initiative. An important success factor in the development of a regional hydrogen economy is the degree to which public acceptance of hydrogen technologies can be widened – an aspect which the project also proposes to tackle.

The H2Rivers project oversees the construction of a hydrogen hub in Mannheim which will be capable of making 400 metric tons of hydrogen a year. The hydrogen will then be sent through a high-capacity filling plant in order to fill trailers which will store it at pressures of 300 bar or 700 bar. Regional filling stations will be supplied by a dozen innovative 700-bar high-pressure trailers. Moreover, a 2-megawatt electrolyzer plant in Waiblingen, which will be fed with photovoltaic power from a local solar farm, will manufacture around 240 metric tons of hydrogen on an annual basis. In addition to this, three new publicly accessible hydrogen filling stations are being built which will then bring the total number of hydrogen refueling stations in the region up to 12.

H2RHEIN-NECKAR The H2Rhein- Neckar sister project focuses on establishing a sustainable local public transport network in Mannheim and Heidelberg through the purchase of articulated fuel cell buses, the construction of hydrogen refueling stations and the kitting out of bus depots. Another important aspect of the project is the accompanying research which, broadly speaking, comprises a technical and an economic element. The technical part will monitor vehicle procurement, vehicle operation and infrastructure measures while the financial part will look at the economic effects of changing over a vehicle fleet.

The intention of the two projects is to contribute collectively toward the establishment of a regional hydrogen economy. This requires users. In order to ensure that the hydrogen being produced is consumed in sufficient quantities, around 90 fuel cell-powered cars, light commercial vehicles, 52 range-extender articulated buses and 10 hydrogen solo buses, three garbage trucks, two street maintenance vehicles and 10 industrial trucks will be put into service (see fig.). This vehicle rollout thus solves the chicken-and-the-egg conundrum.

HYDROGEN INNOVATION CLUSTER A hydrogen innovation cluster is also being initiated which, in addition to taking on a coordinating role in the H2River project, will encourage organizations to share their experiences. It will also undertake public relations work, support dialog between academics, business leaders, policymakers and members of the public, and drive forward the development of a startup and business innovation environment for hydrogen and fuel cell technology.

Linking up over 90 organizations from the Rhine-Neckar region and beyond, the cluster initiative will form the basis for further development and expansion of hydrogen infrastructure. Despite the disruption caused by COVID-19, the online events that have been held thus far on topical hydrogen issues have been extremely well received.

FAR-REACHING EFFECTS Today, almost 9 months after the schemes officially launched, the far-reaching effects of these hydrogen projects on regional development are plain to see. A large number of new consortiums have now been formed and applications for various funding programs at a regional, national or EU level have been submitted, many of which have already been approved. ||

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Fig. 1: Above the rooftops of Berlin: The electrolysers of the test system are the white and blue layers under the PV module.

Category: Development | **Author:** Niels Hendrik Petersen

UNDERSTANDING FEEDBACK

Digital prototypes improve FCs and electrolysers

The development of a real prototype is time-consuming and expensive. Mathematical models make it possible to better understand the physical and chemical processes in a fuel cell or an electrolyser. A simulation helps to create new approaches and designs in Lobar.

The Centre of Excellence Photovoltaics Berlin, PVcomB for short, at the Helmholtz Centre is investigating integrated photovoltaic electrolysers for the direct conversion of solar energy into hydrogen. With the help of software, the scientists were able to study the operation of the electrolyser and also the heat transfer in the device. Specifically, from the PV to the heat exchanger, where the electrolyte is heated before it enters the electrolyser. "With the software, details of the operation can be understood that cannot be assessed with experimental methods," explains Erno Kemppainen. The scientist heads the PV to Fuels Technology group at PVcomB. The aim is to explain observations and also to develop predictions. "Particularly detailed models are also easier to build and modify than when similar models have to be programmed from scratch. The finished elements can be put together almost like Lego bricks," Kemppainen describes.

From a modelling perspective, understanding the effects of electrolyte flow, charge transport, electrochemical reactions and heat transport on each other is essential to be able to understand electrolyser operation. These four main factors must also be taken into account with their feedbacks. But that is ambitious: In general, the most important factors are the catalyst activity and stability as well as the corrosion of each cell component, but with direct coupling with PV, the variable operation of the electrolyser is also a potential problem, Kemppainen explains. "In terms of catalyst activity and the kinetics of the electrolysis half-reactions, the oxygen gas development reaction at the anode of the electrolyser is significantly slower and more difficult than the H_2 development reaction at the cathode, making it one of the main bottlenecks of electrolyser operation," clarifies the scientist.

ANALYSE PHENOMENA IN A COUPLED MANNER For most situations, sufficiently accurate models are available, both for

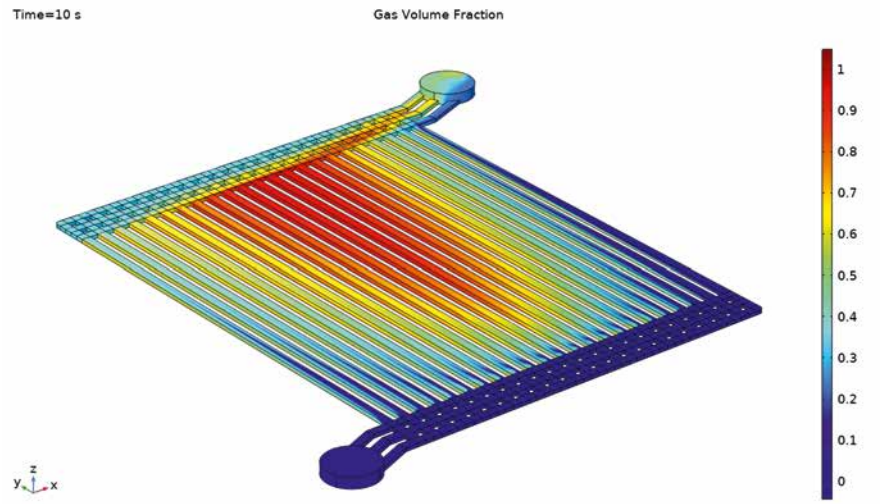

Fig. 2: The distribution of liquid water (blue) and emerging oxygen gas (red) during the operation of a PEM electrolyser. In the channel on the far right, much less gas conversion has taken place than on the left. A new geometry of the electrolyser could enable more efficient utilisation of the catalytic material. [Source: COMSOL]

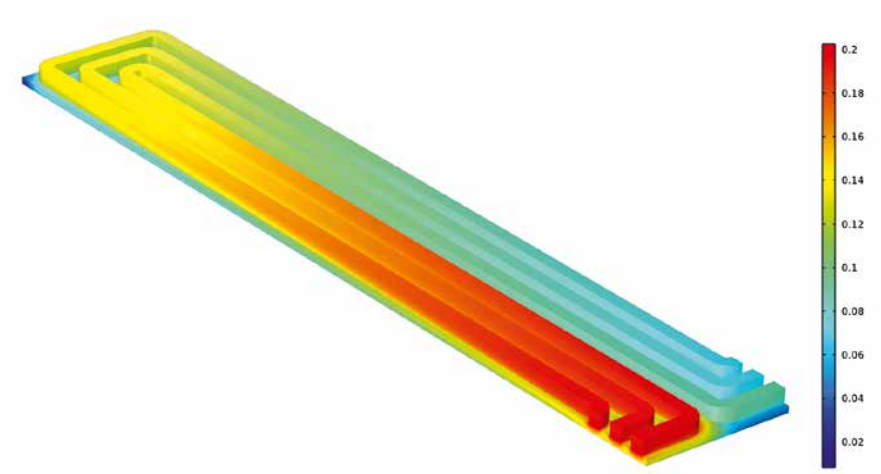

Fig. 3: The simulation of a proton exchange membrane in the electrolyser [Source: COMSOL]

the isolated phenomena and coupled with other phenomena. Precise modulation, however, is very complex: Since electrolysers convert liquid water into H_2 and oxygen gas, an accurate, fully coupled calculation model would ultimately have to take into account all gas bubbles in the liquid electrolyte. However, the bubbles are directly or indirectly influenced by all four main factors mentioned above. The amount of bubbles in the electrolyser again depends on the electricity flowing through the electrolyser and the electrolyte flow itself. Therefore, accurate modelling of the gas bubbles cannot really neglect the interaction with one of the main factors, Kemppainen explains. This in turn makes the bubbles perhaps the most difficult detail of electrolyser operation to simulate, he describes. In addition, the operating temperature also has an effect on everything: The electrolysis reaction and the resistance losses also heat the electrolyser, and the bubbles influence the reaction rate and the thermal conductivity of the electrolyte.

The scientists at the ZSW in Ulm also use modelling software. Mathematical models enable researchers and developers to better understand the physical and chemical processes within the fuel cell. They are thus the basis for the development of completely new approaches and represent an important pillar within fuel cell research, from development to system optimisation.

Simulation thus helps to reduce development time and costs through targeted optimisation. In addition to model development, experimental verification is thus guaranteed. The results of this experimentally supported modelling work flow directly into the development work of the researchers at the ZSW. Practically all questions concerning the dimensioning of distribution channels in the bipolar plate up to the complete FC stacks were developed with the help of modelling. The Fluent software from the US manufacturer Ansys was used here with a special module for cell and stack designs for fuel cells. In this way, local concentration distributions and current densities could be optimised in the development of cell designs.

MULTIPHYSICS AND OWN APPS The manufacturer COMSOL calls the consideration of the special interactions in the software multiphysics for short. This could not only calculate a process such as a flow, but also all other processes that influence this flow. For an FC, multiphysics means, for example, that users can calculate multiphase flows in the cells to simulate simultaneous transport of liquid water and steam. As occurs with low-temperature FCs and electrolysers. Simultaneously, the electrode kinetics and several reactions on the electrode surface can be taken into account, plus the heat transport. "You get a holistic model of the cell, so to speak, which takes all relevant effects into account and can be used to make precise predictions about the real behaviour of this cell and to understand and improve it," describes Philip Oberdorfer, who is responsible for technical marketing at COMSOL.

According to Oberdorfer, one benefit of the software is that users can make their own simulation apps from their simulation models. These apps contain the model and can calculate results, but in particular have an easy-to-use interface so that even non-simulation experts can use them. For example, an app can be used to simulate an FC, and app users can change input parameters and recalculate and evaluate the model.

Virtual product development simplifies the work, especially for complex processes within an FC or an electrolyser. It is technically impossible to determine the values experimentally, both precisely and comprehensively, says Oberdorfer. "But if you have a validated and verified simulation model, you can look at and evaluate every aspect at every location in the cell. In the end, the entire cell can be understood much better," he is certain. With a simulation model, it is also easy to change and play through configurations without having to build a prototype each time. Hundreds, thousands, even hundreds of thousands of different variants could be calculated before the first real device has to be produced. And mathematical optimisation can even be used to determine the best possible designs, such as an efficient electrode arrangement, he illustrates.

The software itself is modular. The module for FCs and electrolysers is completely new. It includes functions for modelling a PEM electrolyser. Thus, two-phase fluid dynamics can be simulated on the anode side of the device, which can help to investigate the iridium-activated electrolytic effect. In a PEM electrolysis cell, two electrode chambers are separated by a polymer membrane. Liquid water can circulate through the anode side. At the same time, much less gas conversion has taken place in the channel on the far right. Any liquid water leaving the apparatus should have been oxidised to release protons available for reduction on the cathode side of the electrolyser. Conversely, the iridium in the large red zone has very little effect because there is almost no liquid water left in these channels that could oxidise it. This indicates the possibility of redesigning the geometry of the electrolyser to achieve more efficient utilisation of the catalytic material (see fig. 2).

MORE COST-EFFECTIVE FC DEVELOPMENT The TU Darmstadt also uses simulation software: In recent years, Maria Catalina Bermúdez Agudelo has worked on the development of tubular HT-PEM FCs (high-temperature PEM fuel cells), both in the production of laboratory prototypes and in the numerical simulation of single cells, and the so-called stacks. "With the help of the software, I was able to couple the inherent multiphysics nature of FCs, evaluate different operational and manufacturing characteristics of FCs, and gain a better understanding of the distribution of internal variables and the interaction between parameters," she describes. In this way, internal processes and parameters can be tested that cannot be measured in the laboratory, or only with great effort. The numerical simulations enable Bermúdez Agudelo to better understand her cell and develop digital prototypes that can later be used to for the production if physical products. Taking into account the validated model of a singular FC, she thus succeeded in developing a stack with the tubular HT-PEM FCs.

Now she is looking for helpful changes in the geometry of the single cell and thus the stacks, as well as the evaluation of stack design options. "This results in significant changes to networking and domain selection, which often leads to convergence problems when solving the model," says Bermúdez Agudelo. Since the software supports virtual product development, important information can now be obtained at an early stage on both the macro and micro levels, the researcher rejoices: "This significantly reduces the development time and costs at the end." ||

Category: Development | **Authors:** Jörg Leicher, Bledar Islami, Anne Giese, Klaus Görner, Johann Overath

HYDROGEN IN THE GLASS INDUSTRY

HyGlass – process heat for industrial applications

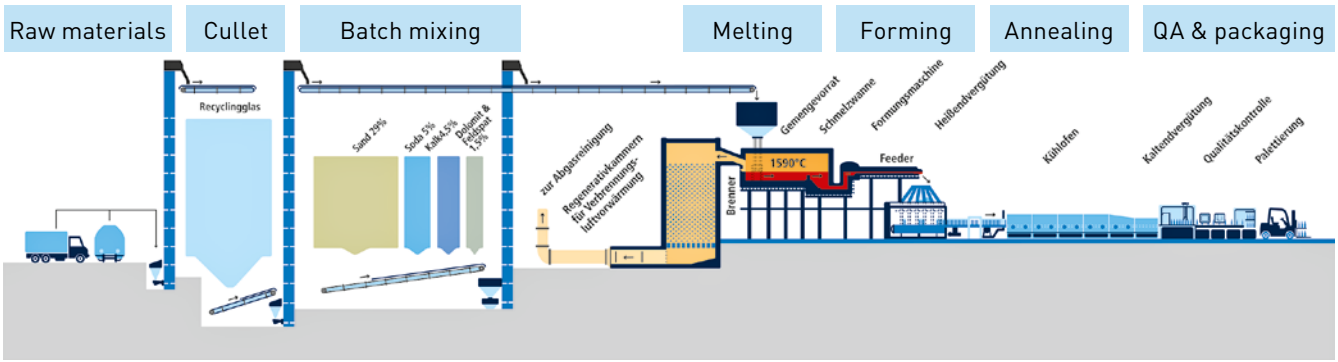

Fig. 1: Glass production process [Source: BV Glas]

Hydrogen is currently being discussed as a decarbonisation option for many sectors, some of them very different, from the transport sector to process heat in industry. The publicly funded research project HyGlass is investigating how hydrogen and natural gas-hydrogen mixtures can be used to decarbonise the energy-intensive high-temperature processes in the glass industry.

