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H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

→ LARGE SURVEY AND MARKET OVERVIEW OF ELECTROLYZERS

→ H_2 ENGINES FOR MOBILE AND STATIONARY APPLICATIONS

Hydrogen Regions, Part VII: HyExpert Emscher-Lippe

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SEIZE THE MOMENT

Dear Readers,

The World Climate Summit in Scotland, the coalition negotiations in Germany, a new era in German politics? Where are we starting 2022?

COP26 showed once again that a power struggle is currently taking place. On the one hand, there are the large, powerful energy suppliers, the gas and oil companies that have been determining events in the energy sector for decades but are in danger of losing power. On the other hand, more and more startups, some of them small, and decentralized innovative technology firms are gaining influence.

The players who have grown big on fossil fuels still have well-functioning networks right up to the highest political decision-making levels, as well as powerful interest groups such as BDEW, DVGW, VDA and Zukunft Gas. For some time now, they've been piping the song of change while at the same time suggesting that existing structures, like the gas network, could be used for a decarbonization of the energy sector and are in fact required for it. With this, horror scenarios of what might happen if action is taken, blackouts and economic crises, are being sketched to warn against the alleged risks of an all-electric world or of too rapid a change.

In contrast, the many new and young companies are offering a cleaner, decentralized world. As early as twenty years ago, the renewable energy industry in Germany had been making attempts to break up centralized structures and to place the clean energy transition into the hands of the people. The overwhelming influence of the four large energy companies at that time was dispelled as much as possible. RWE, Vattenfall, E.ON and EnBW are now completely restructured. Nevertheless, the same players are still determining the fate of our energy supply, and they are chanting the mantra that only centralized structures can guarantee a secure energy supply.

It is therefore not surprising that COP26 produced less overall than many environmental associations and climate protection activists had hoped for (see p. 8), although at least a few hard rules have now been set.

The coalition negotiations in establishing the new German government were somewhat more promising, although there are differing opinions on whether the goals of the Ampel Coalition are ambitious enough. At least there is the feeling of a fresh start. Through their calm negotiations, the three parties have managed to give the impression that this is the start of something new. It seems at least possible that with the SPD, the Green Party and the FDP, a new style of politics will take hold that is characterized more by common ground and less by competition. And this could have widespread implications.

The change of mindset regarding renewable energies and their revaluation could open up new possibilities, not only in energy policy, but the energy industry itself. Sector coupling and the capability of storing solar and wind power in the form of hydrogen will make completely new economic structures possible. Decentralization can then follow pretty much automatically, because the multitude of PV and wind power facilities with downstream electrolyzers will make regional or even local energy supply feasible, without losses due to transport over long distances.

This would make many of the centralized structures that we've inherited redundant. PV plants and wind farms are already operated by regional players today. What seemed complicated at first, like H_2 generation by electrolysis, is nowadays very easy thanks to digitalization and the latest technologies. Small, modern electrolyzers only require a water and a power supply and can be put into operation within a few minutes, as well as controlled via app.

Larger electrolyzers are somewhat more complicated, but potential users such as steel companies have sufficient expertise to operate these themselves. The question thus arises, will we still need gas and oil corporations to supply energy in the future?

Up to now, oil companies have had access to gas fields and oil wells, but this will not be the case in the future. Electric companies will no longer own power plants. Gas providers won't control gas networks.

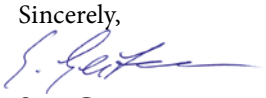
Similarly to the media sector, where the need for the existence of publishing houses is in question as a result of digitalization, the energy sector is facing a complete restructuring. The energy companies seem to have understood this, and it is exactly why they have not grown tired of emphasizing how important their expertise is and how uncertain a future without them would be.

The potential for a decentralization of the energy industry has never been as great as it is today. Of course, central structures remain necessary in some respects to regulate and oversee all the different energy suppliers, but this is much easier to achieve in the digital era than it was twenty years ago.

Decentralized units work efficiently, are flexible and, taken together, can function as safely and reliably as large power plants.

It is now up to the new federal government to establish a sustainable energy supply here in Germany, based on renewable energies and hydrogen, which can then be exported to the world as a precedent. The potential is here, the opportunity is here and the central players have understood that the time for procrastinating and bickering is over. If we take the ruling of the German constitutional court in Karlsruhe that future generations have a right to protection from the consequences of the climate crisis seriously, then we should seize the opportunity to act now, because we will not get another. ||

Sincerely,



Sven Geitmann
H2-international editor

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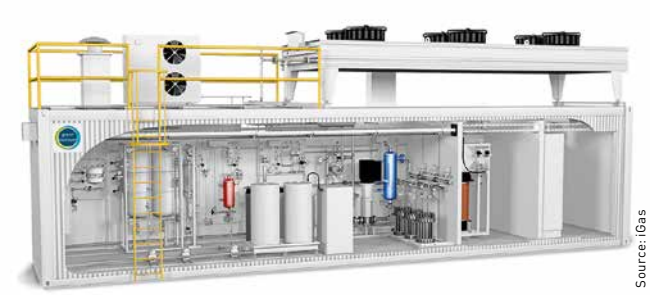

Source: iGas

Source: Wärtsilä

Source: Eric Bakker, Port of Rotterdam

NEW ZBT DIRECTOR

Fig.: Dr. Harry Hoster [Source: JRF]

Since October 1st, 2021, the center for fuel cell technology in Duisburg, Zentrum für BrennstoffzellenTechnik Duisburg (ZBT), has had a new science director. Dr. Harry Hoster also took over as Chair of Energy Technology at Universität Duisburg-Essen, succeeding Dr. Angelika Heinzel, who had retired end of 2020 (see H2-international Jan. 2021).

The expert for fuel cells can refer to extensive experience in this sector as a result of his scientific work in São Paulo and in Singapore as well as at Uni Ulm and TU München. Most recently, he was a professor of physical chemistry and the director of Energy Lancaster, a research center, at Lancaster University. The physicist explained, "The institute has an outstanding reputation in this field and, with its committed scientists, stands for excellent basic and applied research in its core areas of hydrogen, fuel cells and batteries." ||

MINERAL OIL INDUSTRY RESHAPES ITSELF

en2x Wirtschaftsverband Fuels und Energie e.V.

Aware of the changing framework conditions in the energy sector, the hitherto dominant players are attempting to adapt to the new situation. At the beginning of November 2021, the German national mineral oil industry association (Mineralölwirtschaftsverband, MWV) and the national institute for heating and mobility (Institut für Wärme und Mobilität, IWO) announced that they wanted to work together from now on as the association en2x, officially Wirtschaftsverband Fuels und Energie eV, in order to, as they say, "accelerate the clean energy transition." The name en2x derives from energy-to-X, that is, the conversion of a primary energy source into any other energy carrier for application or storage of that energy.

Dr. Fabian Ziegler, Managing Director at Shell Germany, was chosen to be president of the managing board. He explained, "The future of fuels and energy must be greenhouse gas-neutral. In order to achieve this goal, an extensive transformation process is necessary, which we as an association want to help shape... Whether CO_2-neutral hydrogen, alternative fuels, new products for the chemical industry or charging stations with electricity from renewable energies at the gas station, the current mineral oil industry wants to make new offers to its customers and renew the range of services to be sustainable."

The vice president of en2x is Wolfgang Langhoff, Chief Executive Officer of BP Europa. The two chief executives are former MWV manager Dr. Christian Küchen and former IWO manager Adrian Willig. ||

WYSTRACH BECOMES NORWEGIAN

Fig.: Jochen Wystrach [Source: Hexagon Purus]

The wave of mergers and acquisitions has continued all the way to Wystrach GmbH. The Weeze-based family-run supplier of hydrogen storage systems is joining forces with Hexagon Purus. As Wystrach informed at the end of September 2021, the Norwegian company is taking over the business founded in 1987 in Nordrhein-Westfalen, along with its around 200 employees.

Hexagon Purus SA, with its more than 180 employees worldwide, offers emissions-free mobility solutions, from type 4 pressure vessels to fuel storage and distribution systems, battery sets and electric powertrain solutions for commercial vehicles. The production of fiber-reinforced components will continue to happen at Hexagon Purus GmbH, formerly Hexagon xperion, in the largest Hexagon Purus location, Kassel, while Wystrach will be the main site for the assembly of hydrogen systems.

Jochen Wystrach, co-managing director at Wystrach and son of the founder, reported, "We actively went on the search and found in Hexagon Purus a strong, industrially oriented parent company." His partner in management, Wolfgang Wolter, added, "The entire market is forming and we want to continue to play a central role in the development and preparation of hydrogen systems." Hexagon Purus SA is part of Hexagon Composites ASA, a Norwegian publicly listed company with over 1,000 employees at 23 locations. ||

HYDROGEN MANIFESTO SIGNED

On October 6th, 2021, during the Green Hydrogen Forum at The smarter E Europe Restart 2021, the German hydrogen and fuel cell association DWV (Deutscher Wasserstoff- und Brennstoffzellen-Verband) as well as Hydrogen Europe together with the European Fuel Cell Forum published "The Green Hydrogen Manifesto." It contains twelve demands addressed to policy-makers and governments at the EU, national and regional level. The authors' aim is to promote the role of hydrogen as the means to a circular economy and full decarbonization and to create a sustainable hydrogen and energy economy.

For example, there are calls for the CO_2 emission potential of energy carriers to become the new currency for energy systems. Furthermore, the signers demand credible and glob-

ally recognized certification of hydrogen, as a global commodity, as well as the creation of an "EU Hydrogen Special Envoy," as a special office of the EU that would promote hydrogen strategies and partnerships with non-EU third-party nations. Furthermore, a solid EU legal framework for the regulation of hydrogen networks shall be introduced.

At first, around 100 institutions signed the document. Directly after the presentation, 100 more signatures were added, among them companies such as Bosch, GE, Viessmann, Nel, ITM Power, John Cockerill, Terega and Haldor Topsøe. ||

→ www.thesmartere.de/green-hydrogen-manifest

FCH JU BECOMES CLEAN HYDROGEN PARTNERSHIP

During European Hydrogen Week, beginning of December 2021 in Brussels, the president of the European Commission, Ursula von der Leyen, reaffirmed the role of Europe as leading in the expansion towards greater production of clean hydrogen. She explained to the nearly 2,000 registered participants, "This is without doubt a global undertaking, but I want Europe to lead the race."

In addition to numerous lectures and discussions by high-ranking speakers, several EU Commissioners and numerous company heads, the establishment of the Clean Hydrogen Partnership was center stage. The Partnership will be assuming all the activities of the FCH JU, the Fuel Cells and Hydrogen Joint Undertaking. The European Council adopted the Regulation for its establishment on November 19th, 2021. The aim is to accelerate the development and introduction of a European value chain for clean H_2 technologies. For this purpose, the EU is making 1 billion euros available for the period 2021 to 2027, which is to be augmented by private investments of at least the same amount. Together with the Hydrogen Alliance, the goals of the EU hydrogen strategy for a climate-neutral Europe are to be implemented in this way. The focus is on the production, distribution and storage of clean hydrogen, especially in those sectors that are otherwise difficult to decarbonize, for example heavy industry and heavy transport. ||

Source: European Union

"We have to scale up clean hydrogen production, expand its applications, and create a virtuous circle where demand and supply feed each other and bring the prices down... Clean hydrogen is the energy of the next generation."

Ursula von der Leyen, President of the European Commission

Category: News | **Author:** Sven Geitmann

A FEELING OF OPTIMISM AFTER 25 YEARS

DWV demands concrete roadmap for economic miracle

Fig.: Host Olaf Lies, environmental minister of Niedersachsen

On October 26th, 2021, the German national association for hydrogen and fuel cells (Deutsche Wasserstoff- und Brennstoffzellenverband, DWV) celebrated its 25-year anniversary at the Vertretung Niedersachsen in Berlin and appropriately held a parliamentary evening with numerous prominent participants. A central theme was that DWV has been advocating for a sustainable hydrogen and fuel cell industry since 1996 and now also expects agreement from the new federal government on a detailed, concrete roadmap for the ramp-up of an H_2 economy.

Aware of the coalition negotiations taking place in Berlin at the same time, the association called for "rapid action" and agreement on "concrete measures for a rapid market ramp-up." The representatives of the H_2 industry present agreed that "only with the combination of renewable energies and hydrogen can an investment-secure and economically successful rebuilding of the German as well as European energy industry occur" and called on the new federal government to set the necessary regulatory framework for more planning security now.

> "It's in the hands of the new federal government to swiftly transform the Germany economy for the benefit of its citizens."
>
> *Werner Diwald, president of DWV*
>
> "The Ampel (traffic light) coalition could literally light up hydrogen."
>
> *Jorgo Chatzimarkakis, CEO of Hydrogen Europe*

Notable about this evening was the repeated statement by various representatives that sufficient capital is available and that money is really not the problem. However, in order for these financial resources to be invested, the companies would need confidence and thus planning security. Then, the unanimous opinion is, there will be no lack of money.

DWV is committed to the development of a green hydrogen economy as a component of a sustainable energy supply. Other types will always also be in play in the hydrogen industry, even if people say that they don't want to play color games. ||

TRADE FAIR WITH H_2 FOCUS

Fig.: Basilios Triantafillos, Global Director for Hannover Messe

The trade fair company Deutsche Messe AG appears confident that in 2022 it will be holding an in-person Hannover Messe once again. The organization made clear already in fall 2021 that hydrogen will play a central role in the industrial trade show of 2022, taking place May 30th to June 2nd. Deutsche Messe together with Hydrogen + Fuel Cells Europe is holding a networking event centered around hydrogen (see photo) in November at the Landesvertretung Niedersachsen in Berlin. It will be followed soon after by the traditional press conference, this time with Ove Petersen, CEO of GP Joule, which explicitly indicates the future importance of hydrogen.

In addition, Portugal, an extremely interesting partner country for the hydrogen sector, is also taking part this time. On the Iberian Peninsula, for example, Port of Sines, with an expected electrolysis capacity of 265 MW in 2025 and 2.5 GW by 2030, will become the key hub for green hydrogen in the country. ||

→ www.h2fc-fair.com

HYDROGEN SUMMIT IN GLASGOW

Parallel to COP26, on November 11th, 2021 the Hydrogen Transition Summit took place in Glasgow. There, Seifi Ghasemi, president and CEO of Air Products, the main sponsor of this conference, explained, "Climate change is real. We need to switch the energy supply to renewables." Ivo Bols, president of the Europe and Africa branch of Air Products, said that his company will play an "important role in the H_2 community." Jean-Pierre Brisson, attorney and partner at the law office Latham & Watkins, which has advised in particular US fossil fuel companies on CCS issues, advocated pro blue hydrogen.

To which Chris Goodall, an independent commentator on new technologies, countered that the blue hydrogen route is primarily a way for conventional energy suppliers to retain power. He therefore clearly voted for the direct implementation of a green H_2 economy. ||

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

TRADE FAIR INDUSTRY REORGANIZES

New dates for energy storage and H_2 events

Not least because of the pandemic, there will be a few changes in the trade fair organizing domain. Energy Storage Europe (ESE) in Düsseldorf will not take place in the spring as usual, but from September 20th to 22th, and under a new name, Expo for Decarbonised Industries. Another difference is that the energy storage fair will be prevented from coinciding with the world-leading glass production fair Glasstec. According to Messe Düsseldorf, it shall create a "suitable platform for decarbonization of industries and businesses in Germany."

EXPO FOR DECARBONISED INDUSTRIES
20 - 22 SEPT 2022
DÜSSELDORF
ENERGY STORAGE

Project director Gerrit Nawracala hopes that it will "provide targeted answers to the challenges and questions that arise in connection with climate protection, energy costs and security of supply for our customers." As before, the new concept will be backed by the national association for energy storage systems BVES and likewise by the German association for machine and plant engineering VDMA. The organizers of Expo for Decarbonised Industries explained to H2-international that the event has been pushed back to the fall because of the extra preparation needed to further develop and plan the new fair. This additionally would avoid a "scheduling collision with ISH," Messe Frankfurt's HVAC and water systems fair.

The spring, however, will not be devoid of an energy storage fair, as ees Europe is scheduled as usual. With the motto "Innovating Energy Storage," Messe München is inviting manufacturers, project developers, system integrators, users and suppliers from the battery and renewable energy branch to the event on May 11th to 13th, 2022. Under the umbrella of The smarter E Europe, the events ees, Intersolar, Power2Drive and EM-Power had just recently, in October 2021, attracted around 26,000 visitors to the exhibition grounds of the Bavarian capital. The two organizers, Solar Promotion and Freiburg Wirtschaft Touristik und Messe (FWTM), expect the number of exhibitors to grow from 450 to 480 in 2022. Storage systems and green hydrogen in particular will again be presented as the core of the clean energy transition.

H_2 EXPO & CONFERENCE

COMEBACK OF H_2EXPO Northern Germany continues to gear up for the emerging global hydrogen economy and is reactivating an old brand: H_2Expo is coming back. Hamburg Messe had tried in 2020, with an H2Insights venue, to organize hydrogen companies for a WindEnergy event, which did not really work out. Apparently, after their own opinion barometer registered that "overall over 55 percent estimate a high to very high probability that the production of green hydrogen will play a significant role for wind energy in the next three years," Hamburg is getting a hydrogen fair again.