Glass is a material that is indispensable in modern society and is used almost everywhere – as containers for food, drinks and vaccines, as windows in buildings and vehicles, as glass fibres in IT technology or even as insulation material. Production is energy-intensive and requires process temperatures of up to 1,650 °C to melt the glass. In further process steps, heat at different temperature levels is required to thermally homogenise the melt, shape the product and cool it down in a controlled manner (see fig. 1).

The glass industry covers about 75 per cent of its energy needs with natural gas, which corresponds to about two per cent of German gas consumption. The production processes are highly optimised to be able to manufacture glass products with high quality and efficiency with low pollutant emissions. At the same time, however, the use of predominantly fossil energy sources also generates considerable greenhouse gas emissions.

DECARBONISATION OPTIONS FOR THE GLASS INDUSTRY In view of the climate targets in Germany, Europe and worldwide, but also as a result of pressure from customers and society, the glass industry, like many basic industries, is also faced with the question of how it can decarbonise its energy-intensive manufacturing processes. Green electricity is an option, but for physical reasons alone, not all types of glass can be electrically melted. In addition, the size of electric melting tanks is technically limited. Therefore, the use of hydrogen is an interesting alternative.

Hydrogen is relevant for the glass industry, as well as for many other sectors of the thermo-processing industries, for

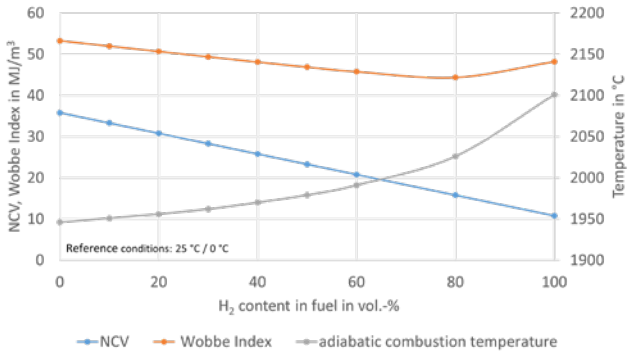

Fig. 2: Influence of H_2 in the fuel gas on calorific value and combustion temperature [Source: GWI]

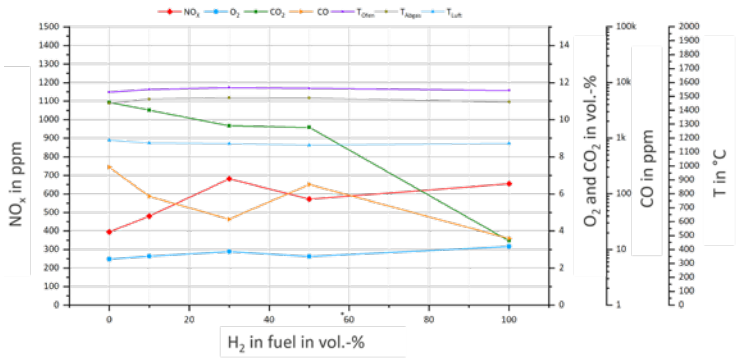

Fig. 4: Change in exhaust gas composition [Source: GWI]

another reason: The gas industry in Germany and Europe is planning to feed more hydrogen directly into the natural gas grid in the future, with up to 20 percent H_2 by volume being discussed. This means that existing plants (more than 40 per cent of Germany's natural gas consumption is currently accounted for by industry) will also come into contact with H_2 concentrations. Considering the often sensitive industrial manufacturing processes with their high demands on product quality, efficiency and pollutant emissions, this can be a considerable challenge.

The combustion properties of hydrogen and natural gas differ significantly: For example, hydrogen has a considerably lower volumetric calorific value, but at the same time the resulting combustion temperatures are higher (see fig. 2). This means that significantly higher volume flows are required to realise a given necessary energy input into the process. The flow and heat transfer in the furnace chamber will change accordingly, with possible effects on product quality and process efficiency.

At the same time, higher local temperature peaks, local overheating of components or also higher nitrogen oxide emissions (NO_X) are to be expected as possible consequences. However, it is difficult to generalise how exactly these changes affect a specific industrial manufacturing process, as industrial firing processes are very heterogeneous and often highly specialised. Therefore, detailed investigations for different industrial processes are necessary to assess the impacts and to develop solutions.

HYGLASS For the glass industry, such investigations are the focus of the HyGlass research project. In this research project, funded by the state of North Rhine-Westphalia, the Gas- und Wärme-Institut Essen e.V. (GWI) and the Bundesverband der Glasindustrie e.V. (BV Glas) are jointly investigating the effects of higher H_2 concentrations in natural gas, but also of pure hydrogen, on combustion processes in glass production. The project has a duration of 18 months and will be completed by the end of 2021.

In addition to heat transfer, efficiency and pollutant emissions (nitrogen oxides are particularly relevant here), the focus is also on glass quality. For this purpose, experimental investigations are being carried out on a semi-industrial burner test stand at the GWI, in which a so-called underport firing, a typical burner configuration in the glass industry, is simulated on a pilot plant scale for a burner output of about 500 kW. Although the outputs of industrial plants are significantly higher (up to 100 MW), the geometry, air flow rate and air preheating temperatures are based on real applications, so the measurement results can be transferred to melting units in industry.

Measurements are carried out with natural gas (as a reference), various natural gas-hydrogen mixtures and pure hydrogen. These investigations are accompanied by CFD simulations (Computational Fluid Dynamics), which can be used to analyse flow, mixing, combustion, heat transfer and pollutant formation in the furnace chamber. On the one hand, these simulations serve to better understand and visualise the changes resulting from the altered fuel in these complex processes. On the other hand, such simulations can also be used to simulate how real plants react on an industrial scale to the addition of hydrogen or the complete substitution of natural gas with hydrogen.

DIFFERENCES IN THE COMBUSTION PROCESS Figure 3 shows a view of the burner test bench for natural gas, various natural gas-H_2 mixtures and pure hydrogen. It is obvious that the flame pattern changes increasingly with increasing hydrogen contents. A visible effect is that the flame becomes more and more transparent. Since heat transfer by radiation plays a central role in high-temperature processes in particular, this change in radiation behaviour is likely to have an impact on product quality and process efficiency, which will be investigated in more detail as the project continues.

Another aspect that is important when switching from natural gas to natural gas-H_2 mixtures or even pure hydrogen is the exhaust gas composition. With the combustion of natural gas, carbon dioxide (CO_2) and water vapour are formed as reaction products, whereas with the combustion of hydrogen, only water vapour is formed, but in higher concentrations. In addition, there are combustion-related pol-

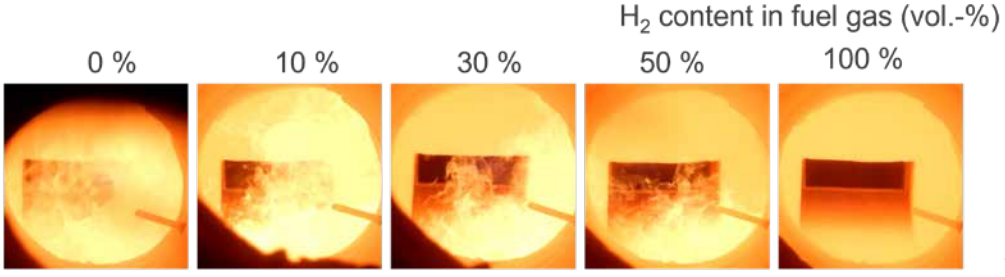

Fig. 3: View into the combustion chamber [Source: GWI]

lutants in which nitrogen oxides (NO_X) in particular play a major role for high-temperature processes and for whose emissions strict limit values are prescribed.

In the combustion of gaseous fuels, the so-called thermal NO_X formation plays the essential role, which is exponentially temperature-dependent. With higher H_2 contents, the temperatures in the flame rise (assuming a constant fuel gas-air ratio), so that, especially in high-temperature processes such as in a glass melting tank, an increase in NO_X emissions is to be expected.

These trends are also evident in the test bench measurements: With the same burner capacity, air number and air preheating temperature as well as constant furnace chamber temperature (an important control variable for many thermo-processing plants), higher NO_X values were measured with increasing H_2 concentrations in the natural gas (see fig. 4).

Computer simulations of real glass melting furnaces yield comparable results. It must be taken into account here that the burner systems investigated are designed for natural gas. With appropriate measures, the increase in NO_X emissions at higher H_2 levels should be manageable, as the underlying formation mechanisms are the same as for the combustion of natural gas.

In further investigations, the effects of the fuel change on other combustion processes in the production process, for example in the so-called feeders, are to be examined. CFD simulations will also transfer the knowledge gained to industrial-scale plants.

In addition to pollutant emissions and process efficiencies, product quality plays a key role in industrial manufacturing processes. The combustion of hydrogen or natural gas-H_2 mixtures significantly changes the furnace chamber atmosphere and heat transfer. Therefore, melting tests are carried out in which glass samples are melted with the different fuel gases and then analysed. In this way, the effects of, for example, different water vapour contents on the melting process and glass quality are to be investigated. The melting tests have been completed in the meantime, and the material analyses are currently being carried out.

SUMMARY Hydrogen represents an interesting decarbonisation option for many industries, especially in the provision of high-temperature process heat. At the same time, these production processes are usually highly optimised and very sensitive; changing process conditions can have an impact on product quality, process efficiency or even pollutant emissions. Therefore, detailed preliminary studies for the specific industrial processes are necessary for a conversion from natural gas to natural gas-H_2 mixtures or even pure hydrogen.

The "HyGlass" project, funded by the state of North Rhine-Westphalia, carries out these investigations in a practical manner for applications in the glass industry. The initial results and analyses indicate that the changes resulting from the differences in fuel properties are technically manageable, but require adjustments to existing processes and, above all, appropriately designed measurement and control technology in the plants. ||

→ www.in4climate.nrw/best-practice/2020/hyglass/

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HYDROGEN COMPRESSION WITH METAL HYDRIDES

Novel compression concept for hydrogen refueling stations based on metal hydrides

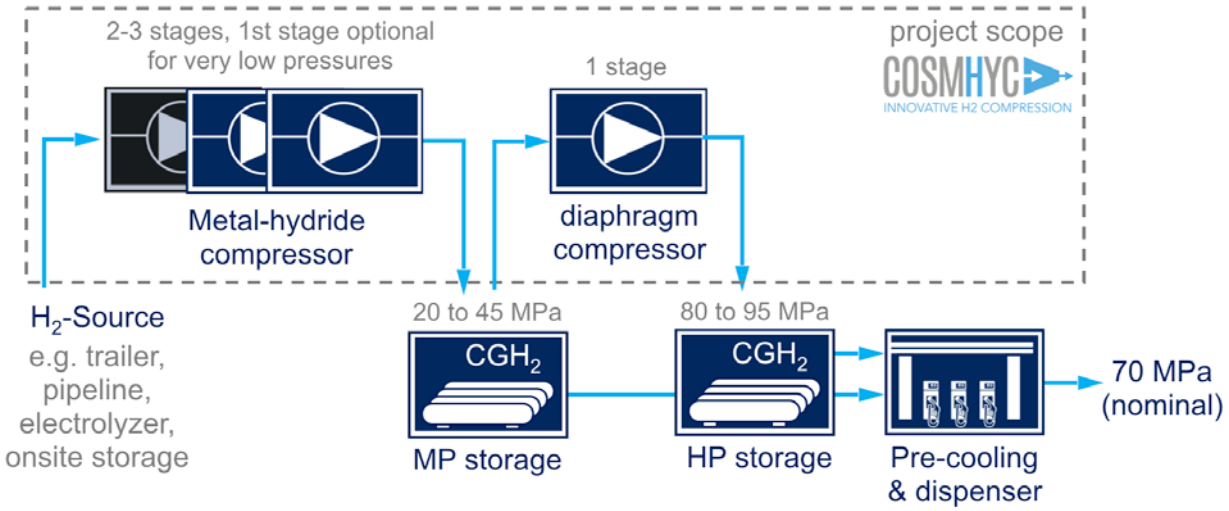

Fig. 1: COSMHYC project scope

Gas compression is a key process for transporting, distributing, storing and dispensing hydrogen. It accounts for a relevant share of costs and energy consumption in most hydrogen supply chains from initial hydrogen sourcing to final hydrogen use. Today, various compression technologies are applied, depending on use cases, flow rates, and input and output pressure levels.

Hydrogen refueling stations (HRS) are a specially challenging application for compressors. The input pressure levels are often in the range of atmospheric pressure up to about 5 MPa, depending on the gas supply concept of the station. The output pressures of the compressors need to be as high as 90 to 100 MPa in case of passenger car refueling (nominal vehicle tank pressure at 70 MPa) or at about 50 MPa in case of heavy-duty vehicle refueling of e.g., buses, trains or trucks (nominal vehicle tank pressure at 35 MPa). This results in large compression ratios that need to be covered within the HRS. Multiple serial compressor stages are usually applied to do the job.

Industry is permanently working on the optimization of existing compressor technologies to reduce compressor's energy consumption, wear and tear, costs and footprint and also to increase reliability and operation dynamics. Novel compression concepts are also developed and tested such as ionic liquid pistons, bladder accumulator-based compression, electrochemical compression or compression based on the use of metal hydrides.

The Fuel Cell and Hydrogen Joint Undertaking (FCH JU) has supported the development of metal hydride-based compression since 2017 under the Horizon 2020 program. In an initial project called "COSMHYC" (COmbined Solution of Metal HYdride and mechanical Compressors) a prototypical hybrid compressor combining metal-hydride and diaphragm compression for 70 MPa refueling was developed and tested between 2017 and 2021. Based on positive results from this project, a second project called "COSMHYC XL" was started in 2019 (ongoing) to also address 35 MPa heavy-duty refueling of buses and trucks. In 2021, a third project "COSMHYC DEMO" started to support the demonstration of the technology at a real HRS, in France. Within this project series, the metal-hydride compression technology is to be increased from initially TRL 3 to a targeted TRL 7 at the end of the demo project. Further, the diaphragm compressor is adapted and optimized for the use in the hybrid concept. The project consortium consists of the following partners: EIFER (project coordination and hydride compressor development), Mahytec (hydride and reactor development), NEL (adaption of mechanical booster compressor), Steinbeis 2i (communication and innovation management), LBST (techno-economic evaluation).