H_2Expo had already been held in the Hanseatic city for several years in a row by the turn of the millennium. Now, it's coming back in 2022 as "H_2 Expo and Conference" and, what's more, accompanied by WindEnergy Hamburg. Taking place September 27th to 30th, it will be only three weeks before Hydrogen Technology Expo Europe in Bremen. Project manager Anja Holinsky, who had already led H_2Expo for ten years, will get support from, among others, the renewable energy research cluster Cluster Erneuerbare Energien Hamburg, where since the turn of the year, Katja Löwe, project leader of the real-world hydrogen research lab Wasserstoffwirtschaft Norddeutsches Reallabor, has been active. ||

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

MESSE STUTTGART TAKES OVER F-CELL

Peter Sauber says farewell after over 20 years

Peter Sauber filled the fairgrounds of the Haus der Wirtschaft in Stuttgart with exhibitors one last time. To conclude his long career, the fuel cell pioneer presented, with the customary professionalism, an f-cell as eventful as in the best days, despite pandemic conditions. All of the available exhibition spaces were booked and it would have been even grander if the area were larger, remarked Sauber, showing H2-international the waiting list as proof.

On September 14th and 15th, 60 exhibitors and more than 1,000 motivated visitors once again bustled about at the f-cell symposium, the last one to be organized by Peter Sauber Messen und Kongresse. Also on site were representatives of Landesmesse Stuttgart, the trade fair company that assumed both the event concept and the employees from the Peter Sauber agency in October 2021 (see H2-international Oct. 2021) and was already diligently working on preparation of the events planned for 2022. Roland Bleinroth, the managing director of Messe Stuttgart, explained, "F-cell is, for all who have a secure energy supply, industrial applications in production processes and clean mobility in focus, an indispensable meeting point from which impulses to the entire world propagate."

This behind-the-scenes change of organizer did not dampen the interest at f-cell in any way. Rather, the industry representatives were glad at the opportunity for live networking and listened with interest to the speakers. For example, they listened to Kurt-Christoph von Knobelsdorff, managing director of the national hydrogen and fuel cell organization NOW, state that CO_2 emissions in the transport sector need to be halved by 2030 and that energy storage, especially that for nonimmediate use, must take on greater importance. And participants heard Patrick Schmidt from the energy consultant group Ludwig-Bölkow-Systemtechnik shout, "Get the stuff out to generate more acceptance (of the technologies)."

The 21st "f-cell awards" went to Univerzita Karlova Mathematics and Physics Department in Prague and to Faun Umwelttechnik, a garbage collection and street cleaning vehicle manufacturer from Osterholz-Scharmbeck, Germany. The next f-cell will take place under the designation Hydrogen & Fuel Cell Conference and Trade Fair on October 4th and 5th, 2022, at the Stuttgart fairgrounds. ||

THE 3RD 24H2CHALLENGE

This time, 18 hydrogen-powered cars participated in the competition 24-Stunden-Wasserstoff-Challenge ("24-hr hydrogen challenge"). Weiter mit Wasserstoff ("further with hydrogen") from Hessen won. The winners benefitted from, among other things, the fact that one team forgot all of their fuel cards at a stop and had to turn around just before reaching the next station. Another team drove an extra 270 km to get to a hydrogen fueling station, but after several attempts to fill up, could only get 100 grams of H_2.

NEW BREMEN-BASED H_2 TRADE FAIR APPEALING

With the Hydrogen Technology Conference & Expo, a hydrogen and fuel cell fair has taken place in the city of Bremen for the first time. On October 20th and 21st, around 130 exhibitors seized the opportunity to finally be in the presence of customers and business associates after the long break on account of COVID. The number of participating institutions, however, were not enough to fill the exhibition hall. As a result, the fair gave the appearance of being rather improvised. Stand numbers were missing, a map of the hall was only to be found on the app, and the stands were for the most part small and sparse in terms of presentation material. When asked, the exhibitors said that they were just getting a feel for what the new trade fair could bring.

Participation in the event was quite extensive, especially considering the competing events in fall 2021. The World Hydrogen Congress in Rotterdam and Intersolar alongside the energy storage fair ees Europe in Munich had just taken place at the beginning of October. And the month before, Automechnika in Frankfurt am Main and f-cell in Stuttgart had as well.

The idea of a trade fair dedicated to hydrogen attracted not only more than 100 exhibitors from various countries, but also, according to the organizers, around 2,500 visitors. Despite admission being free, the audience was mainly composed of industry professionals, especially participants in the Hydrogen Technology Conference running in parallel. With the sparse signage posted around the exhibition grounds, there were hardly any visits from people who by chance were in the area of the hall. Nevertheless, there was such lively exchange at the stands that the presenters praised the high quality of the discussions. Irrespective of the current boom in this industry, the basic idea of giving the little hydrogen branch its own trade fair seems to be a promising one. It'll be interesting to see how the Hydrogen Technology Expo in 2022 turns out, since the planning time is relatively short. At least it will not overlap, on October 19th and 20th, with f-cell, which is scheduled for October 4th and 5th. ||

Category: Policy | **Author:** Matthias Deutsch

TARGETED HYDROGEN SUPPORT

Policy instruments for market introduction

The think tank Agora Energiewende in a joint study with the consulting firm Guidehouse analyzed the most important policy instruments for introduction of green hydrogen to the market. Along the route to climate neutrality in 2045, Germany needs 60 terawatt-hours of CO_2-free hydrogen already by 2030, mainly for the development of a climate-neutral industry and security of electrical supply (Prognos et al. 2021). To promote the expansion of hydrogen production through renewables in an economically prudent way, financial resources should flow primarily to areas where future markets for green hydrogen are indisputably being created. So far, renewable green hydrogen is not yet competitive with hydrogen generated from fossil fuels, which is mostly produced by steam reforming of natural gas.

It is often stated that on the demand side, the use of hydrogen is particularly important for those sectors of the economy that are difficult to decarbonize or defossilize. However, a closer look shows that this is less about the respective sectors, but rather about specific applications within all sectors. For easy orientation, a subdivision into (1) consensus applications, (2) controversial applications and (3) non-recommendable hydrogen applications is useful (see Fig. 1). This subdivision is based on an evaluation of international energy scenarios (Agora Energiewende 2021).

Green molecules needed?	Industry	Transport	Power sector	Buildings
No-regret	· Reaction agents (DRI steel) · Feedstock (ammonia, chemicals)	· Long-haul aviation · Maritime shipping	· Renewable energy back-up depending on wind and solar share and seasonal demand structure	· Heating grids (residual heat load *)
Controversial	· High-temperature heat	· Trucks and buses ** · Short-haul aviation and shipping · Trains ***	· Absolute size of need given other flexibility and storage options	
Bad idea	· Low-temperature heat	· Cars · Light-duty vehicles		· Building-level heating

* After using renewable energy, ambient and waste heat as much as possible. Especially relevant for large existing district heating systems with high flow temperatures. Note that according to the UNFCCC Common Reporting Format, district heating is classified as being part of the power sector.

** Series production currently more advanced on electric than on hydrogen for heavy duty vehicles and buses. Hydrogen heavy duty to be deployed at this point in time only in locations with synergies (ports, industry clusters).

*** Depending on distance, frequency and energy supply options

Agora Energiewende (2021)

Fig. 1: Need for molecules in addition to green electrons

Based on Guidehouse (2021).

The figures assume a natural gas price of €20/MWh and a CO_2 capture rate of around 75%. All figures are in 2019 euros.

Fig. 2: Renewable hydrogen cost gap

H_2 CONSENSUS APPLICATIONS IN EVERY SECTOR There is a broad consensus on the necessity of hydrogen for applications where certain chemical properties, the high energy density or the storability of hydrogen are indispensable. These are steel and ammonia production by direct reduction, long-distance air and sea transport, and stored as a long-term backup for renewable-sourced electrical systems. Another application is to satisfy the "residual heat demand" (residuale Wärmelast) in heating networks. That is, the amount of energy still required for heating after renewables, ambient heat and waste heat have been considered as far as possible.

Controversial hydrogen applications include those where, in technological competition with direct electric applications, hydrogen still needs to assert itself, for example high-temperature heating. A non-recommended hydrogen application is that of low-temperature heating in industry and buildings as well as for passenger cars and small commercial vehicles. The reason is that direct electric solutions, such as heat pumps or battery electric vehicles, have considerably lower conversion losses and therefore use renewable electricity much more efficiently. To keep the costs for the H_2 market ramp-up as low as possible, public funding should therefore prioritize consensus applications.

THE COST GAP ABOUT THREE EUROS PER KILOGRAM OF H_2 The fossil fuel-sourced hydrogen used today costs about 1.4 euros per kilogram to produce (see Fig. 2). Adding to that the CO_2 emissions price of about 50 euros per tonne, this hydrogen, without or with carbon capture, costs roughly 2 EUR/kg. Green hydrogen, in contrast, costs between 3.4 and 6.6 EUR/kg. Thus there is an average cost difference of around 3 EUR/kg. This calculation was

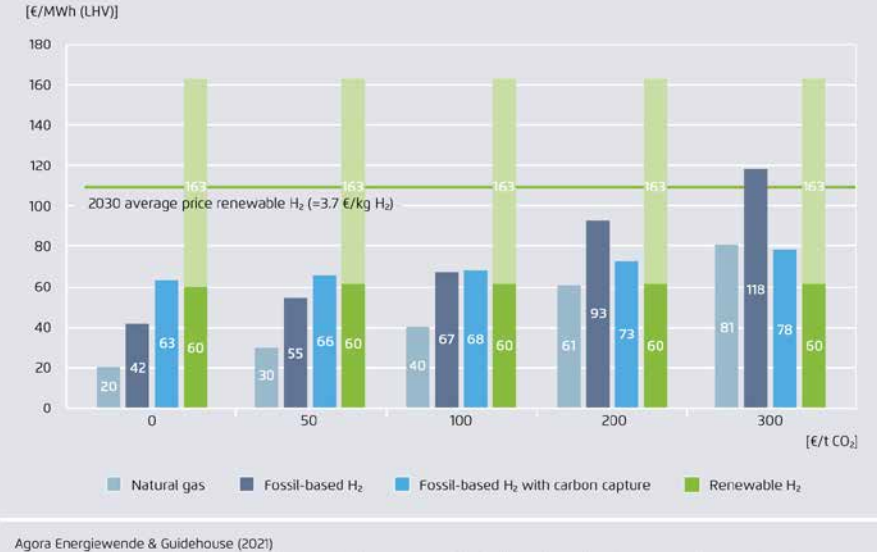

Fig. 3: Impact of carbon pricing on the economics of hydrogen production pathways, 2030

Policy support instrument for renewable hydrogen	Billion € p.a.	
	Min.	Max.
CCfD for DRI steel (scenario 1): with current free allocation regime (2022-2035/2040)	1.1	2.7
CCfD for DRI steel (scenario 2): with effective CO_2 price gradually increasing from 50€/t (2021) to 90€/t (2040)	0	1.6
PtL quota for aviation (2025-2030: 10% und 2030-2050 increase to 100%).	1.4	1.9
Support for H_2-fuelled combined heat and power plants (2025-2035)	0.3	1.1
H_2 supply contracts (2022–2030 (phase 1) & 2030–2040 (phase 2))	0.8	5.3
Total	**2.5**	**11.0**

The cost projection for the CCfD instrument in lines 1 and 2 represent alternative and mutually exclusive scenarios with regards to the evolution of Europe's carbon leakage policy. Note that Guidehouse assumes an aviation quota of only 5%. A comprehensive overview of policy support instruments can be found in the report.

Fig. 4: Financing needs for renewable H_2 in Germany

based on natural gas prices of 20 euros per megawatt-hour. Even though natural gas currently costs considerably more, futures contracts on the market indicate a price expectation of around 25 to 35 EUR/MWh for the year 2023/24.

Although green hydrogen is not yet competitive, globally there are already a number of electrolysis projects in the pipeline, and they add up to about 30 to 90 gigawatts of power. This raises the question of how to close the gaping cost gap. Are project developers hoping that customers will be more willing to pay for green hydrogen or are they speculating and waiting for politicians to introduce additional subsidy instruments? There is much to suggest the latter.

COST REDUCTION THROUGH SCALING AND LEARNING EFFECTS The price of green hydrogen will mainly be influenced by (1) the cost of electricity and so the cost of renewable energies, (2) the annual operating hours of the electrolyzer and (3) the system costs for electrolysis. While the generation costs of wind power and photovoltaics will incidentally continue to fall, electrolysis system costs, so the costs per kilowatt for the installed electrolysis capacity, ought to be reduced in a targeted manner. This will not happen automatically, but requires someone to install electrolyzers and pay for the learning curve. In order to pave this learning path, electrolyzer manufacturers need stable hydrogen demand and predictable project pipelines so that they can invest in giga(watt)-factories.

To establish this predictability, support instruments are needed, as green hydrogen has not been competitive so far. Application of tax money to promote this production pathway simultaneously requires its responsible investment, which is why green hydrogen should be channeled into consensus applications. Conversely, a lack of agreement on applications could unnecessarily delay the market ramp-up of green hydrogen.

THE ROLE OF THE CO_2 PRICE The CO_2 price tacked onto emissions will be an important support post that makes hydrogen economically viable in the long term. In the short to medium term, however, it has only a limited effect, because even CO_2 prices of 100 to 200 EUR/tonne in the EU Emissions Trading System do not yet provide sufficient incentives for production of green hydrogen. Even with high CO_2 prices, the expected average price of green hydrogen, at 3.7 EUR/kg, is many times higher than that of fossil fuel-sourced hydrogen, as Figure 3 shows.

With CO_2 prices expected to remain low, additional support instruments will thus be needed for some time to come. In light of this, some stakeholders are calling for a hydrogen quota. However, a general quota for green hydrogen is not targeted enough to introduce these in the main required applications and poses further problems in terms of technological feasibility, distribution and efficiency. Thus other policy instruments are required.

SUSTAINABILITY AND SYSTEM INTEGRATION These support instruments need to be complemented by rules regarding sustainability and system integration so that hydrogen from electrolysis does not cause an increase in CO_2 emissions. This will require clear criteria for climate neutrality, a strategic roadmap for hydrogen application and suitable locations for hydrogen production in the energy system, taking into account the grid bottlenecks that already exist today.

Green hydrogen is definitely urgently needed for certain applications in all sectors in order to achieve the target of climate neutrality. The new German government will have the task of advancing the development of green hydrogen through a strategic approach that has rapid reduction of costs as a goal. The CO_2 price of the 2020's will not create a stable demand for green hydrogen, underscoring the need for a hydrogen policy framework.

Such a framework should initially target consensus applications where hydrogen is clearly needed. Furthermore, the question arises as to how development of the necessary H_2 infrastructure could be driven forward against the backdrop of financial risks and regulatory provisions. For this, the establishment of a national organization for hydrogen infrastructure should be considered (Agora Energiewende und Forum New Economy 2021) ||

HYDROGEN SUPPORT INSTRUMENTS

Suitable instruments and framework conditions to specifically promote the use of green hydrogen in consensus applications are:

- climate protection contracts, so-called Carbon Contracts for Difference (CCfD), which enable the transformation to a climate-neutral industry (Agora Energiewende, FutureCamp et al. 2021)
- a power-to-liquid quota of ten percent in air transport by 2030, signaling that Europe intends to import significant quantities of PtL fuels
- fully hydrogen-capable gas-fired power plants as a backup to electricity generation from renewables and to cover the residual heat demand of district heating
- scalable green lead markets that will help develop a business case for green hydrogen
- hydrogen supply contracts that promote competition between H_2 producers in the EU and abroad

In order to create the necessary framework for the market ramp-up of hydrogen with these funding instruments, between 2.5 and 11 billion euros per year are expected to be needed in Germany for H_2 consensus applications (see Fig. 4).

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FOUR WINNERS AND TWO LOSERS

Scheuer earns harsh criticism for behavior regarding DZM and ITZ

Instead of only one center for hydrogen, there will be four Innovations- und Technologiezentrum Wasserstofftechnologie (ITZ) centers in the future, as the German ministry of transport and digital infrastructure (BMVI) informed the public at the end of September 2021. At first, in April 2021, three finalists had been selected from the 15 applicants (see H2-international Apr. 2021): Chemnitz, Duisburg and Pfeffenhausen. Then, a special rule was conceived for the region Bremen-Bremerhaven-Stade-Hamburg in order to be able to support their promising approach as well. The respective potentials were then estimated on the basis of feasibility studies specifically made for this, and based on them, the jurors decided in favor of a 3+1 strategy. The total of four locations will be operated under the umbrella of the German center for future mobility (DZM).

Fig: Andreas Scheuer, at the end of his term, again under scrutiny

In August 2021, the German minister of transport at the time, Andreas Scheuer, gave the starting signal for work on the new national center for future mobility, Deutsches Zentrum Mobilität der Zukunft (see H2-international Oct. 2021). This national contact point for automotive H_2 applications is currently being set up in Munich. There's talk of 400 million euros and about 200 work positions for the DZM. With regard to its settlement in the capital of the state of Bayern, however, there had been reservations, because no call for tenders had been made. Rather, the CSU-party federal minister had just considered his own state. On the side of the federal government at that time, it had only been said that this was "not a process relevant to public procurement law" and "an obligation to carry out a competitive procedure" was not present.