HOW METAL-HYDRIDE COMPRESSION WORKS

Hydrogen compression with metal hydrides works completely differently compared to conventional mechanical compression technologies. The key component of a hydride compressor is the reactor which is made out of a pressure vessel containing a heat exchanger and a special metal alloy – the hydride. Compression itself is a four-phase process (see fig. 2).

First, hydrogen is fed into the reactor chamber at source pressure and ambient temperature. The metal hydride absorbs the hydrogen into its matrix while emitting heat. This heat is permanently taken from the reactor. The amount of hydrogen absorbed increases, the pressure in the reactor remains constant.

After saturation of the hydride, the second phase starts. The valve of the reactor is shut and heat is applied into the reactor using the heat exchanger. The increasing temperature of the hydride reduces the hydride's capability of hydrogen absorption and thus releases the hydrogen. This results in an increased pressure within the reactor.

In the third phase, heat is continuously applied to continue the desorption process with the reactor valve now open. Hydrogen is withdrawn from the reactor at elevated pressure.

During the fourth and last phase, the valves are closed and the metal hydride is cooled down to enable the start of a new absorption and desorption cycle.

Compression with metal hydrides is a batch process which can be made a quasi-continuous process by using multiple reactors per compressor. This also helps to optimize the

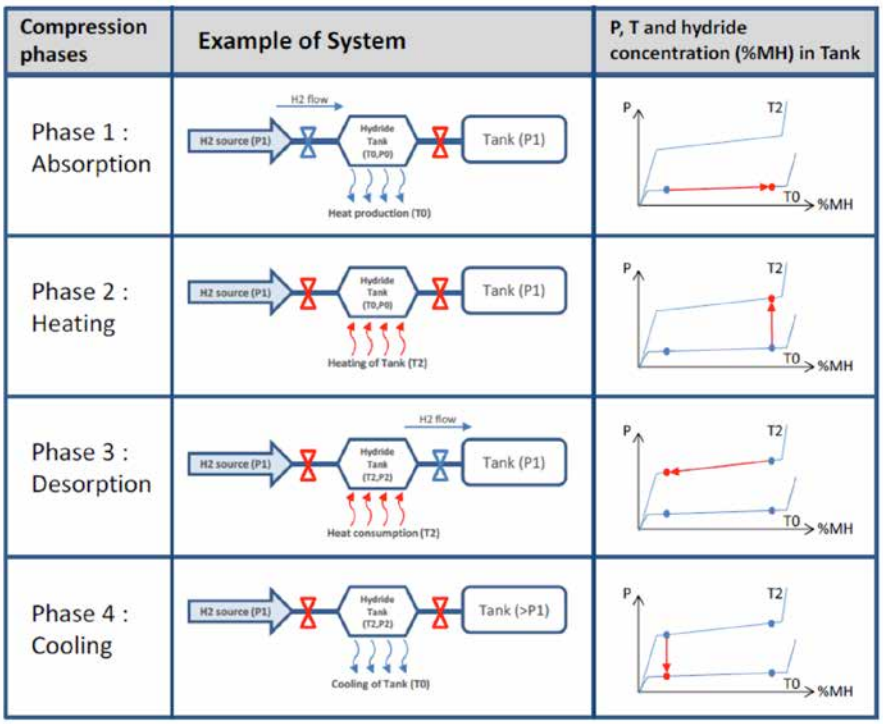

Fig. 2: Multi-stage compression [Sources: LBST]

heat recovery within the compressor system and thus reduces the amount of external heat required to drive the entire hydrogen compression process.

In contrast to other compression technologies, the main energy required for compression is heat with some additional electricity for auxiliaries such as process control or blowers. The required temperature level depends on the used metal alloy and the targeted input and output pressure of the system. It is usually in the range of about 100 to 150 °C.

Metal-hydride compression can be a viable alternative to other compression technologies, in particular at low and very low source pressures and moderate output pressure. Low and very low input pressures especially at an HRS, lead to large pressure ratios which pose a challenge for mechanical compressor technologies, especially in terms of electricity consumption. As with other technologies, multiple compressor stages might also be required

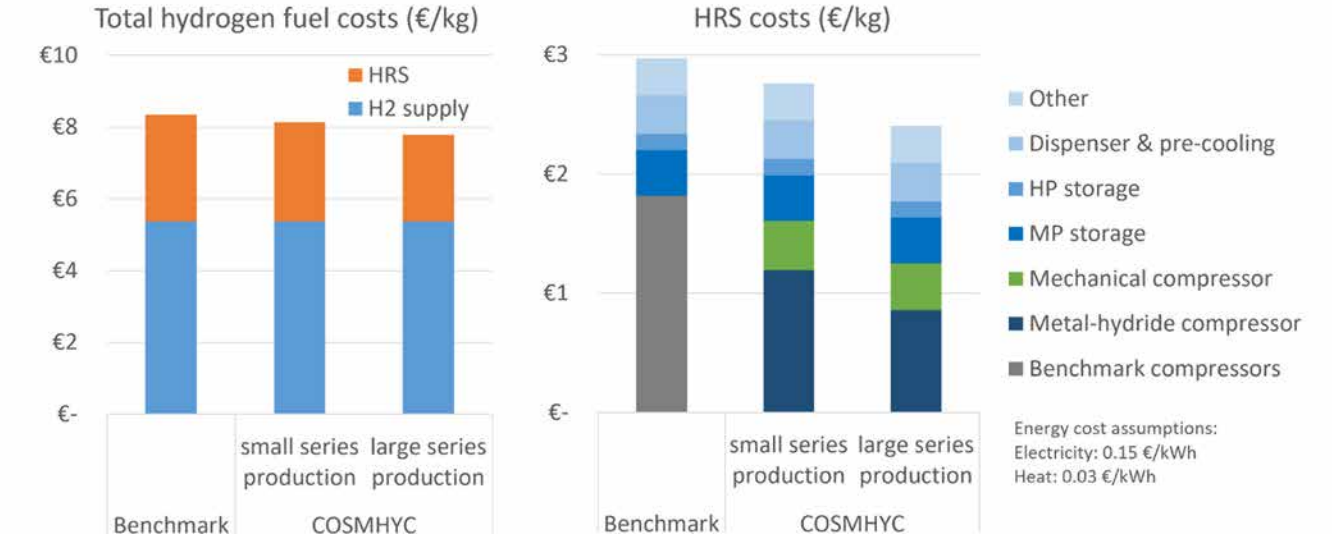

Fig. 3: Expected cost benefit [Source: COSMHYC]

with metal-hydride compressors, depending on the available temperature and targeted pressure levels.

System optimization usually focuses on the metal hydride composition (material costs and material availability e.g., without rare earth, temperature level and hydrogen uptake), reactor and heat exchanger design (cycle time and heat losses) as well as overall system design (heat recovery and overall system performance).

METAL-HYDRIDE COMPRESSION AS BASIS OF AN OVERALL HRS COMPRESSION CONCEPT A metal-hydride compressor cannot be operated efficiently at high dynamics and output pressures. For an optimized overall solution for 70 MPa HRSs, metal-hydride compression needs to be combined with a peak load fueling compressor based on conventional technology. The so-called hybrid compressor solution developed in the COSMHYC projects combines metal-hydride and diaphragm compressors. For other compression applications e.g., overnight filling of 30 MPa transport trailers, metal-hydride compression can be used as a stand-alone compression technology.

For a 70 MPa HRS, the metal-hydride compressor works as a base-load compressor taking hydrogen from the source pressure up to 45 MPa to be stored in medium-pressure (MP) storage. This is a process with very limited dynamics and a high compression ratio, thus perfectly suited for a metal-hydride compressor. Depending on the hydrogen source pressure, two or three metal-hydride compressor stages are applied.

To be able to supply the dynamic fuel demand at a refueling station, an optimized single-stage diaphragm compressor is applied to take hydrogen from the MP storage to 95 MPa high-pressure (HP) storage. This compressor has been optimized for dynamic operation, improved efficiency, long maintenance intervals and reduced noise within the COSMHYC projects. The capacities of the MP and HP storages can be selected based on the expected hydrogen supply and fuel demand profiles. To further improve overall HRS performance, hydrogen from the MP storage can be directly used during the first phase of refueling (cascaded refueling concept).

POTENTIAL TECHNO-ECONOMIC PERFORMANCE Based on the learnings from the prototype design, construction and testing within the COSMHYC project, an economic evaluation has been performed. The cost reduction effect of future series production was estimated for small (up to 50 units per year) and large (at least 100 units per year) series production. Cost reductions are achieved e.g., by reducing the complexity of the overall system which leads to a reduction of required components and materials, by improved design which e.g., contributes to quicker assembly, by optimizing the profile of requirements for components as well as by higher purchase volumes which reduces purchase costs. The economics of an HRS based on the hybrid compressor concept were then compared to an HRS using preproject state-of-the-art hydrogen compressors. The HRS performance was specified based on H2 MOBILITY Deutschland specifications for a 200 kg/day HRS which is able to serve about 30 vehicles per day.

Based on the assumption of series production and energy costs of EUR 0.15/kWh for electricity and EUR 0.03/kWh for heat, a cost advantage of about EUR 0.2 to 0.5/kg was calculated for the refueling station using the metal hydride-based hybrid compressor concept. This cost delta is caused, in particular, by differences between electricity and heat costs. Heat is usually less expensive than electricity. However, heat and especially electricity costs are site specific and vary between different European countries and also within a country e.g., in Germany depending on the legal status of the operator (e.g., HRS as part of an energy-intensive industry serving a captive company fleet vs. public HRS operated by a small company).

CONCLUSIONS AND OUTLOOK Metal hydride-based hydrogen compression in refueling stations has been developed toward market readiness over the past several years. First real-world demonstration is imminent. Cost reduction potential for series production has been identified. A hybrid concept with metal-hydride and mechanical compression can become an economic alternative to conventional compression at hydrogen refueling stations. Cost advantages are site specific and depend on the availability of low-cost heat. Providing low-cost heat to the compressor system by using technologies such as solar thermal energy or heat pumps (for heat regeneration) are in the focus of current projects to reduce the impact of external heat costs. ||

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THE STOCK EXCHANGE IS ALSO GUIDED BY INTERESTS

Stock analysis by Sven Jösting

The daily price fluctuations of the shares in the hydrogen and fuel cell sector discussed here – primarily those from the USA and Canada – give an indication that very different interests determine events here: Thus, on many days in July 2021, there was a concurrence of price declines with almost identical percentage losses in the prices of all these shares with manageable trading volumes at the same time. In other words: The buy side held back and the forces betting on falling prices had the upper hand. However, no selling pressure could be detected, which is reflected in the amount of shares traded.

At the same time, the number of short sold shares increased significantly for some of these stocks, because short sellers were so visibly betting on falling prices and caused the shares to fall even more. This development also shows how differently the potential of hydrogen in its various colours – depending on the production method and energy for conversion – and the fuel cell are seen. This can best be seen in the discussion concerning electro-mobility: There seems to be a camp thinking there, in the sense that some clearly see the battery and others the fuel cell with the conversion of hydrogen into electricity as having the benefit.

I, on the other hand, see the two variants as complementing each other. On the stock exchange, however, there can be very different moods and assessments, which are then naturally reflected in the prices of the shares concerned.

Fig. 1: Historical prices for companies discussed [Source: www.wallstreet-online.de] Retrieved August 15, 2021

CONSOLIDATION – BUT NO CRASH Seen in this light, the sharp price decline in the shares mentioned here, as well as in almost all other H_2 and FC shares since February 2021, was not a crash. The panic selling that always accompanies a crash was missing. Rather, the decline in prices was accompanied by only moderate turnover and thus represented a compensation for a price exaggeration that had previously taken place in the short term. This consolidation is now coming to an end, leading to a long-term upward trend and successive price increases. Because in view of the excellent prospects for hydrogen and the various fuel cells (PEM, SOFC, etc.), the companies or their shares discussed here will follow a positive path.

This can be deduced from the fact that there are already projects worth more than US$ 500 billion worldwide (projects worth US$ 1 billion are added every week – source: Hydrogen Council), which are based on hydrogen, its production, transport and fields of application. In addition, many countries (Japan, South Korea and China) are massively relying on hydrogen in many markets and applications. For all the companies discussed here, it is true that they have specialised in certain markets and products, that they have abundant know-how or intellectual property, and that the technologies developed are available and about to be used on a large scale (ramp-up of production). Moreover, these companies have extremely healthy balance sheets.

Strategic alliances are being worked on in parallel. So my clear conclusion is that it makes sense not to be worn down by temporary declines in prices and instead to bet on the big long-term trend. This can also mean using currently still low prices as a basis for additional purchases, possibly reductions in the price of existing positions, rather than selling, as short sellers do.

As an investor in this profession, you should bring something very important with you: Time and understanding for a new mega-trend that is slowly developing and then gaining momentum. One year is nothing. But: The trend is your friend. The industry's prospects could not be better, which of course also applies to the shares of the companies presented here.

BALLARD POWER – 2022 WILL BE THE YEAR OF THE BREAKTHROUGH

The company has now been in the fuel cell business for more than 40 years, with founder Geoffrey Ballard initially relying on lithium batteries before favouring fuel cells and moving the company in that direction. Technologically, the Canadians have always been at the forefront, optimising and

positioning themselves and investing massively (over US$ 1 billion) in research and development. This will now pay off step by step.

Many joint ventures with well-known large companies in various markets will see the first fruits through contract awards from next year, as some test series and prototype development will be completed, leading to marketable products. The orders for bus stacks placed in recent months by well-known customers such as Tata Motors (pilot project in Delhi) lead the way. And an order for 15 modules can then become one for 150 or 1,500 or an OEM agreement – in perspective.

As far as Ballard is concerned, I'm betting on China for the time being, since the People's Republic is currently leading the way here. Unfortunately, the government has still not mentioned any amount that is to flow into the hydrogen theme complex in the form of subsidies, but the money is coming. With its partner Weichai, the Vancouver-based company is ideally positioned via joint stack production. Modules or stacks for 20,000 commercial vehicles can already be produced at Weichai today. Although this is currently the world's largest production, it could soon change if China implements all that is planned (including 1 million FC vehicles by 2030 and 3,000 H_2 filling stations).

SIEMENS ORDERS FC MODULES FOR RAIL VEHICLES Meanwhile, the partnership with Siemens is taking shape: Siemens Mobility GmbH has placed the order for initially two FC modules for the new hydrogen-powered passenger train Mireo Plus H with Ballard. This train is designed for a speed of 160 km/h and a range of 800 km. Initially, test series are planned in Bavaria before going into large-scale production. Both companies together seem to be setting out to compete with Alstom and Hydrogenics (a subsidiary of Cummins) in Europe.