It was similar with the ITZ competition. In the beginning, there was only slight irritation at the appearance of the Bavarian representatives during the application process, who seemed all too confident of victory. And at the press conference announcing the three finalists, the words of Andreas Scheuer, incumbent federal minister of transport, CSU politician and member of the Bavarian Landestag for the district of Passau, gave the impression that Pfeffenhausen had already been determined the winner. In addition, the answer to the H2-international team's question of how conflicts of interest should be avoided in the procurement process was curt and lacked any real substance.

CHEMNITZ, DUISBURG, PFEFFENHAUSEN & HAMBURG In the end, it was decided that the ITZ competition in addition to the Hydrogen and Mobility Innovation Centers (HIC) in Chemnitz, Sachsen, as well as the Technologie- und Innovationszentrums Wasserstofftechnologien (TIW) in Duisburg, Nordrhein-Westfalen, as well as the Technologie-Anwenderzentrum Wasserstoff (WTAZ) in Pfeffenhausen, Bayern, should also benefit Northern Germany, where a technology cluster for air and water transport are to be established in the locations Stade, Bremen/Bremerhaven and Hamburg. The jurors thus decided on a multi-track procedure, which had also been proposed in the July 2021 edition of H2-international.

Furthermore, Minister Scheuer said, "We have thought about how we can further strengthen the strengths of the North... We have tried not to lose anyone by the wayside who has already gotten quite far." When asked, he reassured that each of the non-winning applicants would also receive support through two other pots and would therefore not be left empty-handed. The whole project of setting up the ITZ centers is to be implemented by 2025.

A total of 290 million euros from the federal H_2 pot has been allocated for the ITZ program. The bitter part of the competition results is that the four sites will have to share the money originally intended for one winner, and at that, not equally. Duisburg has been allocated 100 million euros in total, but two-thirds of this is coming from the state of Nordrhein-Westfalen.

The holdback for Chemnitz was even more drastic. Although they were considered a promising candidate for weeks, the team of Prof. Thomas von Unwerth still only got 60 million euros. Over a third of the money was poured into Pfeffenhausen, in Niederbayern (Lower Bavaria). The BMVI is making "up to 290 million euros available by the end of 2024, of which up to 100 million euros will go to Niederbayern," said the press release about the decision.

> "I'm truly shocked by the audacity of Scheuer and Söder... After a months-long feasibility study, the sites were going to be announced Thursday last week. However, to everyone's surprise, the press conference was postponed at short notice because of new talks between the minister-president of Bayern (Markus Söder) and Minister Scheuer... One week later and the results of the feasibility study are now no longer valid, as Scheuer had shifted the funding distribution among the three locations and the research focuses to favor the Bavarian competitor. Last week, Sachsen and Chemnitz should have gotten 90 million euros for the national hydrogen center to be established there. Now, it's been cut by a third, in order to serve the political interests of the CSU... The Free State of Bayern is benefitting disproportionately like no other state from the allocation of funds by the federal ministry of transport. The following can be named as examples: the decision for the DZM to be located in Munich, the recent special program to renovate road bridges throughout the country, the federal program to expand broadband, the allocation of road construction funds, the federal program to beautify train stations, etc."
>
> *Detlef Müller, Bundestag representative for Chemnitz, to regional newspaper Leipziger Zeitung*

WIDE INFLUENCE OF ANDREAS SCHEUER Mid-November 2021, the newspaper WELT had also published an article under the title "Wie Minister Scheuer einem bayerischen Dorf eine lukrative Ansiedlung besorgte" (How Minister Scheuer got a Bavarian village a lucrative establishment). It said that research had shown that "in two evaluation rounds since the beginning of the year, the winner was not the 5,000-inhabitant nest of Pfeffenhausen, but the application from Chemnitz in Sachsen." The newspaper refers to internal documents that the ministry of transport had to publish in accordance with the German freedom of information act, the Informationsfreiheitsgesetz (IFG).

As H2-international previously reported, NOW and Projektträger Jülich (PtJ) were responsible for the first stage of the selection procedure in the competition. So it is interesting that Dr. Julia Reuss, the then partner and since August 2021 wife of Andreas Scheuer, was until the end of June 2021, so in the early days of this procedure, head of the supervisory board of NOW. A BMVI spokesman explained to broadcasting network Bayerischer Rundfunk (BR), however, that the supervisory board is, according to the bylaws and articles of association, not involved in the operational proceedings of NOW GmbH, and that this "also goes for the competition regarding the location for the Innovations- und Technologiezentrum Wasserstoff."

According to research by WELT, Chemnitz was already ahead in the preliminary decision with 3.55 out of 4.00 points. Ahead of Duisburg and Pfeffenhausen, each with 3.45 points. And while the locations in Sachsen and Nordrhein-Westfalen showed important strengths, the evaluators acknowledged weaknesses of the location in Bayern, such as "barely any local hydrogen projects thus far."

In the final decision, which was made by the consulting firm Prognos, the outcome was again Chemnitz in first, with 40.9 out of 50 possible points, followed by Pfeffenhausen (36.6), Duisburg (36.4) and the Northern German cluster. The assessors from Prognos also criticized that for the Southern German candidates with "comparatively isolated position," a "regional integration of existing activities in the area of new business promotion... would unfortunately be made more difficult." In addition, the start of operations in Pfeffenhausen is not planned until 2025, unlike in Chemnitz and Duisburg, which are at the beginning of 2024. After the criticism from WELT, however, the project coordinator for Bayern, Tobias Brunner, explained to BR, "We want to put the first facilities into operation in 2023 and then be in full operation by 2025, so we are very well keeping pace. I wouldn't know right now which location is moving faster."

In mid-August, the assessors from Prognos recommended in the draft of an interim report that the money be broadly distributed over the country. A concept with several locations would be "clearly superior to a concept with only one location," they wrote, and advised to include all four sites. Which is also what ended up happening.

Concerning the amount of the final subsidies, the federal ministry of transport explained, according to WELT, that each of the three sites had been awarded up to 60 percent of their stated "need" and that Pfeffenhausen had declared the most with 170 million euros. However, it can be read from the documents that Duisburg, at the time of April 2021, had given an estimate of 250 million euros.

Why in the end most of the money went to Bayern remains a question. There might also be something in the fact that besides Minister-President Söder and Federal Minister Scheuer, someone else was visibly pleased with the results. Manfred Weber, group leader of the Christian-democratic European People's Party in the EU Parliament, lives only ten kilometers (six miles) by car from the new ITZ location.

BR IN THE ROLE OF A "PRESS-SPOKESMAN" The commentary of Bayerischer Rundfunk that appeared only one day after the WELT article made it clear that this is indeed a difficult subject to handle. It is being said at BR that those in Bayern are now looking even more anxiously at Berlin, because "how much money will actually flow in the end depends on the new Ampel (red-yellow-green) coalition anyway" and that "all are hoping that the new government will support the national center." This is to be understood as an "appeal, not only in the interest of the Bavarians."

From the view of Berlin, the current uproar is not entirely unjustified. Why else would there be a deliberate attempt to act "in a de-escalating manner" from the federal and Southern German side at the moment? If everything were clean, they would be able to just act informative. Instead, however, a deliberately de-escalating commentary appears at the broadcasting station of the very state that is under criticism. And it's easy to imagine that the people with contacts spanning as far as Asia would also have sway over those media outlets.

It should be noted that there has hardly been any public criticism of these events from the applicants in Sachsen and Duisburg themselves. Overall, they seem to be more pleased that they all have been considered and that a widespread, nationwide H_2 network can be developed through these centers, with each location having its own thematic focus.

DZM IS TO BE "PROTECTED" FROM SUCCESSORS Last but not least, on November 17th, however, the newspaper Handelsblatt reported that Andreas Scheuer wants to "protect the national center for future mobility, DZM, from its successors." According to the report, the outgoing minister of transport wants to make the DZM in Munich "into his foundation."

As the newspaper reported, a spokesman for the ministry basically confirmed such foundation plans, saying that "as things stand," a "Stiftung bürgerlichen Rechts" (foundation under civil law) is planned. It was said, "This legal form is best suited to fulfil the objectives pursued with the establishment of the DZM. Further details are currently being worked out and agreed on." DZM business manager Julia Schmid explained to Handelsblatt that the center should be detached from day-to-day political business and be an "opinion sculptor" itself on why "new ways should be proposed and taken." She further clarified, "We are not an agent of the BMVI."

What is certain, according to Handelsblatt, is that so far 322.5 million euros of the federal budget is reserved until 2024, on top of the 6 million euros that were made available so far for the launch of the operations. In addition, there has already been mention during the coalition talks that the DZM would be "reorganized." ||

H2-INTERNATIONAL SERIES

This magazine for hydrogen and fuel cells is currently presenting the various regions in which hydrogen clusters are forming, one after the other, as a special series. This includes the HyLands regions (HyStarter, HyExperts, HyPerformer, see p. 42) as well as the regional laboratories dealing with H_2 topics. The series will be expanded in subsequent issues of H2-international to encompass the four ITZ locations, as soon as concrete concepts are available.

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

HYDROGEN – THE ECONOMIC MIRACLE

Sustainable growth in the electrolyzer sector

The production of hydrogen is now recognized as an emerging market right around the globe. Many diverse electrolyzer manufacturers (see overview on page 22) are experiencing unprecedented demand. A great many new players are jumping on the bandwagon and increasing numbers of conventional energy suppliers are pivoting from traditional power sources to renewable energies and embedding hydrogen in their portfolios. So what is the current situation vis-a-vis electrolyzers and what can we expect in the future? This article seeks to shine a light on these and other questions by providing a general – though not necessarily exhaustive – roundup of recent developments.

Fig. 1: Electrolyzer stack fittings
[Source: Green Hydrogen Systems]

Chairman of the German Hydrogen and Fuel Cell Association, Werner Diwald, makes the assumption that an electrolyzer capacity of between 108 and 350 gigawatts will be needed in Germany alone by the year 2050. For this to be reached, around an extra 5 gigawatts would have to come online each year, starting in 2030. Worldwide, he expects the potential to be over 78,000 gigawatts.

While total installed capacity has long languished in the three-figure megawatt range, the capacity in just the European Union is set to increase to 40 gigawatts by 2030, according to official plans. The actual figure should, however, be far higher if today's expansion targets are anything to go by. The International Energy Agency has indicated that currently 850 gigawatts of electrolyzer capacity are required globally in order to ensure that climate neutrality is attained by 2045.

EXPONENTIAL GROWTH EXPECTED Plants are getting bigger. In 2017, the 5-megawatt PEM (proton exchange membrane) electrolyzer installed by Siemens in the Neuhof area of Hamburg was then the largest of its kind. Nearly four years later and that record has been pushed up fourfold. In 2021, Cummins announced that it had brought into service a 20-megawatt PEM electrolyzer, the biggest in operation at that time, at a hydrogen production site belonging to Air Liquide in Bécancour, Quebec. The plant produces 3,000 metric tons of green hydrogen a year, powered by local hydroelectricity which is in plentiful supply.

Work on a further Siemens electrolyzer plant began on June 9, 2021, at the Wunsiedel energy park. This was followed by the arrival of the shipping container with an 8.75-megawatt power input capacity on Nov. 9. The plant is expected to manufacture 1,350 metric tons of green hydrogen on an annual basis starting from summer 2022. Bavaria plans to invest a total of "one billion euros in hydrogen projects" in the next few years according to a statement by Minister President Markus Söder.

In a similar move, Trianel and municipal energy supplier Hamm have revealed that they are planning a hydrogen joint venture entitled Projektgesellschaft Wasserstoffzentrum Hamm. The initiative entails the construction of a 20-megawatt electrolyzer on the site of the Hamm-Uentrop gas power plant in Germany by the year 2024.

A project on an even bigger scale is envisaged by Linde. The company wants to build, in its own words, the "largest PEM electrolyzer plant in the world" in Leuna, Germany. The 24-megawatt facility, provided by joint venture partner ITM Power, will begin operations using certified green power. From mid-2022, the plant will produce up to 3,200 metric tons of green hydrogen a year, running on locally generated renewable electricity.

At the same time, work is continuing on the construction of a 100-megawatt electrolyzer at the former Moorburg coal power plant in Hamburg's port area, with the build due to last until 2025, at least that is the suggestion of economy senator Michael Westhagemann. The companies Vattenfall, Shell and Mitsubishi Heavy Industries signed a relevant agreement together with municipal energy supplier Hamburg Wärme in early 2021.

A three-figure megawatt capacity project is also on the cards for the H24All scheme. In all, 15 organizations from Belgium, Denmark, Germany, Norway, Spain and Turkey have teamed up to build a 100-megawatt alkaline electrolyzer plant at a European site belonging to energy company Repsol, in a scheme that comes under the European Commission's Green Deal. The aim is to lower the cost of hydrogen produced from renewables to roughly EUR 3 per kilogram.

Stefan Kaufmann, innovation commissioner for green hydrogen, emphasized the point that today a fifth of all electrolyzers come from Germany – a market share that he would like to see at least retained in future.

At the end of 2020, wind power plant construction company Siemens Gamesa announced its collaboration with Green Hydrogen Systems, also known as GHS. The latter's electrolyzer is being supplied with electricity from a 3-megawatt wind turbine at a site in Brande, Denmark. Gas produced by the facility, which operates in islanded mode, will be used to refuel a hydrogen Everfuel truck. Likewise Ørsted is deploying a GHS electrolyzer stack (see fig. 1) which will enable it to use two 3.6-megawatt offshore wind plants for hydrogen production purposes.

ENAPTER SETS UP STACK FACTORY IN SAERBECK In October 2020, electrolyzer manufacturer Enapter announced its intention to establish its new facility for the series production of electrolyzers in Germany's Saerbeck. In preparation, an office space for 10 employees was initially acquired on the 900,000-square-foot (82,000-square-meter) Enapter campus in February 2021. Groundwork then began in September 2021 which was accompanied by an address given by North Rhine-Westphalia's energy minister Andreas Pinkwart. The objective is to achieve a production capability of around 10,000 units of the company's proprietary AEM (anion exchange membrane) electrolyzers a month from 2023 onward.

The Saerbeck municipality in North Rhine-Westphalia has gained attention for its climate credentials since the area is supplied entirely by locally produced renewable energy. Enapter CEO Sebastian-Justus Schmidt consciously chose this location after extensive research because of its favorable conditions and the opportunities it provides for a circular economy. Talking as work to build the manufacturing halls, warehouse, offices and laboratories was about to start, he said: "Our entire DNA is focused on speed when it comes to research & development and market launch." A total of EUR 105 million is set to be invested at this site which is expected to create 300 new jobs.

For the time being, Enapter continues to manufacture its stacks along with other peripheral equipment in Pisa, Italy. Its products are then integrated into easy-to-handle racks by H2 Core Systems, for example. Uwe Küter, who has been working at H2 Core Systems since September 2021, explained the division of responsibilities between the manufacturers and the plant construction companies: "Enapter develops everything concerning the electrolyzer modules and works continuously to improve these; the plants themselves are built by its partners (system integrators) around the world. […] Plants are sold via the partners. We extend the electrolyzers further and fit them out with other components according to customer requirements, be it a fuel cell or compressor or supercap, etc."

Speaking to H2-international, Ulf Jörgensen, H2 Core director, stated that scaling up was in full swing at the company's base in Heide. He went on to say that the manufacture of electrolyzer cabinets takes only three weeks. The racks can then be connected at their destination within 15 minutes and subsequently controlled by an app. Primarily the managing partner of TC-Hydraulik, Jörgensen has a background in fluid technology and has recently become increasingly involved in the hydrogen sector. Hydrogen, in his view, is a fluid just like any other and his company is perfectly capable and competent in its handling.

A relatively new development is Enapter's step into the megawatt sector. Whereas previously its sights were set primarily on smaller systems, in July 2021 the Italian-German company revealed plans to accelerate the development of the AEM Multicore at megawatt scale in a collaboration with FH Münster university that would use funding from the Ger-

INEOS TO INVEST EUR 2 BILLION

One of the largest investments in electrolyzer technology was announced by Ineos in mid-October 2021. The British company, which thanks to its 26,000-strong workforce is, by its own calculations, the third biggest chemical corporation in the world, unveiled its intention to raise more than EUR 2 billion for the manufacture of green hydrogen. The center of attention here is Inovyn – a subsidiary founded in November 2020 that has extensive experience in this branch of technology. Inovyn emanated from the joint venture established with Solvay in 2016 after Ineos had previously taken over a number of entire companies and business areas from BASF, Norsk Hydro and DEA. Ineos Holdings emerged in 1998 from petroleum company BP.

According to press statements, the initial plants will be set up in Belgium, Great Britain and France within the next 10 years. The first 20-megawatt system, which will use hydroelectricity to power hydrogen production, will be located at Ineos' site in Rafnes in southern Norway. The second plant, rated at 100 megawatts, could be constructed in Cologne's Chempark where green hydrogen is due to be used for producing ammonia and potentially also e-fuels. This project has successfully passed the first stage of the selection procedure for Important Projects of Common European Interest, otherwise known as IPCEIs.

"Europe is crying out for more investment in green hydrogen and Ineos' announcement today shows our determination to play a leading role in this important new fuel."