This market has huge growth prospects and is now being addressed. Alstom and Siemens are equally the leaders in the industry, surpassed only by CRRC in China. In China, Ballard is already working with the world's largest rail traction manufacturer, CRRC. Trams with Ballard equipment are already running in China. I expect the first really big orders to come out of this in 2023/24.

JOINT VENTURES AS A BASIS FOR GROWTH Ballard, meanwhile, is calmly expanding its international alliances. Most recently, the partnership with W. L. Gore & Associates was added. This company, with a turnover of more than US$ 3.8 billion and 11,000 employees, is – like Ballard – considered a pioneer in the field of fuel cells, with Gore having special expertise in membranes. Gore-Select, the latest generation of membranes, is already in use at Ballard. Thus, it is a strategic partnership from which both sides benefit. Even if the big turnovers are not reached tomorrow.

REPORTS ON THE SECOND QUARTER With a turnover of US$ 25 million, the analysts' forecast was achieved. The bottom line was a minus of US$ 0.07 per share (expected: minus US$ 0.05 per share). However, these figures have no relevance for me. This is because Ballard is working intensively on optimising the stacks, the production processes and the materials used, and is expanding its manpower. This will also create important cost benefits over the competition. Hubertus Mühlhäuser was recently appointed to the Executive Board. He has held many senior positions, including CEO at CNH (Fiat Industries) and AGCO.

Fig. 2: Hubertus Mühlhäuser [Source: CNH]

There is still US$ 1.24 billion in cash in the bank. Ballard expects strong growth impulses from Europe, where the bus sector is gaining momentum – still slowly, but then with increasing and later even high speed, if, among other things, the climate targets and emission specifications are to be achieved. Many OEMs and municipalities rely on Ballard's experience. It seems that Ballard will make a major investment in Europe (production site or JV) this year. A conference call said: "We are in very advanced discussions with some very interesting opportunities."

India will also be exciting, even if the country has only belatedly recognised the prospects that lie in hydrogen. USA has announced various programmes to kick-start the hydrogen economy there. The recently approved US infrastructure programme will be endowed with US$ 550 billion. 26 US states are planning their own H_2 programmes, led by California with a US$ 2 billion mobility sector programme.

Ballard also sees good growth opportunities in the establishment of a production line for electrolysers. However, the company will not enter into the production of hydrogen itself – gas producers such as Linde, Air Products or Air Liquide or oil companies can do that better.

Conclusion: This year is still for positioning, while 2022 will see good growth, and possibly an explosion of growth in the years after that. To do this, you have to understand how long the process takes, from product development to optimisation to test runs, before large-scale production begins. In some markets, such as buses and trucks, all this has already been completed; in trains and ships, the programmes are in full swing, but large-scale orders will not come until 2023 to 2025. The current prices are suitable for new purchases as well as for reductions for the medium-term investor. Traders can bet on the news from China, as this should – in case – have a very positive effect on the share price.

BLOOM ENERGY – A COMPANY GOES ITS OWN WAY

What a roller-coaster ride: from US$ 5 at the low in 2020 to over US$ 44 at the beginning of 2021 and now at US$ 22. I did not expect such a sharp decline, but the upward exaggeration has now been followed by a downward one, which may have been helped along by the fact that around 18.4 million shares were sold short (July 2021).

Current prices are already a bargain for medium-term investors and also for myself. After all, growth of 30 per cent annually so far makes a much higher valuation seem justified. The company is on track to achieve a sustainable transition to profitability – if not in 2021 (already cash flow positive), certainly in 2022. The stock exchange has no choice but to call for higher prices here.

MORE AND MORE HEDGE FUNDS JOIN IN Institutional investors in particular, who hold almost 60 per cent of Bloom shares, want to invest more in environmental technology and sustainability. Interestingly, Insider Monkey reported

that the number of hedge funds involved had risen to an all-time high of 22, with amounts ranging from US$ 25 million to US$ 33 million. These actively trade the share, so that many a stronger price movement downwards as well as upwards has its justification in this.

The big funds and capital accumulators – institutional investors with US$ 100 million each invested in Bloom – tend to take a long-term view and gradually add to their holdings when prices are weak. For me this is a good sign. These large institutional investors are, for example, Ameriprise (over US$ 460 million), Vanguard Group (US$ 314 million) or Blackrock (US$ 200 million). Recently, the investment bank J. P. Morgan raised its preliminary target price from US$ 29 to US$ 34. Others are sure to follow.

IMPORTANT NEW TECHNOLOGIES A milestone was recently reached in the use of SOFC systems to drive LNG tankers, which Bloom has been working on with Samsung Heavy Industries (SHI) since 2019. Now came the certification from DNV (international certification society for ships) and ABS (American Bureau of Shipping). This was accompanied by the statement: "80 per cent of world trade is carried by sea. Bloom Energy and SHI have developed a novel solution to reduce harmful emissions and modernise one of the world's oldest forms of commerce with innovative clean energy technology."

Also new is a process that uses the methane that escapes during the production of natural gas and crude oil and prevents harmful emissions. With MiQ (cooperation between RMI and Systemiq), Bloom wants to show companies in the oil and gas industry new ways to minimise pollutant emissions. According to the company, 75 per cent of the 84 million tonnes produced worldwide each year could be technically prevented at very little cost. This would be the CO_2 equivalent of the emissions of 60 per cent of all coal-fired power plants.

Heliogen's Sunlight Refinery Solar Power Generation System (highly concentrated solar energy) is combined with Bloom's electrolyser technology to produce green hydrogen very efficiently (30 per cent more efficiently than other systems, according to Heliogen). Heliogen (HLGN) goes public via SPAC.

REPORTS ON THE SECOND QUARTER A total of 433 acceptances (basis for orders) were accepted. An increase of 41 percent compared to the same period last year. Please note that the time from contract award to implementation, approval and funding takes up to one year, depending on the project. Turnover reached US$ 228.5 million, an increase of 22 per cent. The non-GAAP loss was US$ 23.6 million or US$ 0.23/share. This was driven by higher costs for materials, raw materials and vendor parts, as well as an increase in the number of employees and higher R&D expenditure. According to CFO Greg Cameron, 2022 should be a very good year for the new powerful 7.5 energy servers, which are expected to deliver over 50 per cent more performance than their predecessors.

Fig. 3: Guillermo "Billy" Brooks [Source: Bloom]

In 2022, the company will also enter the electrolyser production business. It is 45 per cent more efficient than all other systems available today. New on board is Billy Brooks, who was responsible for the Latin American business at General Electric (GE) as well as Head of Global Sales. This again supports my vision that Bloom could be taken over by a company like GE at some point, after all GE wants to invest massively in regenerative technologies.

Conclusion: Bloom is one of the best positioned companies in the FC industry. The optimisation of the core technologies as well as the various technological cooperations (JVs) lead to the forecast of very high long-term growth. The currently depressed prices are a very good basis for the medium-term investor to enter the market. For me, a US$ 100 share in three to five years.

NIKOLA MOTORS – EX-CHIEF EXECUTIVE OFFICER FACING CHARGES

Fig. 4: Trevor Milton [Source: Nikola]

Former CEO, company founder and major shareholder (with an estimated 20 per cent of the company still owned) Trevor Milton has been charged with making "misleading, false statements directly to the investing public" via social media and television, print and podcast interviews, according to an SEC investigation. A court has frozen assets worth US$ 100 million belonging to Trevor Milton. However, the company has nothing to do with it. Construction work at the Coolidge plant is progressing according to plan. In parallel, there were various cooperation agreements with distributors as well as service points for repairs – now already 116. In addition, Nikola is expanding the sector of consumables – electricity supply contracts for battery-electric trucks as well as for the in-house production of hydrogen. The H_2 infrastructure is being built in parallel.

Nikola is massively expanding its distribution structure: 51 locations in nine US states are added, raising the total number of locations to 116. Nevertheless, the share price has recently fallen again, but this is normal, especially since the short sellers are still betting massively on falling prices.

I have a feeling that the lawsuit against the ex-chief executive will not have any effect on the current development at Nikola for the time being (without commitment), even if the further procurement of capital is psychologically burdened in the short term. I expect additional analyses from investment banks and analysts. Elon Musk, CEO of Tesla, also had to pay US$ 20 million in one case for tweets that influenced the share price, as did Tesla, since the company had tolerated the behaviour of its own boss without intervention. Price turbulence arose here, which was dramatically higher compared to Nikola and its shares. For me, all this is a sideshow.

REPORTS ON THE SECOND QUARTER Approximately US$ 143.2 million was the loss (minus US$ 0.36/share) as a logical consequence of the expansion of the Coolidge factory as well as tooling and truck development costs. By the end of this year, this production site should theoretically be able to produce 2,400 trucks, and by 2023, 20,000 units per year should be able to roll off the production line. By the end of the year,

there should still be US$ 500 to 530 million in the account. It is interesting to note that the vehicle manufacturer has entered into a financing agreement with Tumin Stone Capital. Thereafter, Nikola can sell up to US$ 300 million worth of new shares to Tumin at a price and time determined by Nikola. I see this more as an ATM programme, whereby Nikola can issue new shares step by step, while Tumin can hold them or resell them on the stock exchange. Theoretically, Nikola will still have over US$ 800 million available when this funding is realised.

In addition, it was announced that the first hydrogen filling station will soon be put into operation and that further cooperations are planned, including in H_2 production and with other service and sales partners. The video showing a fully loaded truck driving up a slope with its own engine power was probably directed at the short sellers.

My conclusion: Nikola addresses the right market and will go its way. It would be good if, once shareholder Hanwha has sold its five per cent, another strategic investor were to step in. And since Ballard has the former CEO of CNH on board as a new board member, Nikola should consider buying the stacks from Ballard in the future. I stand by the classification: Buy on bad news.

PLUG POWER – NEW MANAGER COMES FROM TESLA

With US$ 5 billion in the bank, Plug can position itself perfectly in the hydrogen and fuel cell theme complex. This includes its own H_2 production as well as the development of alliances, such as the most recent one with Renault. And it is advisable – in my opinion – to reduce the one-sided focus on the market for forklift trucks (material handling), since the major manufacturers such as Toyota and Kion are pursuing their own hydrogen strategy in the future and the devices of future generations will already have a fuel cell system included, so that the conversion or expansion of a battery is not necessary.

Major customers like Walmart and Amazon have also shown that they are smart partners (supposed billions in profits from warrants), giving Plug orders but leaving many costs and risks with Plug as well. The sector of H_2 filling stations is exciting, as Plug has extensive know-how here and should enter production or could plan to do so (comparable to companies such as Nel Asa), because a very large market is foreseeably emerging here, which is only just beginning. One positive aspect is that top talents are bought in, such as David Mindmind, who was responsible for setting up production in Nevada at Tesla. He is now Head of Global Manufacturing at Plug.

Plug has entered into a Purchase Power Agreement (PPA) with Apex Clean Energy – a leading operator of wind and solar parks in the USA (not to be confused with the Rostock-based Apex Group) – to supply 345 MW of wind power for the joint production of hydrogen. This first project will certainly be followed by others, as Plug plans to produce first 500 and then 1,000 tonnes of hydrogen per day itself in a few years.

REPORTS ON THE SECOND QUARTER Orders for the conversion of forklift trucks (battery out, fuel cell system in) are not as relevant to me as it is portrayed. This is because these incoming orders (billings) have so far come mainly from companies such as Amazon or Walmart and have so far not had a convincing profit margin, but have mainly served to symbolically represent large orders. The only thing that is important is whether a profit is made with the hydrogen, the consumable (liquid, gaseous), which is produced by the company itself in the future. I wouldn't see Billings as the main reason for investing in Plug, even though that always sounds huge. At the end of the day, what counts is what is earned. Plug has to prove that the business model is profitable – as simple as that. For 2021, US$ 500 million in billings are to come, and then US$ 750 million in 2022. In the second quarter, turnover was US$ 124.6 million. The bottom line was a loss per share of US$ 0.18 (a loss of US$ 0.07 per share was expected).

Conclusion: At US$ 5 billion, Plug's positioning in the hydrogen market is well represented. This includes the development of its own production and infrastructure (H_2 filling stations) as well as new growth impulses through its own electrolyser production. Some additional acquisition will certainly come along – I would see an investment in Nikola Motors as a target for Plug. Among other things, a joint H_2 filling station network could be set up and, in addition to the plans for vans, large commercial vehicles, where hydrogen is becoming a very big issue (bigger than for light trucks or vans) (source: McKinsey), could be added.

With a current stock exchange valuation of more than US$ 15 billion, the company has achieved a positioning in line with its growth prospects. I readjust my thinking when the company delivers new impulses or transfers the liquidity into high-yield projects. Analyst Colin Rusch from Oppenheimer sees the share at US$ 62. The average target price of most analysts is US$ 42.63, on the grounds that Plug – now planning its third H_2 production site – is well on its way to being able to produce 75 tonnes of hydrogen a day itself.

WATCHLIST

At this point I would like to point out companies that will profit from the worldwide development of the markets around hydrogen and have a good share price development in sight, but for which I am only an observer at the moment, so that I do not want to make a recommendation regarding their shares.

SIEMENS ENERGY – ONE-STOP-SHOPPING Siemens Energy CEO Christian Bruch put it clearly in an interview to members of the German Hydrogen and Fuel Cell Association (DWV) a few months ago: The technology group wants to be a global player in the hydrogen sector – starting with electrolysis and ending with the use of hydrogen in various markets. The group is now being expanded in this direction, although in the short term the negative influence of the wind turbine subsidiary Gamesa (67 percent share, approx. 11 billion euros stock market value; that of Siemens Energy is only approx. 9 billion euros for 22 billion euros turnover) had a negative impact on their own balance sheet – a loss of minus 307 million euros.

However, I see considerable synergies here, since in the future hydrogen will also be produced via electrolysis at wind turbines, both offshore and onshore, and Siemens Energy's know-how can be perfectly applied here. A company like Siemens Energy will always be at the forefront of many major global projects. Since large institutional investors are increasingly investing in environmental technology com-

panies on the stock exchange, the Munich-based electrical engineering group will clearly also benefit. The current stock exchange valuation does not reflect these very good long-term prospects, with the share price at around 22 euros below the spin-off price of the Siemens parent, after having risen to over 35 euros in the meantime.