Jim Ratcliffe, founder and chairman of Ineos

Fig. 2: AEM Multicore [Source: Enapter]

Fig. 3: In March 2020, Asahi Kasei began operating its 10-megawatt alkaline electrolyzer in Namie, Fukushima, Japan – the largest single-stack system in the world (42,000 standard cubic feet or 1,200 standard cubic meters of green hydrogen an hour) [Source: Asahi Kasei]

man education ministry. The AEM Multicore (see fig. 2) connects up 420 electrolyzer stacks which enables one of these shipping container systems to produce about 450 kilograms of hydrogen a day.

Anja Karliczek, German education minister, explained: "AEM electrolyzer technology could allow us to achieve the goal of cost-effective green hydrogen production." Sebastian-Justus Schmidt added: "Here we will scale up the production of our electrolyzers, thereby lowering the price of green hydrogen. Another reason for our excitement is that we're doing it all with one hundred percent regional renewable energy."

At the end of October 2021, H2 Core Systems immediately submitted an order to Enapter for the purchase of an AEM Multicore. According to reports, the company commissioning this megawatt-class system, the delivery of which is scheduled for June 2023, is the Steinbeis Innovation Center siz energie+ based in Braunschweig. The final destination for the Multicore will be Braunschweig's Research Airport. Hot on the heels, Enapter then announced plans to increase share capital to the tune of at least EUR 30 million.

WAVES OF ACTIVITY ACROSS EUROPE A large production facility for solid oxide electrolyzers is currently in the planning at Haldor Topsøe. The Danish company has set its sights on constructing a factory with a 500-megawatt capacity by 2023 with a view to expanding capacity to up to 5 gigawatts per year. Haldor Topsøe states that its SOEC (solid oxide electrolyzer cell) units have an efficiency of more than 90 percent due to their ability to recover a large amount of heat.

A SIDELINE IN HEAT RECOVERY

Ove Petersen, CEO of GP Joule, indicated during an industry meeting in Berlin that the thermal energy generated by electrolyzers could be utilized in certain circumstances. He calculated that the recovered heat could be worth up to EUR 0.05 per kilowatt-hour. When this is translated into hydrogen production costs, the extraction of waste heat could lead to a drop in the hydrogen price of EUR 1 per kilogram.

In March 2021, Breakthrough Energy Ventures invested USD 22 million in electrolyzer business H2Pro. The Israel-based company has signaled that its aim is to produce green hydrogen for less than USD 1 per kilogram by the middle of the current decade.

Meanwhile in England, the company ITM Power has seen its premises grow many times over through the years. Its former headquarters at Sheffield's old airport (see HZwei, January 2012) was superseded in 2020 by a new 135,000-square-foot (12,500-square-meter) production site in the north of the city. Also in 2020, the Italian network operator Snam joined forces with the British business, bringing with it EUR 33 million in investment. The move was described by Snam as more or less kick-starting "a commercial and technological collaboration to develop future joint initiatives." Talk is of collaborative projects on a scale of up to 100 megawatts by 2025.

There are also a number of PEM electrolyzers being built in France. In 2017, H2V initially negotiated with Nel over the fitting out of six hydrogen factories in Les Hauts and in Normandy. When this collaboration did not transpire, H2V, which is a member of SAMFI-INVEST Group, turned to Hydrogen Pro. Its first hydrogen production plant is expected to have a capacity around the 100-megawatt mark and will comprise several dozen electrolyzers. Jean-Marc Leonhardt, CEO of H2V, told H2-international that the H2V Normandie project was, in fall 2021, at the approvals stage. The H2V 59 project in Dunkirk should also enter this phase at the end of 2021. Other projects are anticipated to follow in the runup to 2025.

In Japan, the Toshiba Corporation is playing an active role in this field. Back in 2015, the company was involved in a large hydrogen research project in Methil, Scotland, in which its H_2 EMS energy management system was used.

SCORES OF CORPORATE TAKEOVERS Testament to the enormous interest in electrolyzer technology is the continuing high number of company takeovers and investments – methods which large corporations in particular are using in an attempt to reposition themselves in the marketplace. One such example is MAN Energy Solutions which completed its

HOELLER COOPERATING WITH AALBERTS
During the Hydrogen Technology Expo, which took place on Oct. 20 and 21, 2021, in Bremen (see p. 10), Hoeller Electrolyzer and Aalberts Surface Technologies announced the start of their wide-ranging collaboration. Their partnership focuses particularly on the surface coating which is crucial for the efficiency of PEM electrolyzer stacks.

wholesale takeover of H-Tec Systems in early 2021. Two years prior to that, the wholly owned Volkswagen subsidiary had secured a 40-percent stake in the company (see H2-international, July 2019). MAN subsequently acquired the remaining shares in electrolyzer manufacturer H-Tec, which was originally set up in Lübeck but has since moved to Augsburg.

H-Tec started out 20 years ago creating hydrogen and fuel cell teaching materials before expanding its electrolyzer division and being taken over by GP Joule. In 2018, the company began operating from a new site in Stapelfeld on the edge of Hamburg and focused on increasing its capacities for electrolyzer production.

2018 witnessed the takeover of Kumatec Sondermaschinenbau & Kunststoffverarbeitung by AVX Interconnect Europe (see H2-international, October 2018). AVX is a wholly owned subsidiary of Kyocera and together the pair launched the new Kyocera AVX brand for the electronic component business in April 2021. Another collaboration which started four years ago is the partnership between AGFA and De Nora. The Belgian membrane manufacturer from Mortsel and the Italian electrode producer from Milan began cooperating on the development of alkaline electrolyzers in order to achieve a better market position.

De Nora is also working with thyssenkrupp Industrial Solutions, which in 2020 boasted that its new highly automated industrial-scale production meant they were "virtually the first suppliers capable of delivering 1 GW per year." Then in October 2021 the news came from thyssenkrupp Uhde Chlorine Engineers that capacity would be scaled up further as part of the H2Giga project. The scheme will make automated gigawatt series production a reality and will be receiving EUR 8.5 million in funding from the German education ministry. In mid-November 2021 it also emerged that the joint venture between De Nora and thyssenkrupp Industrial Solutions – Uhde Chlorine Engineers GmbH – could be floated in the second quarter of 2022, potentially raising EUR 6 billion in capital.

Martina Merz, chair of thyssenkrupp AG, explained: "In recent months we have seen a clear shift in the size of projects toward several hundred megawatts and up to a gigawatt meaning that the market is already demanding large-volume and automated serial production. Simply upscaling is not a feasible option for these orders of magnitude; instead disruptive approaches need to be used which are developed as part of this project and tested and optimized gradually."

In order to make the construction of new hydrogen plants cost-effective, thyssenkrupp is producing prefabricated standard modules, with a single unit capable of making up to 141,000 cubic feet (4,000 cubic meters) of hydrogen an hour. These modules are comparatively easy to transport and install and can be connected up to form various system sizes with capacities ranging up to several hundred megawatts and beyond, the plant construction company has stated.

"Plug is building a hydrogen ecosystem by systematically adding complementary strengths and capabilities through key acquisitions, joint ventures, and other partnerships. [...] Partnerships with Renault, SK, Acciona, Fortescue Future Industries, Airbus and Lhyfe provide access and scale in markets new to Plug."
Plug Power, press release

The story of Diamond Lite makes for a long and winding corporate tale. For many years the Swiss company acted as the European arm of Proton OnSite before being taken over by Alpiq in 2017. However, in 2018 the Lausanne-based energy service provider then separated from the entire Kraftanlagen Group which had been home to Alpiq's electrolyzer division. The new owner is Bouygues Construction.

Meanwhile the US fuel cell manufacturer Plug Power has been gradually assimilating an increasing number of companies, resulting in its portfolio growing substantially. Following Plug's takeover of Giner ELX in the electrolyzer sector, the company, which is headquartered in New York, established – in line with its previous announcement – a joint venture with SK E&S in October 2021 in order to be able to jointly offer fuel cell systems, hydrogen refueling stations and electrolyzers for the Asian market. The South Korean company forms part of the SK Group and holds a 51 percent share in the merger.

This majority stake should ensure that a gigafactory for fuel cell and electrolyzer systems is built in a "major metropolitan area in South Korea" by 2024. According to reports, this location will allow products to be supplied both domestically and to other Asian markets (see also p. 54).

Just a month later, the American company also acquired the Frames Group. The takeover of the Dutch system integrator can be understood as a sign from Plug that it intends to expand its own capacities in Europe in future. The press release giving details of the takeover stated:

SUNFIRE ABSORBS IHT Sunfire acquired 100 percent of Swiss company IHT Industrie Haute Technology in January 2021. Located in Monthey, IHT has been developing high-pressure alkaline electrolyzers for 70 years while Dresden-based Sunfire has been working on solid oxide electrolyzers. The upshot of the takeover is a significant widening of Sunfire's portfolio.

Fig. 4: Modules for alkaline water electrolysis, or AWE, at thyssenkrupp [Source: thyssenkrupp]

Fig. 5: Andreas Frömmel presented key market data at the Marktplatz Zulieferer event (see table)

Nils Aldag, CEO of Sunfire, said: "By choosing the high-pressure alkaline electrolyzer developed by IHT, we have opted for the most advanced and most reliable technology currently available on the market. This business acquisition is a key element in our growth strategy and looks to strengthen and broaden further our global market position as one of the world's leading electrolyzer suppliers." Franco Nodari, director of IHT, called the merger "part of a big mission."

In early December 2021, the company, which now employs over 270 staff, revealed that it will be collaborating with Brandenburg-based wind power developer Enertrag. The two German companies have plans to jointly set up an electrolyzer field trial. It is hoped that the hydrogen center planned for Prenzlau in the eastern part of the country will enable the construction, testing and operation of various electrolyzers with a capacity totaling 15 megawatts. Sunfire itself will contribute a high-pressure alkaline electrolyzer, an S+ model rated at 10 megawatts.

In October, Sunfire then reported its intention to build a new production facility by 2023. According to Aldag, now is the time "to fully exploit the potential." He said: "Therefore we will be expanding our annual production capacity for alkaline electrolyzers from the current 40 MW per year to at least 500 MW per year by 2023." Due to the huge demand, "further scaling to a minimum of 1 GW per year" is envisaged – probably in Germany.

At the Marktplatz Zulieferer event organized by NOW in Berlin, Andreas Frömmel, Vice President Sales and Marketing at Sunfire, outlined current and expected requirements in the electrolyzer sector (see fig. 5 and table – based on figures from FCH JU, Hydrogen Europe, McKinsey as well as Sunfire's own research). According to the market data, there will be a production shortfall of 3.45 gigawatts per year between 2021 and 2024 before the anticipated – some would say hoped-for – scale-up of manufacturing capabilities is able to realize an annual production of around 20 gigawatts from the year 2025 onward.

EUR 109 million was funneled to Sunfire in fall 2021 for its planned scheme. As Nils Aldag elucidated: "never before has an unlisted company dealing in green hydrogen attracted so much investment." Sunfire sees SOEC technology as a future "game changer" which it believes will be used particularly in the decarbonization of industry, e.g., steel and cement, after 2023.

Table: Annual global production capability for electrolyzer capacity

	2021	2025
Cummins	100 MW/year	1,000 MW/year
ITM Power	50 MW/year	1,500 MW/year
John Cockerill	350 MW/year	2,500 MW/year
McPhy	100 MW/year	1,800 MW/year
Nel	200 MW/year	2,200 MW/year
Plug Power	??? MW/year	3.000 MW/year
Siemens Energy	10 MW/year	1,000 MW/year
Sunfire	47 MW/year	1,500 MW/year
thyssenkrupp	1,000 MW/year	6.000 MW/year
New players	0 MW/year	1,700 MW/year
Total	**1.85 GW/year**	**19.2 GW/year**

Source: Sunfire, Marktplatz Zulieferer 2021, own research

AIRBUS SPACE TECHNOLOGY

The strategy of Airbus ought to draw particular interest. The aircraft manufacturer has developed a 100-bar electrolyzer that has been designed for terrestrial applications as well as use in space. An initial 10-bar system was sent to the International Space Station in 2017 in order to facilitate its life support systems and to supply oxygen for the astronauts. The technology consists of an alkaline electrolyzer which is capable of functioning under extreme conditions such as zero gravity, is very light and has a high energy density. It is understood that these advanced systems will now also be used on Earth, for example in supplying energy to domestic properties or in mobile energy systems.

FEST GROUP IS GROWING

At the start of 2021, iGas energy brought on stream an electrolyzer in a tinplate factory in Belarus. The Green Electrolyzer produces 3,500 standard cubic feet, or 100 standard cubic meters, of hydrogen per hour for the on-site furnace. Alongside this, iGas energy, situated in the German town of Stolberg, is focusing its efforts on the further development of electrolyzer technology. As Karl-Heinz Lentz, company director, confirmed to H2-international, the relatively small business, which has 10 employees, merged with Fest GmbH so as to be able to deal effectively with the many inquiries it is receiving.
Both Fest, based in Goslar, and inverter manufacturer IPS-Fest GmbH come under the wing of the Fest Group which in turn is part of the Schmidt-Kranz Group that owns Maximator. Currently Fest is preparing to install a PEM electrolyzer at Infraserv. The system, which is composed of two 40-foot (12-meter) shipping containers (2 x 2.5 megawatts), is expected to be delivered in the first quarter of 2022 and is due to start supplying Alstom's fuel cell trains in the Frankfurt region at the end of 2022.

Fig. 6: View inside the 500-kilowatt Green Electrolyzer [Source: iGas]

In the meantime, Martin Wietschel from Fraunhofer ISI, speaking at congress of German energy agency dena in November 2021, questioned whether a scale-up of this magnitude is indeed possible. Commenting on the European Union's objective of achieving 80 gigawatts by 2030 (40 gigawatts in Europe, 40 gigawatts in imports), he said that an increase of, on average, 9 gigawatts per year would far exceed the level that could be achieved by the solar and wind industry at the best of times. Set against this is the fact that a company such as Nel has now already installed, according to its own figures, over 3,500 systems, working in partnership with Proton OnSite which Nel took over in 2017. This should mean there is sufficient experience for further scaling.

Political leaders now seem to have grasped the potential offered by this new branch of technology. For example, in mid-September 2021, the outgoing German government smoothed the way for future hydrogen production at sea. An ordinance governing this matter entered force in early October, making it possible to trial hydrogen production in offshore wind farms. Germany's current economy minister, Peter Altmaier, stated: "The production of green hydrogen at sea is a really promising area with a high degree of innovation potential. Offshore hydrogen production can play an important role in decarbonizing Germany as an industrial nation." ||

ELECTROLYZER SURVEY

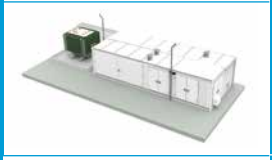
For this market overview, we wrote to a total of 29 companies from Germany and abroad that offer electrolysis stacks, electrolyzers or complete systems for electrolytic hydrogen production. Out of these, 16 filled out our online survey. The companies could specify up to five products. In addition to the technical data of the products, we also asked about further developments in recent years and for assessments of the market (see p. 27). After identifying duplications of stack and system providers, 14 made it into this final overview, which makes no claim of completeness.

Our goal is to continually expand and improve this market overview, which is based on an initial survey from four years ago (see H2-international Apr. 2017). We would therefore be happy to receive information about other providers. ||

Category: Energy storage

MARKET OVERVIEW OF ELECTROLYZERS

GENERAL INFORMATION

	Company	Product	Stack / electrolyzer / system*	Type	Market status	Market introduction	Application
	Airbus DS	ALPHA	stack	alkaline	development	2022	space, aviation, industrial, mobility, power
	AVX/ Kumatec Hydrogen	PEM-40-100 PEM-100-25 PEM-40-1000 **PEM-40-500**	system	PEM	serial product		industrial, domestic, mobility, power sector
	Elogen	**ELYTE10** 50 100 200 1000	electrolyzer	PEM	serial product	2011 2021 2018 2020 2021	power sector
	Enapter	AEM Electrolyser 2.1	electrolyzer	AEM	serial product	2020	domestic
		AEM Multicore	electrolyzer	AEM	development	2022	mobility
	Fest / Green H2-Systems	green Elektrolyseur gEL200 gEL400 **gEL600**	system	PEM	serial product	2020	all
		green Elektrolyseur gEL800 **gEL1000**	system	PEM	serial product	2021	all
	Green Hydrogen Systems	A-Serie: A30 A60 **A90**	system	alkaline	serial product	2017	mobility, industrial, e-fuels
		X-Serie: X1200 6MW	system	alkaline	pre-order (for 2023)	2022	Industry, power, e-fuels

Sources: manufacturer specifications, alphabetic order
*: stack / electrolyzer = stack + balance of plant / system = electrolyzer + water treatment + gas drying
bold product numbers indicate the modell shown on the picture

DYNAMIC OPERATION		DIMENSIONS			ELEKTRICITY INPUT			WATER INPUT		HYDROGEN OUTPUT		
Min. load (%)	Max. load (%)	Height (mm)	Width (mm)	Depth (mm)	kWh_{el} / m^3 H_2	AC/DC	Voltage (V)	l/m^3 H_2	Condi-tions	m^3/h (per unit)	Purity (% vol)	Pres-sure (bar)
25	150	240	180	180	4.3	40 A DC	48	0.8	~ 80 °C	0.44	~ 98, > 99 (H_2)	100
10	100				5.7 5.9 5.5 5.5	AC (3 phase)	400		tap water	20 5 200 100	99.999 (5.0)	40 100 40 40
10 5 5 2.5 5	100				5.4 4.9 4.9 4.9 50	AC (3 phase)	400	3.0 1.99 1.99 1.99 1.99	tap water	10 50 100 200 1000	99.999 (5.0)	30
60	100	307	482	634	4.8	AC (1 phase)	200 - 240	0.8	conduc-tivity < 20 µS/cm	0,5	99.9 (99.999 with optional dryer)	up to 35
3	105				4.8	AC (3 phase)	3 x 400	0.9	conduc-tivity < 20 µS/cm	210	99.9 (99.999 with optional dryer)	up to 35
10	100	3,000	12,000	5,000	5.0	AC (3 phase)	medium voltages	1.4	tap water, other	200 400 600	5.0 and ISO 14687	40
10	100	3,000	1,800	5,000	5.0		medium voltages	1.4	tap water, other	1000	5.0 and ISO 14687	40
16	100	3,000	3,000	2,000	4.7	AC (3 phase)	400	0.9	tap water	30 60 90	99.9999 (6.0)	35
16	100	2,340	2,280	12,030	4.5	AC (3 phase)	10000-33000	1.0	tap water	1200	99.999 (5.0)	35

GENERAL INFORMATION

	Company	Product	Stack / electrolyzer / system*	Type	Market status	Market introduction	Application
	H2 Core Systems	Indoor HydroCab	system	AEM	serial product	2021	domestic
		Outdoor HydroCab	system	AEM	serial product	2021	off-grid
		AEM HydroCluster	system	AEM	serial product	2021	power sector
	Hoeller Elektrolyseur	Prometheus S	stack	PEM	demonstrator / pilot	2022	mobility
	H-TEC SystemS	PEM Electrolyser ME100/350	system	PEM	serial product	2017	all except domestic
		PEM Electrolyser ME450/1400	system	PEM	serial product	2019	all (excluding domestic)
	Hydrogen Pro	Hydrogen Pro	system	alkaline	customer specific	2013	industrial
	Nel Hydrogen	M Series	system	PEM	serial product	2020	industrial, mobility
	Plug Power	1 MW Elektrolyseur System	system	PEM	mass production	2021	industrial
		5 MW Elektrolyseur System	system	PEM	mass production	2022	industrial
	Sunfire	HyLink alkaline	system	alkaline	mass production	2021	industrial
		HyLink SOEC	electrolyzer	SOEC	customer specific	2020	Industrie
	thyssenkrupp	alkaline Water Electrolysis	electrolyzer	alkaline	serial product	2019	Industrie

DYNAMIC OPERATION		DIMENSIONS			ELEKTRICITY INPUT			WATER INPUT		HYDROGEN OUTPUT		
Min. load (%)	Max. load (%)	Height (mm)	Width (mm)	Depth (mm)	kWh_{el} / m^3 H_2	AC/DC	Voltage (V)	l/m^3 H_2	Condi-tions	m^3/h (per unit)	Purity (% vol)	Pres-sure (bar)
12	100	2,200	800	800	4.8	AC (3 phase)	400	0.8	tap water	0.5 - 2.5	99.999 (5.0)	35
12	100	2,200	800	1,200	4.8	AC (3 phase)	400	0.8	tap water	2.5	99.999 (5.0)	35
1	100	2,896	2,438	5,000	4.8	AC (3 phase)	400	0.8	tap water	30	99.999 (5.0)	35
					4.8	DC	384		< 0.1 µS/cm	16	99.999 (5.0)	40
32	100	3,000	6,100	5,000	4.9	AC (3 phase)	400	1.9	tap water	46.3	99.999 (5.0)	15-30
20	100	4,000	13,200	5,000	4.8	AC (3 phase)	400	1.24	tap water	210	99.999 (5.0)	15-30
40	100	2,300	8,950	2,300	4.6	DC	MV/HV	0.9	Purity < 2 µS	2200	99.999 (5.0)	15
1	100				4.5	AC (3 phase)	480	1.44	tap water	250 - 5000	99.9995 with dryer	30
10	100	2,400	2,400	5,000	4.6	AC (3 phase)	400	1.4	tap water	200	99.9999 (6.0)	40
2	100	5,000	5,000	5,000	4.6	AC (3 phase)	400	1.0	tap water	1000	99.9999 (6.0)	40
20	100	2,600	11,200	2,600	4.7	AC (3 phase)	20000	0.825	tap water	2.23	99.999 (5.0)	30
5	100	2,610	3,000	1,450	2.7	AC (3 phase)	20000		tap water	750	99.999 (5.0)	atmos-pheric
10	100					DC	up to 110000	1.0	ISO 3696, type 2	4000	99.9	1.3

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

INCREASING DECENTRALIZATION

Small on-site energy generation is on the up

Until now, the energy supply mechanism in Germany and Europe has taken a centralized form. Massive power plants are responsible for generating electricity and heat which are then distributed via cables or district heating networks. When the boom in solar and wind generation began around 20 years ago, many in the sector hoped that decentralization would follow – a belief that led only to disappointment in many respects. While the number of distributed energy generation systems has indeed risen, the wholesale change once envisaged has yet to materialize.

In the field of hydrogen production there is little consensus on the subject. For instance, a study by the FZ Jülich research center in 2017 drew the conclusion that centralized electrolyzers ought to be installed in northern Germany, a convenient location in terms of space and proximity to large wind farms. At the time, Detlef Stolten from FZ Jülich had "focused primarily" on this centralized concept. Back then Nikolas Iwan from H2 Mobility had similarly expressed "doubts about whether decentralized hydrogen production makes sense."

It's since become clear that the slow progress being made in terms of expanding the power line network means that alternative solutions are now required. Increasingly this is where ideas of local and regional generation come back into play. By way of example, a project in the Swiss municipality of Brütten, near Zürich, demonstrated that a decentralized energy supply based on solar or wind is achievable for a single building. In this case, the environmental organization Umwelt Arena Spreitenbach built an apartment block that was kitted out with a variety of innovative technologies (see H2-international, July 2018).

EMV New Line, which collaborated with Proton Motor on the Swiss project, has since started offering its own solution for self-sufficient properties without a connection to the electrical grid. Catering for all capacities up to the megawatt range, its islanded solution comprises an electrolyzer along with a compressor with appropriate hydrogen safety equipment and a fuel cell that comes with a battery storage system, control equipment and associated software.

The company, based in the German area of Pilsting, said that "Brütten was its entry point" into this branch of technology. In a statement to H2-international, it added: "We have now completed self-sufficiency projects for several single-family homes and also set up our company to run off grid. [...] Up until a few weeks ago, we sometimes had three visitor groups a week coming to view our building's autonomous energy system. The many requests we receive far outstrip our available resources, and for that reason we are now only concentrating on essential projects. We are currently working on a MW hydrogen refueling station for a bus company, for which we are producing 450 kg_{H2}/24 h, and on an energy center for a new development of 130 single-family homes."

EMV director Bajog explained that the Swiss project had taught him that as a supplier it's not productive to focus solely on fuel cells. He likened this to "VW offering its customers just the engine and the customer having to source and assemble everything else related to the vehicle." He therefore took it upon himself to get involved and develop what the energy transition needs so as to be able to offer a complete solution.

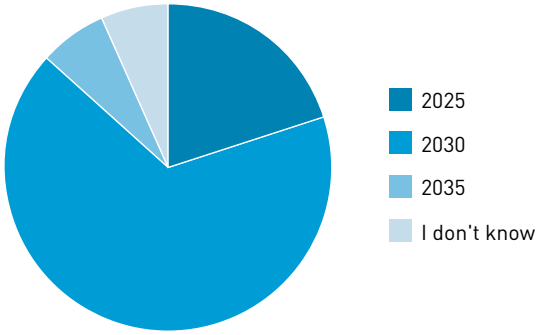
At the moment, EMV is working on a 19-inch rack system consisting of a 2.4-kilowatt electrolyzer, a 2.5-kilowatt fuel cell, a battery back-up unit rated at 12 kilowatt-hours plus a total of 10 hydrogen tanks, each with a capacity of 50 liters, offering 335 kilowatt-hours. The result is a fully autonomous energy supply system capable of providing 6,600 kilowatt-hours of power to a four-person household 365 days a year. An initial system was installed by Bajog electronic in September 2020 in a single-family property with a living space of 2,150 square feet (200 square meters). Even on cloudy days the photovoltaic system with 20 kW_{peak} produces enough electricity – equivalent to 2.1 to 3.2 kilowatt-hours – to charge the battery and guarantee self-sufficient hydrogen production. According to Bajog, these types of systems have been requested by mayors and municipal councils in Lower Bavaria to be integrated into the area's planned new housing developments. ||

BTU COTTBUS FOCUSES ON MICRO WIND TURBINES

The Fraunhofer Institute for Applied Polymer Research IAP is also working on small energy systems. In a collaboration involving BTU Cottbus university and the company EAB Gebäudetechnik Luckau, scientists are developing microscale wind turbines that can be used as a power source for electrolysis. Holger Seidlitz, chair of polymer-based lightweight design at BTU Cottbus, explained: "The wind turbine will be designed so as to be small enough for the general public to install the system in the garden." The notable thing about this new design is its ability to function perfectly well even if there is only a low level of wind. "We have adapted the design of the blades and reduced their mass by around 30 percent compared with conventional micro wind systems," added Marcello Ambrosio from Fraunhofer IAP. The first field trials are due to take place shortly.

Fig.: Prototype of the mini wind turbine developed by Fraunhofer IAP, BTU and EAB [Source: Fraunhofer IAP]

SCALING EFFECTS ALLOW ELECTROLYZER PRICES TO DROP



When do you expect green hydrogen to be competitive with fossil hydrogen (not including the cost for the hydrogen transport)?

We have asked suppliers of electrolyzers for their assessment of various market issues and publish them here in anonymized form. Fifteen companies participated in this survey.

Analysis of the responses revealed that in the past 24 months, the prices for electrolyzers, stacks and complete systems have decreased by up to 20 percent for two-thirds of the manufacturers. Half of them expect the devices to become a further ten percent cheaper within the next 12 months. Five manufacturers even predict a 20 percent reduction in price. This is a similar development to that of photovoltaics in the 2000s and 2010s.

Nearly unanimously, suppliers state that the scaling of production is the main reason for the falling prices. This is consistent with the data from our market overview. The vast majority of electrolyzers are now in series production, but only a few claim to have achieved mass production.

Most of the participants in the survey predict that between 2025 and 230, green hydrogen will be able to compete with gray hydrogen produced from natural gas in terms of price. However, this only involves production, not transport, which could also be a significant factor, depending on the distance and transport route. But perhaps the distances aren't that long. The majority, 11 of the 15 businesses sees their sales market as being primarily in Europe. ||

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

ADVENTURE AT SEA

Hydrogen production on the French Atlantic coast

Fig.: Test facility: a floating wind turbine and research platform [Source: Lhyfe]

French company Lhyfe has plans to establish large-scale hydrogen production at sea. That's where the greatest potential lies, it believes. It's an ambition that could be helped by the legacy pipes and connections from old oil and gas fields. The goal is to have a test facility up and running just off the French Atlantic coast by late summer 2022.

Far, far out in the Atlantic Ocean, the possibilities are enticing. The wind blows continuously and with great force, unhindered by land mass. If wind farms were built here, they would generate many gigawatt-hours of electricity around the clock. And this electrical energy could be used to produce many gigatons of green hydrogen. Luc Graré, who is responsible for Lhyfe's international business, is convinced: "The potential for producing green hydrogen on a large scale at sea is enormous."

Things aren't quite there yet, however. The fledgling hydrogen company is still at the "dry run" stage, so to speak. In Bouin, south of Nantes, Lhyfe has been producing around 300 kilograms of hydrogen a day on land since Oct. 1, 2021. The site's electrolyzer, supplied by Nel, utilizes power from three nearby wind generators in addition to sea water – just as the floating hydrogen plant would do.

A little further north, in Le Croisic, the company is gearing up to launch its first offshore electrolyzer – a Plug Power model – in late summer 2022. Off the coast of Le Croisic, the Centrale Nantes engineering school is trialing new maritime technologies: A wind turbine is positioned on a floating platform in the Atlantic. Treading water close by, like a yellow UFO, is the research station (see fig.), which uses solar and wave power to meet its own electricity needs. It is from this base that observers are looking to prove the seaworthiness and reliability of offshore electrolysis, with an initial aim of producing 440 kilograms of hydrogen per day. "The components have already been ordered," stated Graré.

REUSING FOSSIL-ERA INFRASTRUCTURE For years now, wind farms have been advancing ever further into open sea. Nevertheless, the depth of the water and the distance from land-based connections are still limiting factors which prevent offshore energy production from venturing too far from coastal areas. Yet the arrival of floating foundations means it's now possible for wind farms to be erected in deeper areas of the ocean. And when it comes to connection costs, converting the energy generated into hydrogen could bring about a breakthrough. "A pipeline is much cheaper than a power cable. The specific costs are around an eighth," the electrical engineer from Belgium explained.

Plus, in some cases electrolyzers can be set up in sites that don't need new pipelines at all. In the areas surrounding disused oil and gas fields, you will still often find pipelines running along the seabed which can, circumstances allowing, be adapted for hydrogen with the use of specialized hoses. In Graré's opinion, even the platforms themselves can be reused.

Of particular interest to him is the area of the North Sea which lies off the Dutch coast. By the end of the decade, if not sooner, the Netherlands is planning to stop extracting low calorific gas. This will free up a network of gas infrastructure that extends across the Netherlands and into Germany's Ruhr region.

This could enable supplies to be transported to numerous industrial customers. "Industry is primarily interested in hydrogen as a process gas initially," said the former Nel manager. The intention is to use green gas to harden steel or float glass, for example. However, the cost of using it to generate process heat is still around five times more expensive compared with natural gas, by Graré's reckoning.

For marine electrolysis to be viable, the carbon dioxide price would have to increase to approximately EUR 200, he explained. At the same time, the electricity from offshore wind farms must also become cheaper. "A four or even better a three at the start" is what it would take to put hydrogen production on a competitive footing in Graré's opinion.

SALT, WIND AND WAVES Before this potential can be leveraged, however, the electrolyzer plant must first demonstrate that it can withstand the salt water and the waves of the Atlantic, which can measure up to 65 feet (20 meters). "We have investigated the wave loading

through a combination of lab tests and simulations – similar to what the automotive industry does," outlined Graré, who originally started out in the solar sector. Furthermore, Lhyfe has not only carried out its own assessment of the technology but has also commissioned service provider DNV to carry out a risk analysis.

So far so good, but the real test will be how both the electrolyzer and the method of operation perform in practice. "We needed a compact plant for our demonstration project and therefore we opted for a PEM electrolyzer," said Graré. When it comes to the question of whether PEM electrolysis could be advantageous in terms of flexible operation, he remains skeptical. "Electrolysis is not the bottleneck in relation to flexibility – rather it's the compressor." This is where pressurized electrolysis could come in. Another possibility would be to add a battery on to the plant which would enable the equipment to weather any fluctuations in the electricity supply. The feasibility of this option remains to be seen.

BIG AMBITIONS IN EUROPE Whatever the technical challenges, Lhyfe seems highly optimistic that the Plug Power electrolyzer will prove its worth. The companies have jointly announced their intention to install a total of 300 megawatts of decentralized electrolyzer capacity on land and at sea in Europe by 2025. The goal is to supply hydrogen to customers in industry and the mobility sector. On top of that, they are collaborating on a 1-gigawatt hydrogen production project. Lhyfe is keeping details of the initiative under wraps – except to say that it is due to take place in Europe. It could be some time before the partnering companies tackle any joint projects in North America.

Next in line, though, is the test in Le Croisic. The installation itself is pretty straightforward. The research platform will be towed into the harbor and fitted with the electrolyzer, which comes preassembled in a 40-foot (12-meter) container, complete with water treatment unit and other peripheral equipment. Offshore hydrogen production is then expected to start in late summer or early fall 2022 – albeit only on a small scale for the time being. ||

OXYGEN FOR THE SEA

Lhyfe has plans for around 60 projects across Europe. The schemes will use different models supplied by a variety of manufacturers, among them Nel and Green Hydrogen Systems, with the target of producing 10 metric tons of hydrogen a day. According to company founder Matthieu Guesné, this would be enough to supply an urban area such as Lhyfe's home city of Nantes, which has 0.6 million inhabitants, with sufficient hydrogen. In early December 2021, German railway company Deutsche Bahn announced that, from 2024, it will be sourcing green hydrogen from Lhyfe for its H2goesRail project. According to its statement, this will involve the installation of a dedicated electrolyzer from Green Hydrogen Systems, with an annual hydrogen production capacity of 30,000 kilograms. The electrolyzer will be sited in the German city of Tübingen and the resultant gas used for refueling a hydrogen train.

One notable aspect of Lhyfe's floating hydrogen production facilities is that the company hopes to release the oxygen produced back into the sea, in effect injecting oxygen into the salt water. It's an idea which netted the company a total of EUR 50 million in summer 2021 from investors such as SWEN Capital Partners and Banque des Territoires. To date, the funding has predominantly been used to employ a large number of young people and produce some nice-looking press photos. What will ultimately come of the plans, only time will tell.