HYZON MOTORS – TO THE STOCK EXCHANGE VIA SPAC A shell company has helped Hyzon Motors make its stock exchange début: SPAC (special purpose acquisition company). The current value of the company is approximately US$ 1.7 billion, based on the total number of shares. Hyzon builds trucks that run on hydrogen. The US start-up sees itself as technologically quite advanced, after all, the know-how acquired within the last twenty years by Horizon Fuel Cell Technologies in fuel cell research has now been successfully transferred to the public limited company, which has only existed since 2020.

Only 15 per cent of the issued shares are tradable in free float on the stock exchange. Ten percent of the shares are in the hands of the SPAC initiators. A good US$ 626 million was available to the company after the IPO. On the negative side, early-stage investors such as Blackrock, Fidelity, UBS and others are registering their shares and warrants, which are not yet freely tradable, in order to sell them on the stock exchange bit by bit to the value of up to US$ 557.9 million. At the same time, this increases the share of free float, which is to be welcomed.

Hyzon uses components available on the market (from DAF, among others) to build the special trucks, but concentrates primarily on the drive system and fuel cell and hydrogen management. In addition to a production site in the USA, another is planned in Europe. Some vehicles are already on the roads in Europe and the USA, as well as in Australia – here also FC buses that are being tested in use in high heat conditions.

Hyzon plans to reach an annual capacity of 40,000 commercial vehicles (trucks and buses) by the end of 2025. The company's statement that it was able to reduce the total weight of the hydrogen storage system by 43 per cent, the costs by as much as 52 per cent and the number of production components by a remarkable 75 per cent is interesting.

In any case, Hyzon is tackling one of the largest first world markets for the use of fuel cells: Commercial vehicles. It is estimated that a global market worth between US$ 1 billion and US$ 30 billion p.a. will be created in 2030. According to a study by McKinsey, the share of hydrogen-powered heavy trucks is expected to rise to over 70 percent by 2050.

Fig. 5: Siemens Energy partners with Messer Group in Spain – like here in Tarragona [Source: Siemens Energy]

Fig. 6: Hyzon-Truck [Source: Hyzon]

TESLA – CONTRADICTORY REPORTS

The second quarter of this year was a very good one for Tesla, with 201,250 electric cars delivered – a record. On the other hand, more and more comments are appearing that the quality of the vehicles leaves much to be desired. In addition, the market share of this frontrunner in battery-electric mobility is falling massively. In Europe, it is only about 5 per cent in the last quarter (but 13 per cent in China), because companies like VW are gaining a lot of ground and other manufacturers are constantly launching new models. Tesla will certainly find answers, such as a low-cost variant, Model 2, which according to media reports could make its début in 2022.

SUPER FIGURES FOR THE SECOND QUARTER More than US$ 1.14 billion profit was achieved – these are really good figures. Turnover increased to US$ 10.7 billion. In terms of profit, however, special gains, expressed in regulatory credits, amounted to US$ 358 million, albeit much lower than in the previous quarters. Here, it can be assumed that these windfall profits will expire in 2022, as other e-car manufacturers no longer need the takeover because they produce enough battery-electric models themselves.

It will be interesting to see how the ramp-up in Texas (the Cybertruck will not be available until 2022) develops and how the other planned models, including the Semi as an e-truck, develop. There is still US$ 16.5 billion in the bank, but is that enough for all the aggressive investment plans? Whether there will even be production in India or Russia remains to be seen. For me, the question remains whether a stock exchange valuation of over US$ 700 billion is justified, even if one often hears that Tesla is not a vehicle manufacturer, but a software company.

SOLARCITY TAKEOVER FINALLY IN COURT In July 2021, after many years, a court hearing finally took place regarding Tesla's quasi-acquisition of SolarCity in 2016, valued at US$ 2.6 billion. Some commentators saw this as a bailout, i.e. speculated that Tesla or its leader Elon Musk had taken over SolarCity via an equity swap in order to possibly avert its bankruptcy. If Elon Musk were to lose now, he could lose US$ 2 billion in bonuses via stock options.

Fig. 7: Gigafactory in New York [Source: Tesla]

Also making headlines was the report in the US business magazine Forbes that Elon Musk had pledged over 50 per cent of his stake in Tesla as collateral for loans. The amount of the loans was not disclosed, but with a proportional value of about 22 per cent of the current market capitalisation of over 700 billion US dollars, this corresponds to a good 70 billion US dollars. Elon Musk has also received over 50 million option rights as part of his bonus programme, which are worth over US$ 30 billion (exercise price: US$ 70.01/share). What is he using this credit potential for? Does all this also have to do with Tesla's share price (without commitment)?

HUGE HUNGER FOR RAW MATERIALS Tesla wants to remain at the forefront of the battery market. The US company has not only bought technology, but also secured huge quantities of the important raw materials through subcontracting, such as recently from the Australian BHP Group, where hundreds of thousands of tonnes of nickel are at stake. At the same time, Tesla is buying into mining companies and building up a network of holdings, including its own production (lithium mining is planned in Nevada, among other places) and forward transactions. I see this – keyword vertical integration – as negative in the long term, as it entails massive financial obligations and it does not seem certain to me that all the battery capacities will be used or that there will be a market for Tesla.

On the other hand, it is the enormous leaps in costs, for steel among other things, that can be used to justify the price increases for e-cars. Are only cost increases covered here or is there a higher profit margin? Can price increases be easily implemented against the competitors without losing business?

FAST CHARGING NETWORK FOR ALL It is worth noting the news that Tesla is planning to open up its fast charging network to other electric vehicles. Does the average Tesla driver like it when he can charge quickly, but may have to allow time to get to the charging station himself in the first place? In my opinion, such a step only makes sense if other charging station operators also release their network for Tesla models. Then it would be a win-win situation.

For me, Tesla remains the perfect anti-fuel cell investment. I am therefore betting on sharply falling prices. US$ 700 billion valuation includes all potentially good news, but not supposedly bad news.

LAST TESLA REPORT This is my last post about Tesla, because a company that is only battery electric obviously has nothing to do with fuel cells and hydrogen. For me, Tesla is and remains an anti-FC investment because the utilisation of fuel cell technology using hydrogen, also in passenger cars, will be a very big topic in the coming years and will compete with the purely battery-electric type of drive if the framework conditions are right (H_2 infrastructure, availability and price). A recent study concludes that five percent more charging stations lead to five percent more sales of battery-electric vehicles. What will happen to the sales of FC vehicles if a country like Germany is equipped with H_2 filling stations (over 1,000) throughout the country and the price of the vehicle and the maintenance are on a par with a combustion engine or battery-electric vehicle? ||

RISK WARNING

Every investor must always be aware of his own risk assessment when investing in shares and also consider a sensible risk diversification. The FC companies and shares mentioned here are small and mid caps, i.e. they are not standard stocks and their volatility is also much higher. This report is not a buy recommendation – without commitment. All information is based on publicly available sources and, as far as assessment is concerned, represents exclusively the personal opinion of the author, who focuses on a medium- and long-term valuation and not on a short-term profit. The author may be in possession of the shares presented here.

Category: Market | **Interview Partner:** Peter Rügge

DEVELOPMENT OF A MARKET FOR HYDROGEN

Interview with H2Cloud founder Dr. Peter Rügge

Fig. 1: Dr. Peter Rügge [Source: think utilities]

A sustainable hydrogen world requires not only a comprehensive expansion of infrastructures, but also a functioning market. With H2Cloud, the Managementberatung think utilities AG & Co. KG wants to position a platform for OTC trading (over-the-counter trading, also direct trading or telephone trading) of hydrogen products. Dr Peter Rügge, founder of H2Cloud and managing director of think utilities, explains the background and analyses the market environment.

H2-international: Dear Dr. Rügge, how do you assess the current market for hydrogen?

Rügge: As exciting and very dynamic. A lot is happening in a short time and we hope that the activities will remain coordinated.

How is the H_2 trade currently handled?

At the moment, long-term supply contracts are concluded between the suppliers and the demanders. Transport is included. Much is reminiscent of the "old" gas economy. Currently, the hydrogen market is still intransparent and illiquid. The profit margin for suppliers is currently relatively high, as few players are involved in the oligopolistic market and thus relatively little information is available. In addition, the current volumes of supply and demand are not systematically recorded. This also means that the market opportunities for new producers or consumers are not clearly identifiable.

What quantities are we talking about here? Where do these mainly come from and what are the current sales markets?

If we take the current assessments for Germany, the annual demand is 57 terawatt hours, EU-wide without Germany it is 256 TWh. The quantities are produced predominantly in Europe for the process industry and the chemical industry, but also for other customer segments.

How many active providers and demanders are we talking about here at the moment?

This is a manageable market – we still have an oligopoly that supplies the customer segments mentioned. While this oligopoly can meet the current demand for hydrogen, it is not in a position to provide the necessary supply quantities of hydrogen needed for widespread decarbonisation.

You want to change this situation with the H2Cloud. What approach are you taking?

Market activity comprises the economic relations between all suppliers and all demanders of a certain good in a certain space at a certain time. Two basic questions have to be answered by the mechanisms of the market in controlling and allocating the production of goods: How do suppliers get information about what goods to produce and in what quantities? And: How are demanders' plans coordinated so that there is a balance of supply and demand plans?

The solution is simple, since the coordination of supply and demand is achieved through markets by adjusting the price of any good in such a way as to bring supply and demand into line. In the hydrogen market, we are still a long way from this coordination, which is also known in economics as the "invisible hand". Of course, the European and German support measures, for example, are aimed at activating the hydrogen market and enabling the market ramp-up so that sufficient supply quantities are possible. Since today's hydrogen market can be described by low transparency of supply and demand quantities, with low market liquidity and high transaction costs, we see precisely here starting points for effectively developing the market for hydrogen.

To what extent do you sense interest from the market for a corresponding solution?

We are experiencing a lot of interest from a wide variety of market participants in the gas industry, who are naturally pushing into the developing hydrogen market. In the course of EU funding under the Important Projects of Common European Interest, IPCEI, a lot of money is also available already. But we are also pleased about foreign interest. We are surprised that we have received so much positive feedback. In the meantime, we are in talks with various national and international energy suppliers.

What is the timetable for the launch? What are the biggest challenges in implementation?

We want to launch in the second quarter of 2022. Until then, we still have a lot to do. These include talks with associations, business development or project acquisition. The current situation – coming from the existing market – can also be described as an upheaval, as new suppliers and demanders are pushing into an existing oligopoly. This also means that action is interest-driven. In addition, the regulation issue, which is still open at this point, is unsatisfactory, as the investments in the transport and distribution infrastructure are insufficient as a result.

Speaking of regulation: Which transport products do you want to use for trade: H_2 trailers, pure hydrogen grid or blending into gas networks?

Trailer and truck-related transport will continue to play a role in Shipping for a certain period of time. Production and

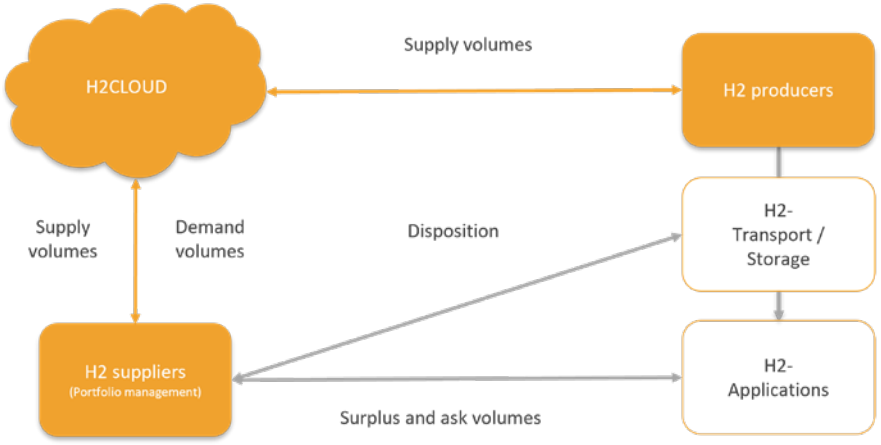

Fig. 2: H2Cloud connects producers and suppliers in different ways [Source: think utilities]

delivery locations in conjunction with availabilities give hydrogen suppliers and demanders good indicators for the subsequent logistical processes. An entry-exit system with balancing groups is not yet relevant.

To what extent are you planning to include hydrogen storage in the trade?

We are a trading platform and not a storage operator. However, depending on the development stage of the H_2 market, we will offer corresponding services and functionalities.

What trading products will the portfolio include? What is the role of the spot market and what is the role of the futures market?

OTC trading is initially the indicated trading method. Initially, only OTC trades with physical settlement will be mapped on the H2Cloud. Here, load profiles and required quantities can also be realised in the form of standard products – base or peak. In the development of the hydrogen trading market, it is clear that first the spot market and then the futures market will develop.

From a trader's perspective, to what extent will H_2 trading differ from the usual electricity and gas trading? To what extent is a specific H_2 solution needed here?

There are only insignificant differences in the trading procedures. Certainly, the topic of guarantees of origin and certificates plays a greater role. Those who are familiar with gas trading know that some technical properties of the energy sources trigger certain requirements that we had to consider for H_2 trading. Examples are the different degrees of purity, which have also led to different H_2 classifications at the DVGW in analogy to gas families. This has its relevance, as purity plays a role in certain application processes.

What concrete significance do guarantees of origin have for trade?

They are important in the question of the actual CO_2 reduction shares. The political goal of CO_2 reduction based on green hydrogen is important as a signal, but it is known that this cannot be achieved in a timely manner, because green hydrogen produced from renewable electricity is in short supply for various reasons. Therefore, over a longer period of time, other hydrogen production processes are also necessary to develop this market. We will offer all colours on our platform and oblige the suppliers to keep the proofs and to mark them in the offers.

In the past, several online trading platforms have already successfully established themselves in OTC energy trading. These have a head start here over a newcomer like H2Cloud. Will they not become equally active here? What chances do you see here?

We cannot assess this exactly, but we assume so. However, several broker platforms have already been common since the emergence of electricity trading. Competition in this sense not only stimulates business, but also raises speculation and arbitrage opportunities. Our platform is designed in such a way that we have our own Unique Selling Points, which we consider necessary: We are independent and take European conditions into account.

Does this mean that the H2Cloud will be an internationally oriented platform right from the start?

Hydrogen trade and the hydrogen market are not national issues, but international from the very beginning – we take this into account at H2Cloud right from the start.

In the first step, you plan with regional market areas. What will these be and what are the backgrounds?