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

GREEN HYDROGEN FROM GARBAGE

Several approaches to using bioenergy

Hydrogen is a jack of all trades. Above all, it should help to make industrial processes, heat supply and also the transport sector climate-neutral. Meanwhile, the H_2 itself must be green. Right now, the need is greater than the supply, but in addition to wind and solar power plants, biomass from waste or sewage sludge can also be used to produce green gas. There are already some promising approaches and projects in Germany, which could also give the struggling biogas sector a boost again.

Out of waste such as sewage sludge and plastic waste can be pulled out green hydrogen, the joker in the deck that the German government constantly brings up when it comes to the clean energy transition. The innovative process developed by a startup from Augsburg, Green Hydrogen Technology, consists of two stages. In the first stage, feedstock such as sewage sludge is converted into hot gas. Then, from this gas and plastic waste, gaseous H_2 is obtained. The second stage can also be operated independently and thus docked onto an existing biogas plant.

GREEN HYDROGEN TECHNOLOGY Very soon, the company's process will also be tested in practice. The next step on the way to series production is the construction of a test facility in Leoben, Austria. The casting of the concrete floor in November 2021 marked the start of construction. In May, installation of the 12-meter-high (39-foot) facility with a total area of about 150 square meters (180 square yards) should be complete. June 2022, hydrogen might be produced from plastic waste there for the first time. The facility will be erected by specialists from the firm R&R Beth, based in Bad Lobenstein, Thüringen.

As soon as TÜV has certified the composition of the hydrogen gas product, according to Green Hydrogen Technology, they will go to commercialization of the stage 2 plant. They want to address municipalities and industrial sites in particular. "The technology is particularly interesting for customers who already operate a biogas plant or have access to biogas. They only need stage 2 of our system. Instead of the hot gas from sewage sludge, the biogas is then used as the starting material," explained Jean Wiech, CFO of Green Hydrogen Technology.

The development costs for the process so far is around three million euros, which was financed by the company itself. Green Hydrogen Technology's business model would be to either operate the plant in cooperation with a company or municipality or alternatively to license use of the patented technology to them. The demand for green hydrogen is expected to increase further in the future, as many industrial sectors need to significantly reduce their CO_2 emissions.

The potential of biomass has also been confirmed by various scientific institutes. The paper "Wasserstoff- und Brennstoffzellenstrategie für die Region Stuttgart" (Hydrogen and fuel cell strategy for Region Stuttgart) states, "In addition to pyrolytic production processes of biomass and fermentation residues, hydrogen production from wastewater (via plasmolysis), the conversion of organic waste materials and the reforming of biogas are also very promising." This is from a study done by ZSW Baden-Württemberg together with Fraunhofer IAO and the DLR. That is, the Baden-Württemberg center for solar energy and hydrogen research, the Fraunhofer Institute for Industrial Engineering, and the German national center for air and space travel.

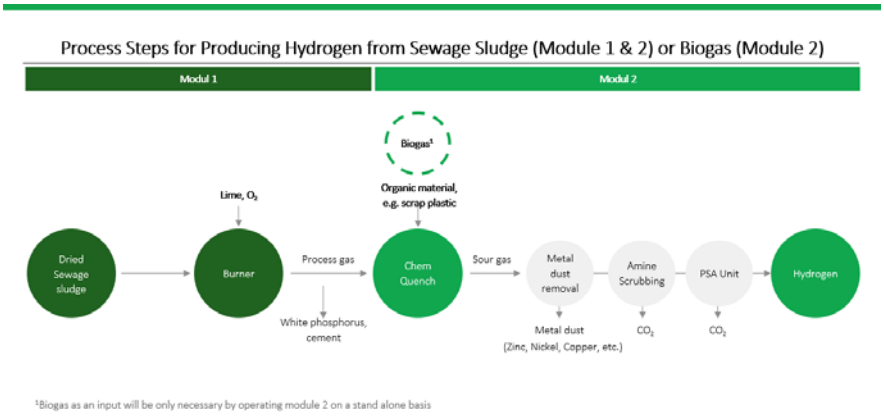


Fig. 1: Process flow: Out of dry sludge comes green and very pure H_2

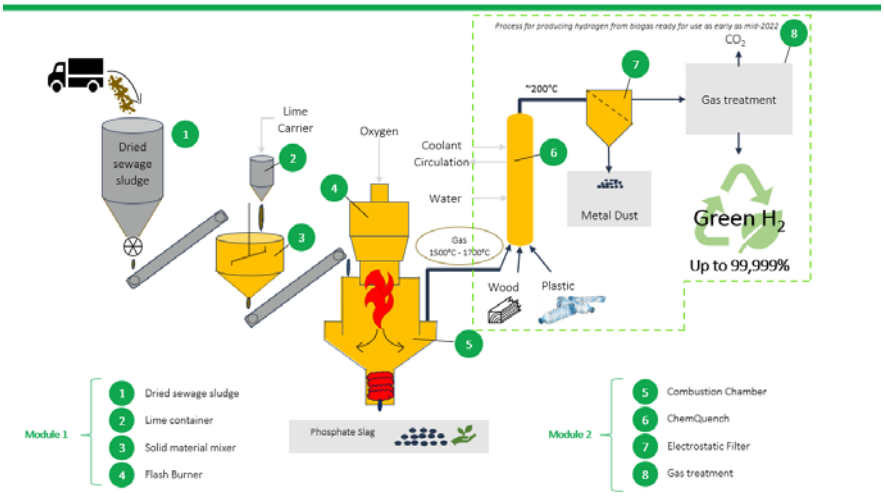


Fig. 2: Feedstocks such as sewage sludge are converted into hot gas (Module 1). Afterwards, gaseous H_2 is obtained by reaction of this gas with plastic waste (Module 2). [Source: Green Hydrogen Technology]

BAVARIAHYDRO Green Hydrogen Technology is building another hydrogen production facility, in the Bavarian city of Kelheim. The project Donau H2UB involves green hydrogen generation as well. The facility should be in operation by fall 2022. As reported by the hydrogen-specialized investing firm BavariaHydro, investment in this project is in the tens of millions. "We will use liquid manure from regional farmers, sewage sludge from the municipal sewage treatment plant and compostable waste as an energy source to produce, via the detour of biogas generation, green hydrogen from biomethane," explained Giorgio Karhausen, Head of Strategy and Project Development at BavariaHydro.

With the help of the innovative technology, BavariaHydro is pursuing a dual approach to sustainability. On the one hand, says Giorgio Karhausen, there is focused energy production from sustainable resources, to significantly reduce CO_2 emissions in transportation. On the other hand, it reduces waste at the same time, because waste such as liquid manure, green waste and sewage sludge is used. For the scientific monitoring, the city of Kelheim is taking part as a "hydrogen region" (Wasserstoffregion) in the HyLand program of the federal ministry for transport and digital infrastructuer (BMVI). "One kilogram of hydrogen corresponds to about three liters (0.7925 US gallons) of fuel. A public transit bus consumes an average of around 53 liters of fuel per 100 kilometers (22.53 US gallons per 100 miles)," explained Karhausen. He calculates that a hydrogen-powered bus could cover the same distance with about 7 to 8 kilograms of H_2.

MAINOVA With the project MH2Regio, Frankfurt am Main is breaking new ground. In this, only green electricity is to be used for H_2 generation by electrolysis. For this, an infrastructure for green hydrogen is to be established throughout the city on the river Main. In this way, the clean transportation transition is to be achieved in local public transport as well as in the transport of heavy materials and wares.

Participating in this project are the regional energy supplier Mainova and the city waste removal company FES (Frankfurter Entsorgungs- und Service) as well as their jointly operated waste-to-energy plant MHKW Frankfurt (Müllheizkraftwerk Frankfurt), which is to supply the green hydrogen. In this approach, thermal energy is generated during waste incineration, which is fed to two steam turbines via a steam circuit. The turbines generate electricity for the grid and for H_2 production. Since 50 percent of the incinerated waste is bio-sourced, from wood and green waste, the electricity generated in this way is considered green electricity and is also certified accordingly.

BTX ENERGY At the university of applied sciences Hochschule Hof in Hof, Bavaria, the startup BtX Energy developed a process to produce high-quality hydrogen from biomass. In addition to the marketing of turnkey plants for steam reforming of biogas, the young business would like to create a complete concept for local production and use of green hydrogen in Region Hof. Behind it is the engineer Andy Gradel, who dealt with the subject in his doctoral thesis. "With this, the production costs per kilogram of hydrogen can even be significantly lower than with electrolysis," hopes Gradel.

In addition to further development of a wood gasifier to market readiness, he wants to above all bring hydrogen production stations for biogas plants to market. After all, the biogas industry is threatened with complete dismantling in the coming decades, since the remuneration for renewable-sourced grid feed-in, set out by the German renewable energy law (Erneuerbare-Energien-Gesetz, EEG), stops after a 20-year period of plant or installation operation. "While most players in the energy market are focusing on electrolysis with surplus electricity from renewables, the new technology makes turnkey plants for steam reforming of biogas possible," says Dr. Tobias Plessing, professor at Hochschule Hof. This could help the struggling biogas industry enormously.

Fig. 3: Business founder Andy Gradel (on the left) presents a turnkey plant for steam reforming of biogas [Source: BtX Energy]

The first plant for demonstrating the functionality and economic efficiency is already under construction. "Everywhere hydrogen can drive the energy transition forward is where agriculture, the green waste processing industry and many other players can make their contribution. Decentralized, immediately convertible, at full load around the clock and, because of the direct material conversion, with impressively high efficiency. We want to support this," says BtX-Energy founder Gradel.

ELECTROCHAEA Yet another Bavarian company, Electrochaea, wants to help decarbonize the heat and transportation sectors (see H2-international Oct. 2018). The company from Planegg, near Munich, has just won over the US oil company Baker Hughes as a 15-percent shareholder. Their technology enables the production of low-carbon synthetic natural gas (SNG) from captured CO_2 and green hydrogen.

Together, the companies want to scale the technology and accelerate the construction of larger plants. Baker Hughes already possesses carbon capture technology tailored to biomass, waste incineration or even industrial plants. The US company wants to use this method to open up new areas of energy-related carbon dioxide utilization (CCU: Carbon Capture and Utilisation). The CO_2 can come from a variety of sources, including biogas, fermentation off-gas, power plants and factories.

"The provision of synthetic natural gas on a grid energy scale would be a remarkable development for energy consumers," says Mich Hein, CEO and Managing Director of Electrochaea. Customers could thus reduce the carbon footprint of the existing gas infrastructure, according to Hein. ||

Category: Energy Storage | **Authors:** Martin Wietschel, Christopher Hebling

HYDROGEN META-ANALYSIS

What conclusions can be drawn from energy system studies?

Three Fraunhofer institutes have analyzed the potential demand for hydrogen and hydrogen derivatives in the runup to 2050 in a meta-study commissioned by Germany's National Hydrogen Council. As part of their meta-analysis, the ISI, ISE and IEG institutes examined recent system studies for Germany and the European Union which described different scenarios with ambitious climate goals. The studies being assessed took a systematic view of the energy landscape, with a strong focus on technical and economic elements. Not all aspects of a transformation pathway were taken into consideration, such as domestic jobs and value creation, existing regulation or adopted support measures. These studies did not work with predictive scenarios; rather they outlined possible developments and technical-economic pathways based on a range of assumptions.

In terms of important factors affecting the demand for hydrogen and hydrogen derivatives, it was noted that the greenhouse gas reduction level has a high degree of influence. Generally speaking, the demand for hydrogen and its derivatives increases as reduction targets become more ambitious. In most studies, it was observed that demand started to rise substantially only when greenhouse gas targets were more than 80 percent, and then continued to increase significantly.

Carbon capture and storage was only seen as relevant in a few national studies. In some EU studies, however, this technology played a somewhat more important role in certain scenarios. The potential role of carbon capture and storage as a game-changer for hydrogen demand should therefore be observed closely and further analyzed.

Most 95-percent reduction scenarios and net-zero scenarios resulted in a relevant requirement for hydrogen and derivatives in the long term (to 2050), with generally higher requirements for synthetic products. For this reason they can be considered important building blocks for ambitious climate policy.

In relation to sourcing, it could be stated that demand particularly for synthetic products in 2040 and 2050, and to a degree in 2030, will be mainly (> 50 percent) covered by foreign supplies according to many studies. It was therefore possible to conclude that the development of strategies and the implementation of large-scale hydrogen production, including transport and distribution infrastructure, should be instigated in good time.

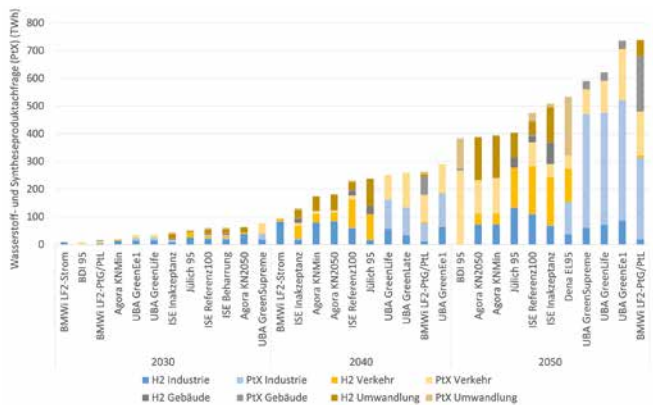


Fig.: Overview of demand for hydrogen and derived products (PtX) in various sectors

In 2030, the demand for hydrogen and hydrogen-derived products expected in the system studies/scenarios was on average only 80 terawatt-hours as, for the most part, the new and ambitious climate goals from the European Green Deal and the amendment to Germany's climate action law were not taken into consideration. The actual requirement was clearly underestimated. A figure of between 400 terawatt-hours and 800 terawatt-hours was expected for 2050. All scenarios, therefore, assumed a much lower requirement for hydrogen and derivatives than is the case for today's fossil fuels (energy requirement in 2020: 2,500 terawatt-hours, 2030: 2,100 to 2,500 terawatt-hours, 2050: 1,400 to 2,100 terawatt-hours).

It therefore followed that hydrogen and its derivatives are not only necessary for the energy transition but are also seen as valuable energy carriers and chemicals. This was also evidenced in their costs – when shown in the studies – which were much higher than current conventional energy carriers.

POTENTIAL DEMAND FROM AN ARRAY OF SECTORS Many studies demonstrated a very high requirement in the transport sector (2050: 150 to 300 terawatt-hours). In 2030 demand was still low and was more apparent for hydrogen-derived products. This was due to the urgency of reducing greenhouse gas emissions and consequently there was an associated need for alternative fuels for existing vehicles. There was an undisputed high demand from within the international aviation and shipping sectors, with demand for synthetic products including biofuels in 2050 noted to be 150 terawatt-hours to 200 terawatt-hours. This field of application was considered a no-regret area. Early moves should be made here and incentive schemes introduced in order to ramp up the market.

A portion of the studies noted an increasing role of hydrogen in heavy-duty vehicle transportation, including in the short term (2030). Nevertheless, there was found to be competition with direct electricity use through overhead line equipment and/or battery-powered trucks. Because of the high relevance of greenhouse gas emissions, a decision should be made in the next three to four years in terms of which particular alternative solutions are to be implemented since the infrastructure, for instance, takes time to put in place.

The results were widely spread when it came to cars and light- to medium-duty trucks and the relevance of hydrogen. Those studies which saw a use for hydrogen in this domain indicated that significant growth would only occur after 2030. Nevertheless, some ambitious rollouts of hydrogen-based solutions for road transportation were envisaged in countries which are major vehicle exporters, especially Japan, Korea and China. These scenarios should be taken into account when drawing up strategy proposals.

The potential requirement for hydrogen and hydrogen derivatives in industry was also, for the most part, judged to be high (2050: hydrogen, derivatives, biofuels up to 500 terawatt-hours). Many studies reported a relevant hydrogen requirement of up to almost 50 terawatt-hours in 2030. The applications that were classed almost entirely as having relevance and being no-regret strategies were as follows:

- Hydrogen direct reduction of iron ore for steel production
- Ammonia synthesis
- Ethylene (predominantly via the methanol-to-olefins route)

The use of these substances particularly in hard-to-abate areas of industry should be accelerated in the next few years so that it can be put into widespread practice in the medium and long term. This also links with the long investment cycles in the associated industrial sectors.

There were wide-ranging assessments of energy use in industry in the studies/scenarios, some of which viewed energy use as less relevant. One of the reasons for this was the existing competition with electricity use, even at low and medium temperature levels. In terms of energy usage at higher temperatures, it was unclear which alternatives would be the most promising. More clarity should be sought on this matter in the coming years.

Heating for buildings was seen as a relevant potential requirement in some studies, albeit with large variations, with demand for up to 200 terawatt-hours stated for hydrogen, derivatives and biofuels by the year 2050. There is competitive pressure in the heating sector caused, among other things, by a combination of energy-saving measures and heat pumps or heating networks. The studies tended to see a possible requirement in the longer term. Whether a hybrid solution of heat pumps/heating networks/insulation on the one hand or gases on the other hand would be the most sensible choice is still to be determined due to the need for parallel infrastructure.

In the transformation sector (electricity and heat generation, refineries), a somewhat lower demand for hydrogen and hydrogen-derived products was indicated in comparison with transport and industry. This was reported to be between 50 terawatt-hours and 150 terawatt-hours in 2050.