Today, we are already consortium partners in various projects with a funding background. We are not able to comment on this publicly at the moment. We assume that we will have to work with regional market areas due to the still insufficient network infrastructure, but that these will connect with each other over time. When this will happen is ultimately only a question of the implementation of the European Backbone and nationally a question of regulation.

The H2Cloud will be based on blockchain technology. Which functions are to be mapped via it?

We are currently examining certain settlement processes that can be implemented most securely with blockchain technology. Basically, we map different processes in the initial version. In addition to accreditation on the H2Cloud, "Set demand" and "Submit offer", this also includes the functions "Establish trading relationships", "Carry out reporting and compliance", "Carry out clearing and settlement", as well as managing the user profile.

Let's move on to the concrete market expectations. Where do you see, say, the hydrogen market in five years' time in terms of the parameters of volumes and liquidity?

We have intensively studied the forecasts of demand in Germany and Europe. Today, the demand for natural gas is around 1,000 TWh in Germany – so what matters is the substitution potential, which today is mainly influenced by state subsidies. In five years, the lower value is indicated at about 400 TWh for Europe. This or the ambitious value of around 700 TWh is also heavily dependent on the expansion of infrastructure. Liquidity will grow at about the same rate.

Given the few production plants, will we be dealing with a demand-dominated market for years to come as demand grows?

The politically forced decarbonisation of demand does not allow an exclusive focus on green hydrogen. A few days ago, the National Hydrogen Council –

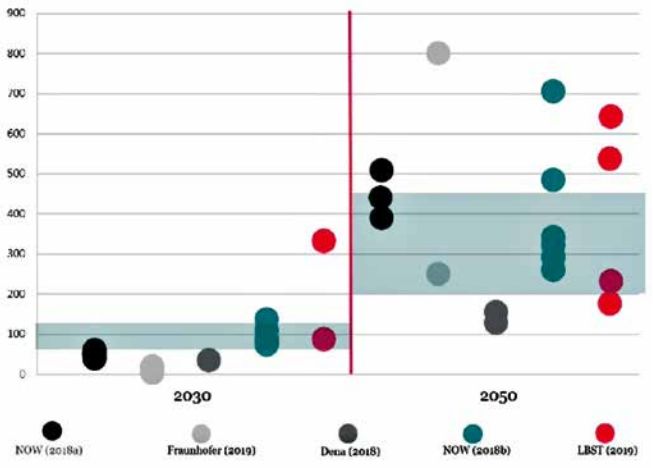

Fig. 3: Projected H_2 demand in Germany. All studies point to a significant increase in demand [Source: LEE-NRW, Wuppertal Institute, DIW Econ2020]

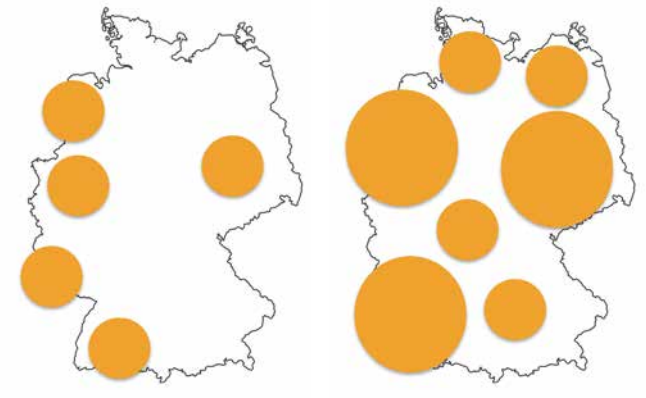

Fig. 4: The development of regional market areas pursues the goal of aggregating as much demand as possible within the areas [Source: think utilities]

as well as many other institutions – pointed out that more H_2 colours are a must for managing the upcoming transformation.

What support is needed from politics to stimulate supply and demand here?

Politics really needs to do much more. First of all, in addition to the framework conditions for promoting the market ramp-up, it is above all the regulatory framework conditions that need to be set in the short term. Let's take an example from the Netherlands, which set clear targets for the development of the H_2 infrastructure with the announcement in July 2021. The perspective projects of H2Global, the funding concept for achieving the goals adopted in the National Hydrogen Strategy in connection with the production of green hydrogen and its import, are also welcome. ||

→ www.beyondgas.de/h2cloud

Interviewer: Michael Nallinger

Category: Market | **Authors:** Kilian Crone, Friederike Altgelt

COMPETITIVE H_2 FUNDING PROGRAMMES

H2Global – Building international hydrogen markets

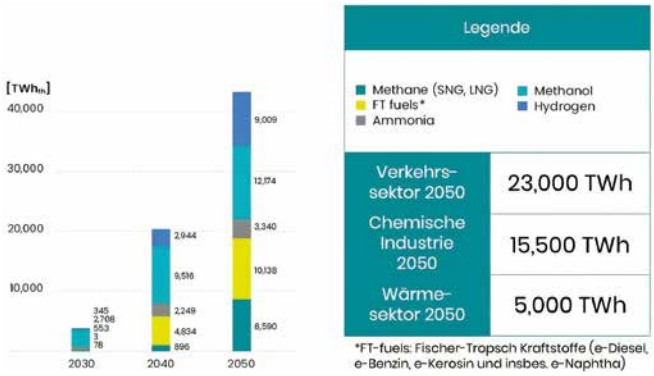

Fig. 1: Global demand for hydrogen-based energy sources 2050

About halfway between Montreal and Quebec City, the small town of Bécancour on the Saint Lawrence River has 13,000 inhabitants. The current world record holder in membrane electrolysis is located in the industrial park, between medium-sized chemical and refinery operations. With a capacity of 20 MW, fed by abundantly available hydropower, the PEM electrolyser supplies 8.2 t of hydrogen per day to part of the local industry.

Seen from the outside, a lot has already happened recently in the development towards a global hydrogen economy. More than 20 countries have adopted national hydrogen strategies between 2017 and today. Big announcements have also been made by the industry; the Hydrogen Council now estimates the global investment pipeline at 500 billion dollars.

But the example of Bécancour also shows: Only where climate ambition, the cheapest electricity prices and year-round availability of renewable energies coincide will larger green hydrogen plants be built. After several years of trend-setting strategies on the part of policy-makers and major announcements on the part of industry, there is accordingly still a gap between what is wanted and what is economically feasible today.

The federal government wants to address this gap via the H2Global funding programme and fund at least five larger, non-European projects via ten-year purchase agreements. In each case, 100 MW of electrolysis capacity is to be put out to tender. 900 million euros in funding is available for this from the National Hydrogen Strategy.

In the design of the funding programmes, lessons were learned from past experience, because the purchase subsidy ensures predictable and guaranteed income. Unlike the usual capital funding of individual projects, continuous purchase is guaranteed for the contractually defined periods and quantities. The experience of two decades of EEG subsidies has also taught us that the development of volumes can be controlled politically, but that pricing must also be thought out from the perspective of the market.

H2Global therefore relies on a double auction system instead of fixed feed-in tariffs. An intermediary (broker) is to tender the provision of fixed quantities of H_2 at prices determined competitively and thus as cheaply as possible and then sell it to the highest bidder. This creates a contract for difference and thus an H_2 market. It is assumed that the necessary financial balance between the willingness to pay on the demand side and the cost structure of the supply decreases over time until the intermediary – and thus the need for state promotion – eventually becomes obsolete.

With a first round of tenders later this year, a foundation is to establish international hydrogen supply chains with funding, but crucial questions are still open.

A SAY FOR THE FEDERAL GOVERNMENT The basic mechanism of H2Global is thus simple and effective. This construct receives equal praise from the Federation of German Engineers (BDI) and the Federal Economics Minister, Peter Altmaier. However, it was also important to his house not to place the execution and implementation in the hands of a state company such as KfW or BAFA. The result is an independent foundation based in Hamburg, financed primarily by industry. This has already intensively accompanied the drafting process in working groups organised by the German Hydrogen and Fuel Cell Association (DWV).

In this constellation, the federal government has two options to ensure the public interest: On the one hand, through the appointment of the Foundation's Board of Trustees. Seats are planned for representatives of the ministries involved. It would also be conceivable and sensible to additionally involve civil society or other independent representatives. The Board of Trustees will have to take care to counteract possible conflicts of interest on the part of industry in the dual role of benefactor-fund recipient and to ensure an evaluation of the individual rounds of tenders, because transparency is crucial in view of the funding amounts.

A further possibility of influence lies in the definition of the funding conditions. Three aspects in particular need to be taken into account here: The selection of tendered products, the question of pre-selection of bidder countries and the definition and assurance of compliance with sustainability criteria.

AMMONIA AND METHANOL INITIALLY IN FOCUS The physical delivery of the imported H_2 quantities to Germany was already set as a criterion at the beginning of the discussions. In conjunction with the early start of delivery, this means: The products put out to tender will probably be ammonia on the one hand and hydrocarbons, especially methanol, on the other. Hydrogen as an end product is left out for the time being. This may mean that certain applications in the transport sector, some of which already have a high willingness to pay, will not benefit.

The market for ammonia in particular is only distributed among a few companies and a handful of locations in Germany, and would then be in direct competition with the development of national production capacities for green ammonia. Against the background of the planned quotas or the targeted prioritisation of the use of hydrogen-based fuels in the maritime and aviation sectors, it would therefore be important to also take these sectors into account.

Methanol in particular could also be used to a limited extent in maritime transport directly and in aviation as an intermediate product for the production of synthetic aviation fuel, so-called PtL paraffin, even during the lifetime of

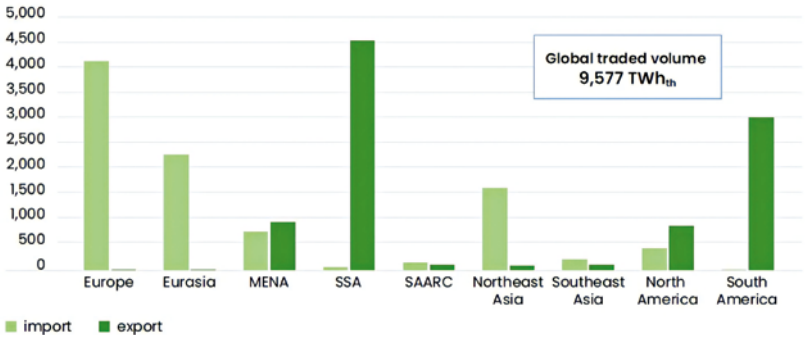

Fig. 2: Global trade volumes of renewable hydrogen-based energy sources 2050

H2Global. In order for air traffic to also directly use imported drop-in-capable fuels via H2Global, separate quantities of a further H_2 downstream product would have to be tendered accordingly. It may even be possible to dispense with the physical delivery criterion for shipping and aviation if the modes of transport using the promoted fuels are travelling between possible production countries and European destinations anyway.

But regardless of the ultimate use of the powerfuels (gaseous or liquefied) promoted by H2Global, there is a need to build a basic infrastructure and organise international hydrogen transport chains. This remaining challenge also highlights the limitations of a funding mechanism such as H2Global, which can only address part of the market ramp-up and is dependent on existing infrastructures.

COUNTRY COOPERATION DEPENDING ON TENDER DESIGN The question of whether the tender criteria should already specify ex ante in which country the hydrogen plants should be located continues to be much discussed. In principle, it would be desirable to have projects from as many countries as possible bid in the tenders. With the still manageable number of serious large-scale H_2 projects per country, this would be the only way to really guarantee the core of the idea – a competitive market mechanism.

Another challenge is to reconcile this with the political desire to cooperate more closely with certain countries for strategic reasons. The fact that this is not always easy and can be planned in advance is shown by the still ongoing foreign policy disgruntlement in the former pioneer country of bilateral hydrogen cooperation, Morocco. Elsewhere, however, commitments are already being made to individual countries to participate in H2Global, as in the German-Australian intergovernmental agreement signed on the sidelines of the G7 summit in June 2021.

It would be desirable to preserve the principle of competition while at the same time taking into account as many central factors as possible, including political stability and existing bilateral energy cooperation. This could be achieved, for example, by having countries with comparable framework conditions compete with each other in clusters in H2Global. This is because the capital costs for project implementation in countries such as Russia, Brazil or Ukraine are sometimes twice as high as in Europe.

In other countries, there is a willingness on the part of the state to put up its own money – conceivably in Saudi Arabia, for example – so that companies there could make particularly favourable offers. Bringing these challenges together could succeed if several countries with similar starting conditions were admitted in individual rounds. Within each of these clusters, the bid price would be the decisive criterion. Nevertheless, even then a diversification of the production locations that would be desirable for political-strategic reasons would be ensured.

UNCERTAINTY DUE TO LACK OF EU REGULATION With regard to the sustainability criteria to be met, the regulations at European level – for example, on the purchase of electricity and permissible sources of CO_2 as a raw material (e.g. for the production of methanol and synthetic paraffin) – will point the way. In its proposal for the revision of the revised Renewable Energies Directive, the European Commission has made it clear that the sustainability criteria set out there should also apply in future to electricity-based energy sources imported into the EU.

It is therefore logical that funding programmes for the production of hydrogen and its derivatives in non-European countries should be oriented towards this. However, a challenge arises from the fact that the concrete specification in delegated acts of the European Commission might not be available until the end of this year.

Likewise, H2Global has already defined its own sustainability criteria, which are to be applied in the context of the tenders. So if the first tender round is to start this year as planned, there will be a certain degree of regulatory

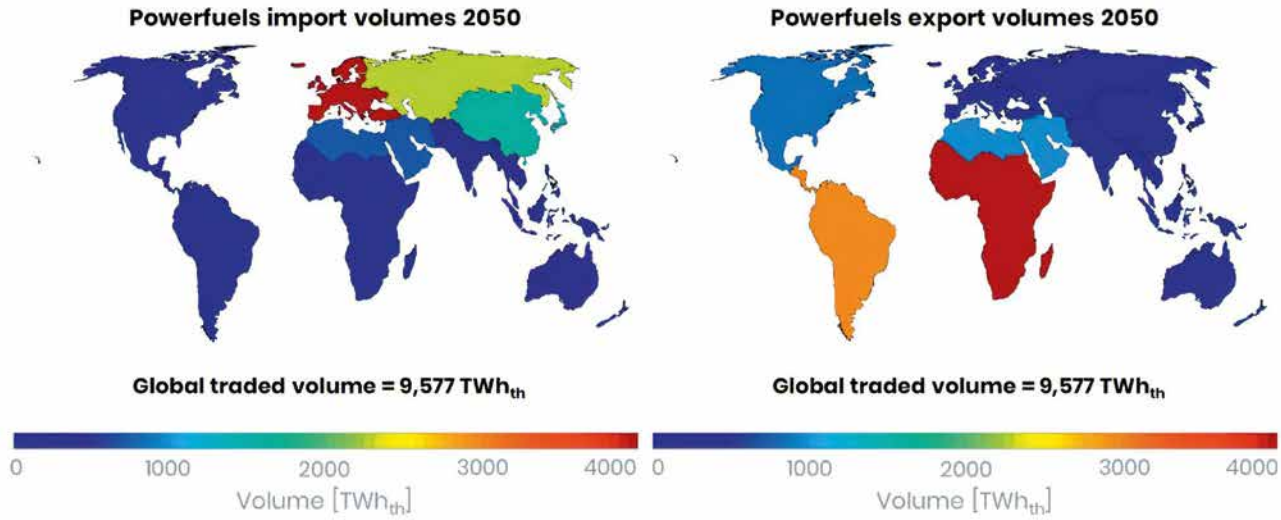

Fig. 3: Import (l.) and export volumes of renewable hydrogen-based energy sources 2050 [Sources: dena & LUT/Global Alliance Powerfuels]

uncertainty. In addition, it has not yet been defined for market participants how the required sustainability criteria must be proven – a task that must be tackled promptly.