In the case of power generation, importance was attached to the issue of reconversion. A consensus was found here that the peak loads would be covered by hydrogen in the long term. However, the studies/scenarios generally identified only low levels of expansion or none at all in the lead-up to 2030 (up to 20 terawatt-hours). Hydrogen combined heat and power plants were only then relevant if the hydrogen costs were favorable. In the case of greater direct electrification, more flexibility measures are needed in the transformation sector. The studies and scenarios judged that larger-scale implementation would be necessary only after 2030. Nevertheless, it is prudent to test out incentives today that encourage hydrogen readiness for new-build plants in order to be appropriately prepared for the future.

The prospective role of refineries was not described in detail in the majority of studies, presumably because of the challenges associated with their modeling and evaluation. This also raises the question of how other vital refinery products for non-energy uses will be supplied if refinery capacity declines as forecast due to the decrease in conventional fuels. However, the early adoption of electrolytic hydrogen could replace the use of fossil-based hydrogen at refineries. It was therefore judged to be a no-regret strategy. Certain conventional refinery products, for instance gasoline or diesel, will likely be in less demand in the future while other products will still be needed. Nevertheless, this involves complex production systems with joint products, making the transformation pathway challenging.

Key parameters for the cost-effective production of green hydrogen were the availability and cost of renewable power, the investment in electrolyzers and their full-load hours along with cost-effective transport options and/or infrastructure. In future, there will be a requirement for electrolyzer capacity on a relevant scale. In order to cover the future need for hydrogen and hydrogen derivatives, electrolyzer technology should therefore be introduced to market more broadly. When considering German installation capacity, most studies/scenarios foresaw a capacity of over 5 gigawatts by 2030. The range given for the period to 2040 was 10 gigawatts to 35 gigawatts; for the period to 2050 it was 43 gigawatts to 63 gigawatts. Here it is important to note that the planning and construction of these types of plant require extensive lead times.

NO-REGRET RULE

In this scenario, the use of hydrogen and/or hydrogen derivatives was seen as essential due to the lack of viable alternative technologies. But even in fields of application where that does not hold true, they can play an important role in the future since they are, for example, more economical or better accepted than competing options. Here, the assessment was not clear as some of the system studies under examination produced differing results. A lack of clarity was also due to the existence of a number of different competing technologies, some of which were rated more favorably.

In the case of hydrogen derivatives, further considerations included investment in further transformation facilities as well as costs for carbon dioxide, namely extraction and transportation. Carbon dioxide sources are therefore necessary. In addition, technologies for sustainable carbon dioxide extraction (biomass, direct air capture) should be developed further and brought to market (no-regret strategy).

The information on hydrogen requirements and import shares leads to the conclusion that it is prudent to build a European hydrogen network. Since the construction of a pipeline network is extremely time- and capital-intensive, such a project should be planned for and carried out in good time.

Little attention was paid by the studies to the question of alternative generation pathways based on fossil energy sources through the steam reforming or pyrolysis of natural gas in order to produce blue or turquoise hydrogen. For this reason there were few remarks on the subject. These pathways could, however, be highly relevant in future because blue hydrogen, at least, could be relatively less expensive than green hydrogen according to current knowledge. Nevertheless, several questions still remain unresolved, for example, the issue of the acceptance of such a solution, the possibly limited storage potential for carbon dioxide, the upstream emissions from natural gas and the time required to build infrastructure. The conceivable role that blue hydrogen could play should therefore be analyzed more deeply and without delay, for blue hydrogen may potentially be considered only a temporary solution. ||

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Category: Electric transportation | **Authors:** Manuel Schaloske, Lena Geiger

H2BW – CROSS-SECTOR UMBRELLA FOR H_2 ACTIVITIES

Establishment of a hydrogen economy in Baden-Württemberg

How can hydrogen find greater use as an energy carrier? What opportunities are available for regional companies, and where will support be offered? To provide answers to these and other questions and thus contribute to the establishment of a local hydrogen economy, the federal state Baden-Württemberg (BW) has created Plattform H2BW. Since spring 2021, regional skills and expertise in the field of hydrogen and fuel cell technology have been bundled under the umbrella of this platform and will be promoted further as such in the future.

The application of hydrogen and fuel cells has been tested, developed and further researched in Baden-Württemberg for years. Numerous players in the country are already active in the field of hydrogen and fuel cell technology today and justify the high economic potential, which was identified in the study published in 2020, "Potenziale der Wasserstoff- und Brennstoffzellenindustrie in Baden-Württemberg." The framework conditions for the expansion of a hydrogen economy are thus in principle given. However, to facilitate the use and further development, Baden-Württemberg is pursuing its own hydrogen strategy, in which the networking and bundling of local H_2 activities is central.

STATE INITIATIVE In December 2020, "H_2-Roadmap Baden-Württemberg" was published. On the basis of 29 measures, this sets out the strategic steps for establishing the state as a location for driving forward hydrogen and fuel cell technology. For this purpose, a comprehensive participation process took place, involving more than 300 stakeholders from industry, academics, associations and politics. To coordinate the individual measures and ensure their implementation, a central institution should then be created to, at the same time, serve as a common umbrella for the diverse hydrogen activities in the country. One that is cross-sector and unifying.

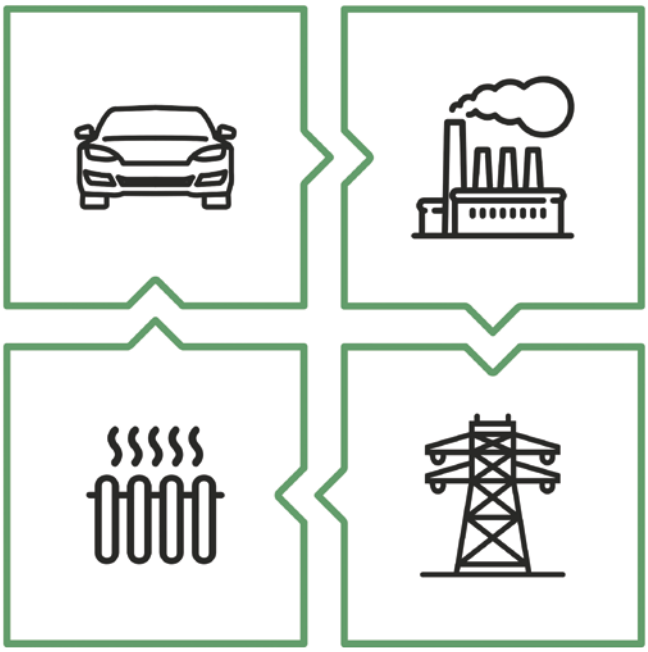

Fig. 1: Sector coupling is the guiding motif of Plattform H2BW

For this purpose, on March 1st, 2021, the state government established Plattform H2BW. The government-owned platform is located within and coordinated by e-mobil BW, the state agency for new mobility solutions. As a first step towards implementation of the H_2-Roadmap, Plattform H2BW is covering the full range of topics within the entire hydrogen value chain across all relevant sectors (see Fig. 1). The field of activity is therefore tailored to this and essentially comprises five core areas.

PUBLIC RELATIONS AND KNOWLEDGE TRANSFER Plattform H2BW is now present in the physical as well as the digital. The goal is to be a single point of contact for people, those experienced in the industry as well as newcomers, to clear up questions around hydrogen and fuel cell technology, and to point out opportunities and possibilities in the hydrogen economy.

NETWORKING With the state's fuel cell research cluster Cluster Brennstoffzelle BW, Plattform H2BW has an effective network, which will be expanded to include more players and from all sectors. Since Plattform H2BW started its work, they've already been able to acquire more than 40 new partners. The platform is also in contact with other regional and national networks and institutions. An important task is to further develop these networking activities and to be a contact point for initiatives beyond the state's borders.

FUNDING For a successful implementation, the measures in the roadmap could be supported with programs that Plattform H2BW would be a part of or initiate. The recent calls for proposals by BW's Zukunftsprogramm Wasserstoff ZPH2 and the EU's EFRE Model Regions for Green Hydrogen will support projects for testing out or applying hydrogen as an energy carrier. In coordination with the German ministry of environment and the project executing agency Projektträger Karlsruhe, Plattform H2BW will drive forward the design and implementation of further support measures in the future.

ACCOMPANYING RESEARCH The results of such projects will be evaluated and classified through concomitant research, which is made possible by the platform. In this way, potential obstacles can be recognized early and communicated to the relevant ministries.

POLICY ADVISING Consequently, Plattform H2BW inherently has the essential duty to pass on the findings to decision-makers in the country and to offer advice to the public sector. This includes the implementation of European directives as well as the strategic further development of the H_2-Roadmap (see Fig. 2).

Fig. 2: The fields of activity of Plattform H2BW [Source: Plattform H2BW]

Plattform H2BW is exemplary of how individual regional activities can contribute to implementation of a higher-level strategy through a central umbrella organization. As an essential point of contact for all interested in becoming involved in the field of hydrogen and fuel cell technology in Baden-Württemberg, whether as a business, academic institution or public sector institution, the platform unifies the skills and expertise present in the state in this industry. Furthermore, Plattform H2BW functions as a postal address for all stakeholders outside the state who have questions about hydrogen in Baden-Württemberg. ||

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FUEL CELLS IN OFF-ROAD RALLYING

Breathtaking racing championships often serve as a test bed for new technologies. But it's not just Formula 1 or Formula E which are putting the latest engineering advances through their paces; off-road races are also getting a look-in.

And now two Formula 1 racing drivers – Lewis Hamilton and Nico Rosberg – are competing in the electric off-road racing series Extreme E, albeit "merely" as team owners. What is special about these racing events is that the all-electric SUVs are powered via AFC Energy charging systems that incorporate a fuel cell and a battery storage unit. Alejandro Agag, Founder and CEO of Extreme E, said: "Hydrogen fuel cell charging in the world of motorsport is truly ground breaking, and Extreme E is the first event of its kind to utilise this technology. The product from AFC Energy offers an end-to-end emission free solution for running our electric vehicles, and I hope it will inspire other organisations to investigate sustainable low emission alternatives when running their events."

Also generating headlines is Gaussin's H2 Racing Truck which was unveiled in November 2021. The French manufacturer of electric transport platforms is planning to enter the truck in endurance races such as the Dakar Rally. The vehicle is expected to go into series production in 2022. The H2 Racing model is based on a lightweight chassis which holds the electric drive unit (a pair of 300-kilowatt e-motors), the 380-kilowatt fuel cell, 80 kilograms of hydrogen and an 82-kilowatt-hour battery pack. The truck features all-wheel drive and claims to reach a top speed of 87 miles or 140 kilometers per hour. Its standout look was created by iconic vehicle designer Pininfarina. ||

Fig.: Gaussin H2 Racing Truck [Source: Gaussin]

Category: Electric transportation | **Author:** Sven Geitmann

CIN CAN'T MAKE HEADWAY

Is Plug Power helping the German intralogistics industry get going?

Fig. 1: The Calvera Industrial Group is building special stations in Spain that can supply 120 fuel cell forklifts per day [Source: Calvera]

Powered industrial trucks are available with diesel, liquid gas and electric drives. For some years now, in addition to rechargeable batteries for electric forklifts and palette jacks, there has also been the possibility of using a hydrogen tank together with a fuel cell. This has been done a zillion times as well in North America. In Europe, the number of hydrogen-powered vehicles remains in the three-digit range. Now, Plug Power is planning to establish a European center in Nordrhein-Westfalen. Is this the starting signal for the upscaling of fuel cell forklifts in the European Union?

On October 5th, 2021, the members of the business cluster Clean Intralogistics Net (CIN) met in a hybrid part live, part virtual symposium. However, there was not really much new to report. The speakers reminisced on previous events, as if the last few years had not passed this consortium at all.

The now 14 member businesses of the business association founded by NOW in 2016 presented mainly themselves, since there didn't seem to be any really interesting news. No spectacular projects, no rapidly increasing sales figures or earth-shattering technical breakthroughs, nothing remotely reminiscent of a spirit of optimism that can otherwise be seen in the H_2 sector at present.

HOPING FOR HELP FROM OVERSEAS There has certainly been a further development. For example, the number of H_2-powered industrial trucks in operation worldwide increased from around 21,000 at the end of 2018 to around 40,000 at the end of 2021. However, Europe played only a marginal role here. Even though the number of FC forklifts and palette movers doubled during this period, it was only on a low level, from 300 to 600.

Appropriately, Kai Hesse, one of the spokesmen for the industry cluster, relatively unemotionally presented the network as well as just the activities of its sponsor, Toyota Material Handling Deutschland, although Toyota is carrying out quite interesting projects in Asia as well as in the USA. Similarly, his deputy, Dr. Thomas Irrenhauser, presented his employer, the BMW Group, as well as the demonstration projects in its facility in Leipzig. Although the symposium program had variety and was moderated well by Tobias König, head of the powered industrial truck division at the German national organization for hydrogen and fuel cell technology (NOW), the lasting impression was that only the USA can provide more momentum.

It really seems that Tim Schultz from Plug Power Europe alone had something to report. His presentation from the point of view of a publicly traded North American company gave perspective on what it's in principle all about and where it might be going. While the other participants mainly reported about the past and about previous attempts, he sketched out how a fuel cell manufacturer that now employs 1,800 people worldwide thinks and acts.

PLUG POWER IS COMING TO DUISBURG Over the years, the US company has developed from a pure manufacturer of FC forklifts to an all-in-one supplier. The group based in New York State does not only offer a range of powered industrial trucks (PITs) from 24-V low-lift palette jacks to 80-V 5-ton lift trucks. Plug also offers the refueling infrastructure and, after takeover of the electrolyzer manufacturer Giner ELX, even the hydrogen generators required for this.

On the user side, Plug Power entered into a joint venture with Renault in June 2021 called Hyvia, thus gaining access to the entire vehicle segment. And even stationary FC systems are to be part of the portfolio in the future. October 2021 was the start of another joint venture, with SK E&S, part of the South Korea-based SK Group. With this, Asian H_2 markets are jointly offered fuel cell systems, H_2 filling stations, electrolyzers and green hydrogen.

In order to gradually open up the European market as well, Plug plans to open a European base in Duisburg in 2022. Schultz already announced that around 60 employees will be hired at the 6,500 m^2 (70,000 ft^2) innovation center, which will house development laboratories as well as a shipping and logistics center. Plug Power Germany GmbH had already been established.

In response to the question from H2-international as to whether his parent company sees great potential in Germany, Schultz confirmed, "Yeah,

we see a strong growth." With regard to the national hydrogen strategies of the neighboring countries, he also stated, "We see that the issue is now on the political agenda." Andy Marsh, CEO of Plug Power, was more articulate, saying end of November, "Plug Power intends to play an important role in the development of green hydrogen in Europe and to make a significant contribution to the European hydrogen strategy. Establishing a headquarters in the Port of Duisburg supports our ambitious goal to lead the development of a global green hydrogen ecosystem."

On October 14th, 2021, in an online symposium lasting several hours, Plug Power outlined how diversified its portfolio is. According to the company, it has now installed more than 400,000 fuel cell systems and developed and built 110 filling stations, capable of delivering more than 40 tons per day (tpd) of hydrogen. In the next few months, two sites are to be built in North America, each capable of producing 15 tpd. The first factory is expected to cost 100 million USD, the second "only" 75 million USD. After that, the construction of a 40-tpd plant is planned. A total of four factories are to be in operation by the end of 2022. By 2025, Plug will be producing 500 tpd in North America.

FC PITs consume 1 kg_{H2} per day, light commercial vehicles require around 6 kg and large trucks 50 kg. Plug customer Amazon alone had installed around 52,000 FC systems and over 165 H_2 refueling stations by the end of 2021, many of which were produced at the 2.5-GW gigafactory for fuel cells and electrolyzers in Rochester, NY, which is powered by hydroelectricity from Niagara Falls.

Just before the mentioned symposium, Andy Marsh had signed with Dr. Andrew Forrest, head of Fortescue Future Industries (FFI), a letter of intent for a 50/50 joint venture to build a 2-GW gigafactory in Queensland, Australia. Marsh had effectively told Forrest that they should build fuel cells and electrolyzers in Australia together to "dominate the world together."

In addition, Plug Power acquired a US service provider for liquid hydrogen, Applied Cryo Technologies (ACT). ACT provides technologies, equipment and services for the transportation, storage and distribution of liquefied hydrogen, oxygen, argon, nitrogen and other cryogenic gases.

ADVANTAGES OF FUEL CELLS IN THE LOGISTICS SECTOR

- The service life of H_2 systems is longer than that of battery systems.
- A FC forklift truck can be refueled in five minutes and is then immediately ready for use. The charging time of a battery is about eight hours.
- Storage space reserved for charging and maintenance of battery systems can be freed up.

In Germany, Mercedes-Benz AG, among others, is still employing Plug Power's Gendrive systems. They are integrated in the Linde forklifts in its demonstration project in Düsseldorf. For the practical phase of this project, which will last from June 2020 to July 2022, a total of ten FC forklifts of different weight classes with 24-, 48- and 80-volt systems were acquired and will be tested. However, the 48-V fuel cell systems showed, as remarked by Matthias Kromm and Wolfgang Radtke, both from Daimler, the problems of too high heat and noise emissions. The forklift operator's thigh would get unacceptably warm. That is why measures were taken to reduce the noise level, after the noise emissions had been significantly above the value of 74 decibels specified by the manufacturer and up to 90 decibels in some cases.