In order to avoid possibly necessary tightening at a later point in time, the first call for subsidies could be oriented towards the hitherto uncritical operating model – i.e. primarily an electricity purchase via a direct line to newly constructed, otherwise unsubsidised PV and wind plants and narrowly define the sustainability term for other possibilities of electricity purchase in order to avoid possibly necessary tightening at a later point in time.

H2GLOBAL – A FUNDING MECHANISM AS AN EXPORT PRODUCT In Québec, the hope is to turn hydrogen into an export product – beyond the province's borders. In view of the criteria currently being discussed by H2Global, however, this location would not come into play, because the purchase of renewable electricity from so-called existing plants such as the hydropower plants there could be excluded in the sense of creating additional generation capacities.

Thus, the abundant renewable resources could then find their way rather to the consumption centres of North America. For this to happen, however, a reliable financing framework would be needed there as well, such as H2Global can offer in Germany. Perhaps – and this is also the hope of the German funding programme initiators – in this way this funding mechanism will itself become a sustainable export product. ||

In the second project phase of H2Global, dena supported and accompanied the concretisation and further development of the funding concept and was represented in this context in the four working groups set up as well as in the Sounding Board of the H2Global Expert Commission. The authors were involved as dena representatives in the working groups on questions of financing and the topic area of countries/products/transport.

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GREEN HYDROGEN GOES PUBLIC

Fig.: A 20" container from Green Hydrogen, like the one on the electrolysis test field in Bremerhaven [Source: Green Hydrogen]

The Danish electrolyser manufacturer Green Hydrogen Systems A/S became a listed company this summer. Shares in the company, which was founded in 2007, have been tradable on Nasdaq Copenhagen under the symbol GREENH since 22 June 2021. The fixed offer price is DKK 40 per share with a par value of DKK 1. A total of 27.5 million shares were subscribed, resulting in gross proceeds of DKK 1.1 billion for the company. This money is to be used for the expansion of the production plant, further technological development and the expansion of the company.

Speaking at the IPO, Thyge Boserup, Chairman of Green Hydrogen Systems, said: "We are in the midst of a fundamental shift in our energy systems towards a carbon-free society in 2050, and green hydrogen will be a cornerstone of that transition." CEO Sebastian Koks Andreassen added: "Discussions with investors have confirmed to us that there is enormous interest in investing in a more sustainable future, in which green hydrogen will play a central role."

Just one month later, on 21 July 2021, Green Hydrogen announced the signing of a supply contract for three GHS HyProvide™ A90 alkaline electrolysers with a total capacity of 1.3 MW to Wenger Engineering. The devices are to be installed in containers on an electrolysis test field in Bremerhaven and use pure wind power for H_2 production.

David Wenger, CEO of Wenger Engineering, said: "The test field is a great opportunity for Green Hydrogen Systems to demonstrate their technology and demonstrate its effectiveness. The findings from this project will not only have a significant scale effect for the hydrogen economy in Germany, but the results can potentially be valuable for the entire green energy turnaround in Europe." Søren Rydbirk, CCO of Green Hydrogen Systems, commented: "With the announcement of its ambitious National Hydrogen Strategy, Germany has the potential to become a world leader in related green hydrogen technologies." ||

DIFFERENCE BETWEEN H2CLOUD AND H2GLOBAL

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH made it clear to H2-international how H2Cloud and H2Global differ:

H2Cloud sees itself as a trading platform for OTC trades (over-the-counter direct trading) with physical execution. The H2Cloud intends to bring together suppliers and demanders of hydrogen and thus support economic pricing. Furthermore, the merging of different market participants is expected to increase market liquidity. All "hydrogen colours" will be tradable on H2Cloud for the foreseeable future.

H2Cloud was developed by the energy turnaround management consultancy think utilities AG & Co. KG as part of its H_2 business services. H2Cloud is, in addition to an event on the topic of hydrogen and classic consulting offers, a pillar of the focus of the consultancy's H_2 activities under the label beyondgas.de.

H2Global is first and foremost a funding instrument. It provides for the temporary compensation of the difference between the purchase price (production plus transport costs) and the sales price (currently corresponds to the market price for fossil hydrogen) for green hydrogen and H_2 derivatives. By indirectly subsidising the price of green hydrogen for a limited period of time, the aim is to stimulate long-term market-based demand for emission-free produced hydrogen in Germany in order to provide incentives for private investment in H_2 production, transport and application infrastructure at home and abroad as quickly as possible.

The Hydrogen Intermediary Company HINT.CO is an intermediary that concludes long-term purchase contracts on the supply side and short-term resale contracts on the demand side in the course of a double auction model in order to bring supply and demand together. On the demand side, this model enables green hydrogen and PtX products to be integrated into the economic cycle at prices reflecting the market.

H2Global is therefore a funding construct with which the price difference between green and grey hydrogen is to be balanced out, in order to create a supply of green hydrogen on the one hand and to integrate green hydrogen into application processes in a timely manner to reduce emissions on the other. One premise of H2Global is that no functioning market for green hydrogen exists at the current time, as potential supply and actual demand prices are too far apart.

H2Cloud, on the other hand, is a trading platform that is intended to facilitate the general tradability of "different-coloured" hydrogen. The prerequisite for this is an existing market, which is also given in the case of grey hydrogen. Furthermore, H2Cloud relies on direct trading between suppliers and demanders of hydrogen, while H2Global uses an intermediary to balance out the price difference.

Category: International | **Author:** Jorgo Chatzimarkakis

EUROPE HAS SET THE COURSE FOR THE H_2 ECONOMY

Guest article by Jorgo Chatzimarkakis, CEO of Hydrogen Europe

Fig.: Signing of the agreement by J. Chatzimarkakis (Hydrogen Europe, left) and Werner Hoyer (EIB) [Source: EIB]

In January 2020, Hydrogen Europe's Executive Board published a visionary paper outlining the path to ramp up a hydrogen economy with twice 40 GW of electrolysis capacity in Europe and the neighbourhood. At that time, it was not yet foreseeable what a ground-breaking character this position paper would have. Because only a few weeks later, a worldwide pandemic broke out that was to have a massive impact on the global economy and politics. Especially in the area of energy demand, a considerable decline was recorded, there were massive drops in the sectors of coal, crude oil and also natural gas. The only sector that developed positively – albeit at a low level – was the renewable energy sector. At that time, it was hardly possible to estimate how much the pandemic would affect further economic development. The crisis that has now occurred had the potential to unhinge the ambitious European Green Deal, the European response to climate change and the challenge of the Paris climate targets.

Despite the crisis situation, it would have been conceivable to return to the old "bread and butter policy" with a renaissance of fossil energies in order to secure jobs and to offer people a perspective. The Vice-President of the European Commission nevertheless opted for a different strategy: Dutchman Frans Timmermans saw the pandemic as an opportunity to make a fundamental change of course. For this purpose, a technology was needed that is emission-free and at the same time can replace fossil energy sources.

FROM THE EUROPEAN GREEN DEAL ... The paper on the ramp-up of electrolysis capacity caught his attention. Within just a few weeks of the outbreak of the pandemic, a digital conference of a size appropriate to the circumstances could be organised. A total of 15 key companies from the hydrogen economy and from the sectors of renewable energies debated with a total of three commissioners and came to the conclusion that they wanted to attempt a European reorientation towards renewable hydrogen.

The talks and discussions resulted in the EU Hydrogen Strategy, which was presented on 8 July 2020. On the same day, the European Hydrogen Alliance was launched, which now has almost 1,800 members, a hundred times as many as the Battery Alliance. Within a few months, in a new record time, the European Commission, together with the hydrogen economy, had thus demonstrated that it can act and, above all, wants to act, in the sense of a climate-friendly transformation of the entire economy.

At the same time, huge funds were decided to speed up the recovery after the pandemic. The package of 750 billion euros was quickly agreed despite heated debate, which also gave the restructuring a financial sounding board. Now the national strategies had to be adapted in line with the European hydrogen strategy.

Under the German Council Presidency, the Member States organised an initiative to support the hydrogen economy through so-called IPCEI projects (Important Projects of Common European Interest). On 17 December 2020, Federal Economics Minister Peter Altmaier invited to a corresponding conference, which was attended by the vast majority of Member States. This defined the strategy and the instruments for the ramp-up.

... TO THE "FIT FOR 55" INITIATIVE What was still missing was the concrete implementation as well as the legislative accompaniment of a process that is already historic in its dimension. To this end, the European Commission launched a huge legislative package, which it presented one year after the adoption of the EU Hydrogen Strategy in July 2021. Under the name "Fit for 55", a total of twelve legislative proposals were presented that are intended to reduce CO_2 emissions by 55 per cent by the year 2030 (therefore 55). There are a total of 1,000 references on the topic of hydrogen on 3,000 pages of legal text. This alone shows how strongly the European Commission is relying on hydrogen as a multi-talent when it comes to the climate-friendly transition in the areas of energy, mobility, industry and heating.

The proposed targets are suitable for creating clear and plannable framework conditions for investments in hydrogen projects. In particular, the focus is on hydrogen produced from renewable sources. For example, half of the hydrogen used industrially to date is to be replaced by sustainably produced hydrogen by 2030. There are also clear targets for the sectors of air traffic and maritime transport fuels that can only be met by a strong growth in hydrogen production.

A detailed analysis of the overall package by Hydrogen Europe showed that it is in the highest interest of the hydrogen economy for the EU Council and the European Parliament to maintain this legislative package in broad terms. It is also particularly important to bring the legislative proposal on renewable gases, expected in December 2021, in line with the "Fit for 55" package. This is one of the priorities for the second half of the year.

RECOVERY WITH HYDROGEN In parallel to the strategic guidance, legislative measures and related instruments, Member States have meanwhile prepared their post-pandemic recovery plans. Especially in the southern EU states, which receive most of the corresponding funds per capita, hydrogen is emerging as the biggest factor for recovery. Italy, Spain, Portugal, but also France and Greece have dedicated large parts of their recovery programmes to hydrogen projects.

In the upcoming implementation of these projects, it will now be a matter of achieving constructive European coordination. In addition to the continuing speed of the measures, precision, risk avoidance and social acceptance will also be important, which is why the necessary haste must not cast doubt on the quality of the projects.

AGREEMENT WITH THE EIB In order to also ensure the appropriate financial framework, Hydrogen Europe has agreed an agreement with the European Investment Bank (EIB) before the end of July 2021, which assures the projects of the support of the EU's house bank and at the same time the largest investment bank in the world. It was also agreed that the pace should be maintained, above all through the determined consolidation of lighthouse projects. These lighthouse projects have reached a level of maturity that makes private financing already possible in many cases. In combination with public funding, there are leverage effects that can significantly increase volumes.

So far, four lighthouse projects are planned, covering the entire EU. Germany is involved in almost all constellations, which is not only due to its central geographical location. It is not a requirement to be funded under the IPCEI framework to be included in a lighthouse project. But of course it is not a hindrance either. Ultimately, it will be a matter of demonstrating the determination of the hydrogen economy and offering the sometimes restless investors a clear, but also rapid perspective.

HOPING FOR THE NEW FEDERAL GOVERNMENT The overall picture for hydrogen in Europe is record-breaking by European standards: In a very short time, ambitious goals were resolutely tackled and both clothed in legislative measures and provided with the necessary financial resources. The framework conditions for a European ramp-up, which is also unparalleled on a global scale, are now in place. Nevertheless, it is now a question of practical implementation and utilisation of the existing instruments.

Many stakeholders are looking ahead to the federal elections and the expected new federal government. Any doubts about hydrogen would be a significant inhibiting factor should they come from a potential coalition partner who could slow down the overall process. So far, the federal government has helped set the pace and had a strong say in it.

It is to be hoped that Berlin will continue to adopt this strategic, visionary and at the same time pragmatic attitude in the future. The European level has respectively done its share in speeding up all processes in an unprecedented way. The ball is now on the penalty spot. ||

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Category: International | **Author:** Michael Jensen

HYDROGEN IN THE NORDICS

What's going on in Denmark, Iceland, Norway, Sweden?

Fig. 1: Copenhagen-Oslo hydrogen ferry planned by Danish ferry operator DFDS [Source: DFDS]

Although the Nordic countries are characterized by widely different sectoral set-ups and geographies, they do share many traits such as being welfare democracies with flexible labor markets and long traditions for environmentally friendly policies and highly adaptable energy sectors.

Being comparatively small open and exposed economies with limited domestic markets the Nordic countries rely heavily on exports. This is one of the main reasons that these countries have developed energy-efficient and flexible industries as well as adaptable energy sectors to minimize exposure to fluctuating energy prices. The environmentally friendly policy tradition combined with the need to maintain competitiveness of economic sectors have made the Nordic countries forerunners within renewable energy.

Bioenergy is huge in countries such as Sweden and Finland, as has been the case for decades, with their ample access to vast forest resources. Denmark has a long tradition for using bioenergy derived from agricultural waste products and the country is well known for its leading position within wind power. Norway and Iceland produce a major part of their electricity from hydropower and have done so for decades. In Iceland geothermal power plays a significant role as well and has potential for further exploitation.

Since the Nordic countries have such a long tradition of environmental protection and renewable energy, they are perfectly positioned for adding hydrogen in the mix to displace fossil fuel use in industries, transportation, housing and power production. Hydrogen used as energy storage helps balancing fluctuating power production from sources such as wind, sun and hydro.

Yet, it is also well suited to replace fossil fuels in industrial processes such as steelmaking or cement production. Sweden being a large steel nation in the Nordic context has, via its national HYBRIT project, already proved that fossil fuel use in steelmaking can be reduced by 99 percent. Volvo recently announced that the carmaker in partnership with Swedish steelmaker SSAB will start production of cars made from carbon-reduced steel produced by the HYBRIT method within this year.

SWEDISH RAILWAY TRACKS ON HYDROGEN The Swedish domestic railway route Inlandsbanan (the Inland track, ed.) has commenced a feasibility study on converting the 1,400 km track to hydrogen operation substituting the current diesel locomotives with hydrogen-powered fuel cell locomotives. As the track is among the few stretches in Sweden still not electrified it will be investigated whether hydrogen operation is competitive in comparison with electrification or conventional diesel locomotives running on biofuels. The scenic track is increasingly popular as a tourist route but also significant for inland passenger and cargo transportation. The feasibility study is conducted in partnership between the track operator Inlandsbanan AB and the power company Statkraft Hydrogen Sweden AB and is expected to be published later this year.

HYDROGEN IN NORDIC MARITIME SECTOR Both Norway and Denmark are significant global maritime players and prioritize carbon reduction in domestic and international fleets. In Denmark, A.P. Møller-Mærsk, the second largest shipping company globally, recently announced that it speeds up the construction of its carbon-neutral liner vessel (container vessel, ed.) to be launched in 2023 instead of 2030. The vessel will run on renewable bio- or e-methanol depending on availability.

Furthermore, to accelerate its overall efforts in reduced-carbon shipping, A.P. Møller-Mærsk has founded the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. In conjunction with national and global partners the center will coordinate and support independent research in carbon-reduced shipping to "create an industry-wide transition strategy by providing overview of the technical solution space and the strategic swing factors" (excerpt from the organization's homepage).

Also in the maritime department, the Danish ferry operator DFDS plans to operate a ferry between Copenhagen and Oslo propelled by hydrogen fuel cells (see fig. 1). The hydrogen fuel for the ferry is to be delivered by another milestone project in Denmark, the Green Fuels for Denmark 1.3 GW

Tab.: Vessel and route details [Source: DFDS]

Onboard Power Production	PEM Fuel Cells
Engine Power	23 MW
Fuel	Compressed Hydrogen
Fuel Tank Capacity	44 t
Passenger Capacity	1,800
Round-trip Time	48 hours
Bunkering interval	48 hours
Avoidance of CO_2 per year	64,000 t

Fig. 2: Hydrogen-powered zero-emission bulk carrier planned by cement maker HeidelbergCement and the Norwegian agricultural supplier Felleskjøpet [Source: Illustration by the partnering companies]

electrolyzer facility that renewable energy company Ørsted has commenced initial phases of with partnering utility HOFOR in the Danish capital area. The ferry is planned to be in full operation by 2027 with the following specifications:

In Norway, several domestic short distance ferry lines are planning to convert to hydrogen operation by replacing diesel engines with hydrogen fuel cells, in new builds as well as existing vessels. Two hydrogen ferries MF Nesvik and MF Hydra have been recently built by ferry operator Norled and will be put into operation on local routes later this year. Also, a Norwegian hydrogen-powered cargo ship is planned for. The ship will be propelled by hydrogen fuel cells and rotor sails. The hydrogen will be stored on board in swappable containers making refueling fast and simple. The cargo ship will be transporting grain and gravel along the Norwegian shorelines and construction of the vessel is planned to begin 2023.

Norway has, up until its oil and gas boom began in the 1970s, traditionally relied heavily on fisheries and the country is still up among the great fishery nations globally with a more recent addition of a huge and economically important aquacultural sector mainly producing salmon for the global markets.

HYDROGEN IN FISH FARMING Hydrogen is also explored for its potential uses in this sector as the research-based spinoff company Biofish AS demonstrates. Biofish AS applies the concept "Green Fish Farm" developed by Norwegian research company Prototech. The purpose of the tailored concept is to obtain zero emissions to air and zero emissions to water in fish farms:

FINLAND GOES SOLID BLACK (CARBON) Finland, like Sweden, has a large natural resources sector based on mining and forestry plus derived processing and manufacturing industries. Wood and paper industries still play an important role in the Finnish economy although the paper industry, due to global lack of demand, has experienced setbacks in recent years.

Finland has a diverse energy sector using nuclear, hydro, biomass, solar, wind as well as natural gas for power generation and heating along with the traditional fossil liquid fuels for transportation.

Curiously, Finland, not being a natural gas producer itself (all NG imported from Russia, ed.), has still explored opportunities in carbon-reduced hydrogen production based on natural gas (methane). The Finnish research company Hycamite TCD Technologies has announced construction of a pilot plant for hydrogen production by "thermo-catalytic decomposition" in the Kokkola Industrial Park.

> "Based on a closed cycle/semi-closed cycle, fish farm location, size, amount and type of generated sludge, the GFF™ concept can integrate different renewable technologies (wind, solar, wave, hydropower, osmotic power) for power generation. This energy can be used locally by the fish farm, but it can also be used to produce oxygen and hydrogen via electrolysis. The produced oxygen can be used to oxygenate the fish from the closed farm, while hydrogen can be used by the local boats. ... The generated sludge can be used to produce biofuels/biogas via thermal treatment and/or anaerobic digestion. Furthermore, an algae/microalgae/shells farm can also be installed around the closed fish farm and used both as bio filters and as a biomass source for biogas production."
>
> *Excerpt from concept description on Prototech's homepage*

Fig. 3: Finnish Hycamite TCD Technologies has announced a pilot plant for methane-based production of hydrogen and solid carbon black in Kokkola Industrial Park on the Finnish west coast. The company's patented process can use any source of methane: fossil or biogenic [Source: Hycamite TCD Technologies]

In the patented thermal process using a sustainable catalyst, Hycamite separates the methane into hydrogen and solid carbon black. The process is highly versatile in terms of the carbon produced. Various allotropes of carbon can be extracted, e.g., carbon nanotubes, graphene or active carbon. The Hycamite process can also be used on biogas to produce pure hydrogen along with carbon. The purpose of the pilot plant is to demonstrate commercial viability as well as scalability of the patented process. Pure carbon has many applications in various industries, medicine and in purification of air and water and has a significant commercial potential for Hycamite if the process can make it at a competitive price point.

ICELAND BETS ON HYDROGEN EXPORTS With its 300,000+ inhabitants, Iceland may be a small nation population-wise, but one should not forget the heritage of its people, the Norse Vikings who set out to explore the Atlantic Ocean, came across this beautiful but harsh and cold island and decided to stay and make use of its resources. The Icelanders are known to be tenacious and strong-minded which are both character traits traditionally needed to inhabit and exploit the island's challenging environments on land and at the surrounding ocean.

Today Iceland is still dependent on one of its main natural resources – the rich ocean fisheries. However, cheap and abundant renewable energy from hydro- and geothermal power plays an increasingly important role for the country. Various energy-intensive industries have relocated to Iceland during the years, e.g., aluminum production, yet due to its remote location Iceland has difficulties exploiting the full potential of its renewable energy sources.

Hydrogen may be the big game-changer for Iceland since cheap, clean carbon-neutral hydrogen will be needed and demanded as the globe changes its energy production to renewable sources. Electrification will be big in the transition but, as is already well known, cannot replace all current energy applications whether in industrial processes, off-grid energy needs or in heavy-duty and long-distance transportation.

Landsvirkjun, the national power company of Iceland sees this opportunity for Iceland and has already conducted a pre-feasibility study together with the Port of Rotterdam, the Netherlands, to ascertain the full potential of hydrogen exports from Iceland. According to the study Iceland could by the second half of the century export hydrogen by ship via the Port of Rotterdam that is equivalent to 2-4 TWh annually reducing emissions by up to 1 million tons CO_2. The study indicates that production and export are technically as well as economically viable and mutually beneficial for Iceland and the Port of Rotterdam.

ICELANDERS WANT TO FLY ON HYDROGEN Iceland's national airline Iceland Air has signed a letter of intent with Universal Hydrogen to convert the airline's fleet of DASH-8 airplanes to hydrogen propulsion. The planes are used on domestic flights within Iceland. In a press release of July 15 this year Iceland Air states that "We are committed to reducing our impact on the environment and believe we are in a good position to become one of the world's first airlines to fully decarbonize our domestic network." There is no official timeline for a hydrogen conversion associated with the announcement.

LOTS OF HYDROGEN PROJECTS IN THE NORDICS Obviously, in the above, we have only been able to pick a few of the current and planned hydrogen projects in the Nordics; there are literally hundreds of them commencing or starting soon. Not so many up and running yet but we are still in the initial exploration phase of hydrogen applications in real world scenarios and scales. Many projects have begun and are under construction such as the aforementioned gigawatt electrolyzer project Green Fuels for Denmark which broke ground near Copenhagen earlier in May. There is no reason to doubt that most of the projects that have received public funding and private investments will materialize; it is just a matter of time. And time is crucial in the global turnaround needed in our energy sectors and other sectors emitting greenhouse gases. ||

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National Organisation Hydrogen and Fuel Cell Technology (NOW GmbH), Fasanenstr. 5, 10623 Berlin, Germany, Phone +49-(0)30-3116116-15, Fax -99, *www.now-gmbh.de*

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www.thesmartere.de

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24-h-Conference by Mission Hydrogen
October 8th
www.hydrogen-online-conference.com

Connecting Green Hydrogen APAC
October 11th to 13th, in Melbourne, Australia
www.greenhydrogenevents.com

The Hydrogen Technology Conference & Expo
co-located with Carbon Capture Conference
October 20th to 21st, in Bremen, Germany
www.hydrogen-worldexpo.com

International Conference and Exhibition
Hydrogen Russia & CIS
20th – 21st October 2021, Moscow, Russia
www.hydrogenru.com

HyVolution
Hydrogen event for energy, industry and mobility
October 27th to 28th, in Paris, France
www.hyvolution-event.com

NOVEMBER

Hypothesis XVI
HYdrogen POwer THeoretical & Engineering Solution International Symposium
November 8th to 10th, Muscat, Oman
www.hypothesis.ws

European Zero Emission Bus Conference (ZEB)
Learn what is next in clean transport
November 17th to 18th, Paris, France
www.zeroemissionbusconference.eu

Compressor Day
Integrated Solutions along the H_2 Value Chain
November 25th in Übach-Palenberg, Germany
www.neuman-esser.de

EVENTS 2022

MARCH

Hydrogen & Fuel Cells Energy Summit
March, 2022, in Porto, Portugal
www.wplgroup.com

JUNE

23rd World Hydrogen Energy Conference
WHEC2022
June 26th to 30th, 2022, in Istanbul, Turkey
www.whecistanbul.org

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Cover image: Offshore wind park in the Nord Sea
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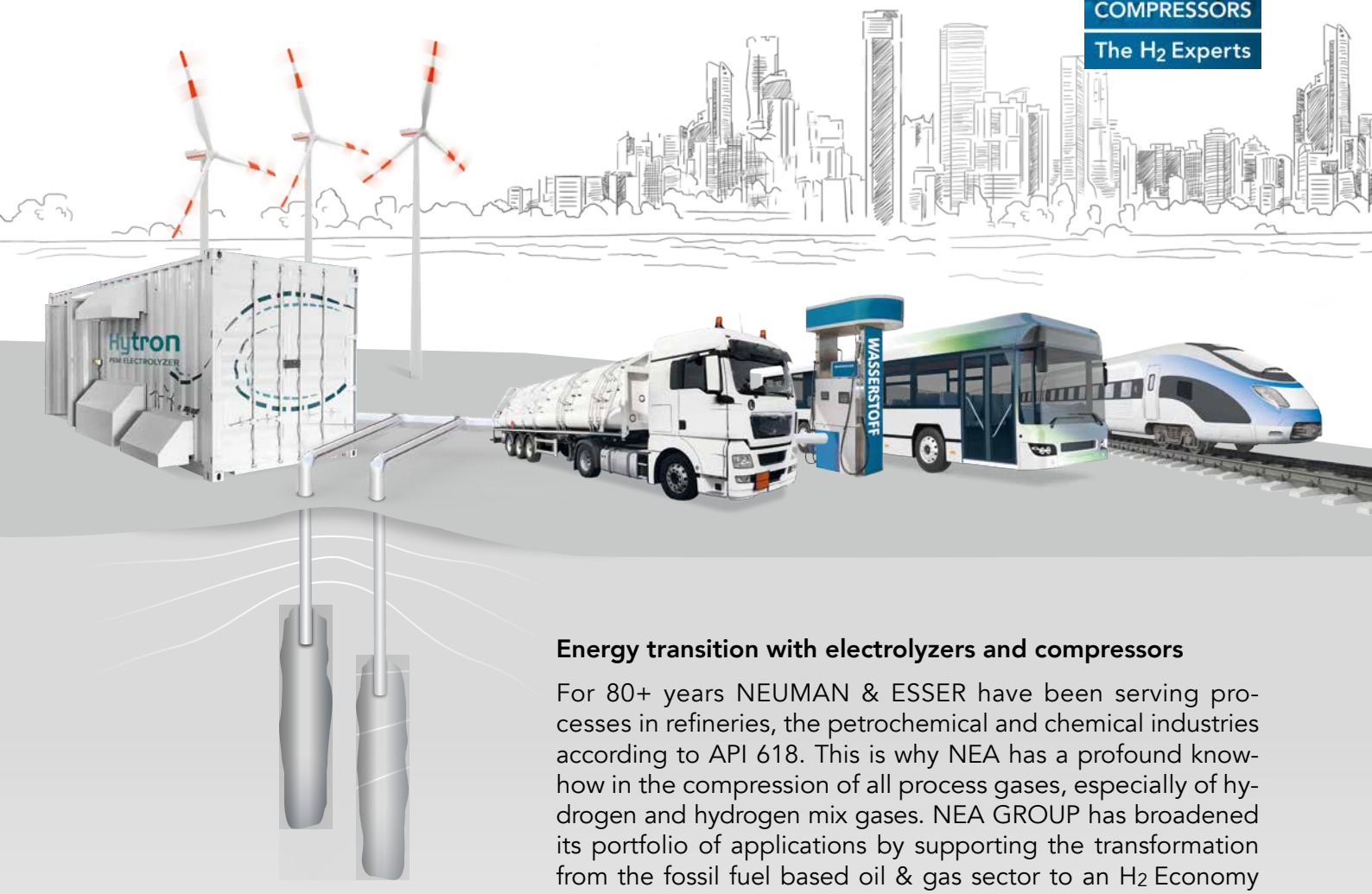

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