FFZ70 PROGRAM COMPLETED In Germany, the BMW facility in Sachsen is still considered the measure of all things. First, the demonstration project H2IntraDrive was run with 11 forklifts and pallet jacks (project duration 2013 to 2015; see H2-international Jan. 2014). The successor program FFZ70 (04/2017 to 03/2021; see H2-international Jan. 2016) with 70 hydrogen-powered PITs was completed in fall 2021. In the meantime, 118 FC vehicles are in operation in the various production halls of the BMW facility, which have access to four H2 refueling stations and consume an average of 50 kg of green hydrogen per day. In total, the FC PITs there account for around 20 percent of the European H2 fleet.

The fact that these figures represent only a fraction of the North American market was only addressed when specifically asked by viewers. On one of the slides from Kai Hesse,

however, it is clear that "lead market USA" consists of more than 35,000 FC PITs on account of "investment tax credits" (ITCs), tax concessions, in the country. Tim Schultz confirmed that ITCs in the USA had been very helpful and had been instrumental in making it economical to refurbish fleets. Accordingly, the CIN spokesman stated, "Maybe we can learn a bit from the USA." With mild resignation, he conceded, "Maybe the American company is somewhat more flexible. This requires some courage." Attempting to sound motivational, he also added, "The risk is manageable."

Germany also promotes the PIT sector, but does not seem to have any strategy on how to initiate a market there. While the Japanese strategy clearly states that it wants to bring 10,000 FC PITs into warehouses and production halls by 2025, in the Federal Republic of Germany, it is hoped that the market will be activated as a result of the national innovation program for hydrogen and fuel cell technology (NIP). NIP II has already been running since 2017. Together with NIP I, already nearly 20 million euros has been allocated to intralogistics applications, including two calls for market activation, but these funds and measures have so far produced few discernible successes. As of yet, there are only 197 planned PIT units.

The potential areas of application are many, whether within the automotive or food industry, in warehouses or industrial parks, in harbors or at airports, in the shipping business or in the logistics sector. There's no shortage of big name potential players either. Nevertheless, it is not clear that, aside from the demonstration projects, there has been much interest in replacing the existing fleet of powered industrial trucks in Germany.

NO HEADWAY MADE IN STANDARDIZATION When asked by H2-international what was needed to accelerate upscaling, the CIN members unanimously identified standardization as the key component. However, this bullet point has been on the agenda in the PIT sector for several years. Progress has only been moderate. NOW has been working on an industry standard to make PITs H_2-ready since 2019. There is also a working group within the CIN, led by Kai Hesse. Nevertheless, there are still no verified refueling protocols like those that exist in the passenger car sector, for example.

The German ministry for transport and digital infrastructure (BMVI) had also provided 4 million euros in 2019 and again in 2020 for the purpose of defining such standards. But apparently there are still quite a few unanswered questions, on top of the fact that the costs are still too high. Which is why Tim Schultz suggested funding incentives to facilitate infrastructure development and reduce the price of H_2. So far, green hydrogen is comparatively expensive, at 10 euros per kilogram. The target is a price level of 4 to 5 euros. In order to put hydrogen in a better position than fossil fuels in the future, some representatives openly advocated an increase of the CO_2 taxation during the symposium.

The CIN members hope for a noticeable cost reduction from symbioses that could arise from multi-purpose use of the infrastructure. By using H_2 storage vessels and dispensers not only for PITs but also for trucks and buses, the initially high investment costs would more quickly reach economic viability. These vehicles indeed all use 350-bar tanks, but the dispensing for PITs is relatively low at 0.6 to 1.8 kg_{H2} per refueling, whereas commercial or rail vehicles require 5 to 100 kg_{H2}.

INTERVIEW

H2-international asked Ralf Glaser, Chief Communication Officer of 1886Ventures, what, in his view, are the obstacles that prevent businesses in this country from switching to FC forklifts, and what would have to be changed in order to achieve upscaling of FC PITs in Europe.

"Medium-sized and large industries in Germany and Europe have set themselves ambitious targets for CO_2 neutrality. Fuel cell technology will play an important role regarding this, among other things, in intralogistics. We can already observe this very well in the USA and Japan. An industrialized country like Germany will follow suit in time. This is also confirmed by our discussions with interested representatives of the most diverse branches of industry in Germany.

Fig. 2: The Globe XLP80 fuel cell stack [Source: Globe]

Nevertheless, FC technology is currently at an economic disadvantage in the initial procurement stage for the operators compared to conventional technologies. In our experience, this is due to the higher acquisition costs and the often already depreciated infrastructure of conventional drives. The US market also shows us how this gap can be overcome. The incentives for a changeover are much more pronounced here than in Germany. Also, in our view, the administrative effort required to obtain funding in Germany is still too high.

And yet there are positive developments that make us confident that FC technology will become a real alternative in intralogistics. In addition to government support, CO_2 taxation will make green technologies more attractive. On the other hand, we expect an additional boost as soon as the cost of green hydrogen falls below the level of 5 euros per kg."

1886Ventures has operated for many years under the name Lab1886 as an innovation hub for Daimler AG. December 2020, the Swabian region-based company still only held a minority stake of ten percent as a strategic partner. The majority of 80 percent was taken over by RB-Capital GmbH. A further ten percent is held by the software company GFT Technologies SE. A startup co-founded by Steven Oji, Globe Fuel Cell Systems, is focused on the intralogistics vehicles sector. For this purpose, the company designed the GLOBE-Aggregat XLP 80, a fuel cell stack with a power of 50 kW. The currently still quite unknown and comparatively small innovation lab is thus positioning itself to become an alternative to Plug Power in Europe. Oji explained to H2-international, "We see an opportunity for a European player."

In addition, forklifts cannot easily be filled at H_2 refueling stations for buses, because the test surge alone, which checks the system for leaks at the start of the refueling process, would fill up the PIT tank. The overlap between passenger cars and PITs is likely to be quite small as well, since H_2 passenger cars use 700 bar as storage pressure. Against this background, it can almost be considered a success that the major players have agreed on 350 bar in the powered industrial truck sector. Schultz, in any event, confirmed that this level of pressure had proved its worth and was sufficient in view of the durations of the work shifts in facilities.

THIRD CALL FOR PROPOSALS IN MARKET ACTIVATION NOW hopes for a further, the third, funding call for market activation of powered industrial truck fleets with fuel cell drive systems. As things stand, this could take place in 2022. Funding of the vehicles and the accompanying infrastructure consists in contributing 40 percent of the additional costs compared to conventional technology. However, only the investment costs, not operating costs.

These market activation programs may be why the forklift manufacturer Jungheinrich, in addition to its around 100 existing units, wants to cooperate with Plug Power and Air Liquide to put 200 additional FC forklifts in operation.

Meanwhile, Hyundai announced that the South Korean vehicle maker is also getting involved in the PIT sector. In fall 2020, Hyundai Mobis announced that, together with the Hyundai Motor Company and Hyundai Construction Equipment, it would develop medium to large FC forklifts and commercialize them by 2023. Hyundai Mobis, the subsidiary of Hyundai Motor Company responsible for the mass production of fuel cell systems, explained, "As the H_2 fuel cell system used for automobiles could not be transferred to its H_2 FC forklift, Hyundai Mobis developed a tailored system for it." ||

FUEL CELLS ENTER LUXURY MARKET

Fig.: Thierry Bolloré
[Source: Jaguar Land Rover]

Support for hydrogen came from unexpected quarters in 2021. British luxury vehicle manufacturer Jaguar reported last June that its Land Rover brand would be developing a prototype of a hydrogen-powered Defender. CEO Thierry Bolloré had previously announced plans to decarbonize all vehicle models by 2036 as part of his Reimagine strategy. However, the first all-electric version of an SUV is not due to launch until 2024 at the earliest. Nick Rogers, who heads up JLR's product development, told vision mobility magazine: "It's absolutely really, really important; we truly believe that hydrogen has a real place and opportunity, particularly in the bigger vehicles."

Similar noises are being heard from Russia. It was there, at an economic forum in September 2021, that luxury automaker Aurus presented its hydrogen-propelled car. An SNA journalist reported that Aurus Hydrogen has a range of over 370 miles (600 kilometers). According to a statement by Denis Manturov from the Russian trade ministry, this model, which has been developed by the Russian automotive research institute NAMI, could go into series production within a few years. Nevertheless, this would initially take the form of a hybrid vehicle. ||

Category: Electric transportation | **Author:** Michael Nallinger

MUCH ENCOURAGEMENT AT THE PREMIERE

IAA Mobility held in Munich for the first time

Fig. 1: The organizers brought the trade fair to the place where mobility primarily takes place: downtown [Source: IAA Mobility]

The two-part trade fair concept was particularly well received by exhibitors. In addition to the halls at the fairgrounds, the Munich city center was also used as an exhibition area. Especially suppliers in the area of fuel cell drives had new things to present. They recognize the high market potential and feel that the technology will penetrate the passenger car sector through the commercial vehicle sector.

"It's all in the mix" is what can be said to characterize the restart of the globally significant automotive show IAA Mobility. Since 1951, Frankfurt am Main has been hosting IAA every two years as the International Motor Show. But the far-reaching transformation processes in the automotive industry have swept away the venue, just as they have swept away parts of the previously predominant business model in the industry. As a visitor, this was immediately apparent upon entering the exhibition halls. Instead of flashy sports cars, visitors entering Hall B1 were greeted by a so-called start-up area with a lounge for networking.

In addition to electric cars, the stands of the 774 exhibitors also featured e-bikes, e-scooters, mobility services and urban planning tools. "Here in Munich, we presented and discussed together what needs to be thought of together in the future," said Hildegard Müller, president of the association Verband der Automobilindustrie (VDA), which together with Messe München organized this year's IAA Mobility. It was a good mixture of exhibitors. Automakers were represented at a total of 98 exhibit spaces, but also present were 75 bicycle brands, 152 supply and tech companies, and 78 startups.

The organizers also brought the trade fair to the place where mobility primarily takes place: downtown. A so-called Blue Lane, where purely emissions-free vehicles could be tested, connected the exhibition grounds, occupied area of 195,000 m^2 (233,000 yd^2), to the exhibition space in the Munich city center, 65,000 m^2 (78,000 yd^2). There was some criticism from citizens and local politicians of a one or other too massive pop-up stand, the so-called Open Space locations, in the city center. Because of this, the responsible committees of the Munich city council said that the areas should be more strictly regulated in the planning for 2023 and 2025.

The vehicles on display were clearly dominated by electric drives. With few exceptions, combustion vehicles were limited to a special exhibition area. Purely battery electric vehicles (BEVs) dominated the scene, but those searching for new developments in fuel cell drive systems could also find them at supplier stands.

"TRADE FAIR WITH INTERNATIONAL APPEAL" The trade fair concept was well received by exhibitors. "As a lead market for vehicles and mobility solutions, Germany needs a trade fair with international appeal like the IAA, even though the number of international visitors in particular was low this year due to the pandemic," said Dr. Achim Moritz, product manager of Fuel Cell Mobility Solutions at Robert Bosch GmbH. He expressed that he fully supports this trade fair concept and welcomes the stronger inclusion of citizens and end consumers through offers of testing, participation and dialogue. For him personally, it was impressive to see how much importance was attached to electrification and sustainability of transport throughout the trade fair.

HYDROGEN AS A FUTURE-FORWARD TOPIC AT SCHAEFFLER The Schaeffler Group also considered the trade fair to be a "complete success." The great interest of the visitors showed that Schaeffler is on the right track to becoming a pioneer of sustainable mobility. With the divisions Industrie and Automotive Technologies, it is optimally positioned to tackle the topic of hydrogen in a holistic manner. Schaeffler's solutions can be used both in the utilization of hydrogen via fuel cells and in the production of hydrogen via electrolysis. As an automotive and industrial supplier, the company benefits from cross-divisional cooperation and the use of synergies in the development and production of technologies for the H_2 industry. This is because similar processes and materials, based on the same electrochemical principles, are used in the design and production of components across all hydrogen applications.

The publicly listed company sees hydrogen as a unique growth opportunity. For this reason, a competence center for

hydrogen technology is currently being built at Herzogenaurach, the headquarters of the Schaeffler Group, in Bavaria. In terms of applications, the focus is on both commercial vehicles and passenger cars, but also increasingly on solutions for railways and industrial trucks.

The Frankish company is also involved in the key project H2Giga, which has received around 500 million euros of funding from the federal ministry for education and research (BMBF). Schaeffler is consortium leader of the subproject "Stack Scale-up – Industrialisierung PEM-Elektrolyse." Here, nine partners from industry and research are driving forward the development of new stack technologies and large-scale production processes for core components of low-temperature electrolysis. In addition, Schaeffler is a Steering Member in the Hydrogen Council, headquartered in Belgium.

Schaeffler expects that by 2030, just under one percent of all vehicles worldwide will be powered by hydrogen. That's about a million vehicles that would need bipolar plates or stacks. "In general, we are expanding our previous focus beyond components to developing products from our understanding of systems," said a rep at Herzogenaurach with regard to the strategy.

At IAA, the family-owned company that employs around 83,900 people worldwide and generated about 12.6 billion euros in revenue in 2020 presented a rolling chassis that will be a scalable and flexible platform for new, driverless mobility solutions. Schaeffler's steer-by-wire technology, according to the company, is a key technology for autonomous driving.

COMPONENTS FOR FILTRATION AND HUMIDIFICATION The supplier Mahle was particularly pleased about the great interest shown by the visitors in its Open Space at IAA Mobility. There, it was possible to experience how much the topic of mobility is already moving a wide audience today. At the trade fair, the major focus in the fuel cell sector was on components for filtration and humidification. "With our solutions for the air supply and exhaust line, we make fuel cells affordable and robust. We particularly benefit here from our broad know-how in the areas of filtration and thermal management," shared Mahle. Both areas are essential for the reliable and economical use of fuel cells. The exhibits were often the starting point for many constructive discussions that helped to understand customers' needs even better.

Fig. 2: Schaeffler presented a fuel cell stack with metallic bipolar plates [Source: Schaeffler]

At the Stuttgart location of the technology company, where there is also a 1,400-m² (1,700-yd²) hydrogen test center, already 100 employees are working on solely hydrogen-related projects. According to the supplier, especially customers in the commercial vehicle sector are becoming increasingly aware of fuel cells. And the Swabian company is not only testing hydrogen in fuel cells, but also in combustion engines. According to Mahle, this is a bridge technology that "can make a rapid and significant contribution to decarbonization of the transport sector."

Regarding fuel cells, they are working on offering the "complete balance-of-plant side." Subsystems are to be increasingly modular in design and thus close up into a single unit. "The currency for the coming years is, in addition to the price, above all the durability and reliability of the products," said a rep from Mahle. The biggest internal challenge in economically difficult times, they see, is the transformation of the business case to smaller series and more flexible cost models. For example, the allocation of development and investment to a very large number of customers without calculable security.

Recently, the supplier introduced an innovative internal coating for fuel cell coolers. This is a paper-thin ceramic skin on the inner aluminum surface of the cooler to ensure that the coolant remains as free of harmful ionic inputs as possible and thus retains its non-conductive properties for a long time.

INDUSTRIALIZATION OF FUEL CELL PRODUCTION At the fair, Bosch presented its entire fuel cell portfolio, from stack to electric air compressor to hydrogen metering valve, up to the corresponding control unit. The feedback again shows, remarked product manager Achim Moritz, that fuel cells are also a topic in the passenger car segment, not just commercial vehicles. "It has a high market potential and is ripe for industrialization. We will start series production as early as next year," he announced. According to his assessment, the demand for hydrogen-based drives will strongly increase particularly for commercial vehicles in the coming years. Bosch believes that in 2030, worldwide about 1 out of 8 new registered commercial vehicles over 6 tonnes will have a fuel cell on board. The fuel cell will increasingly find its way into passenger cars via light commercial vehicles.

"We are working at full speed on the industrialization of our fuel cell portfolio. With the Fuel Cell Power Module, we can offer our customers both a system solution and individual components," said Moritz. In addition, the company is broadening its position in the hydrogen sector and now, in cooperation with OMB Saleri, also offers components for H_2 tank systems. These include, for example, valves and pressure regulators. "Here, too, we want to make the products ready for large-scale production together with our partner," explained the product manager. Bosch estimates the market volume for green hydrogen in the EU will be around 40 billion euros by 2030, with annual growth rates of 65 percent. Bosch wants to invest a billion euros total in fuel cell technology by 2024.

POTENTIAL FOR LIGHT COMMERCIAL VEHICLES The automotive supplier Faurecia also sees itself as a comprehensive provider in the field of fuel cells. The portfolio of Symbio, Faurecia's joint venture with Michelin, covers 75 percent of the hydrogen drive train, from hydrogen storage system to stack, as the company shared at IAA Mobility. The FC technology is particularly suitable for intensive use in light commercial vehicles, which require long range and fast refueling. This would minimize downtimes. Manufacturers and operators of vehicle fleets would increasingly discover the advantages and different configurations of FC electric vehicles, from the range extender to the complete fuel cell drive system.

Faurecia presented in Munich, among other things, it's so-called dual-power system, where the fuel cell system fits into the same installation space as an all-electric battery configuration. This makes the changeover easier and more cost-efficient for the manufacturers, as the same production platform can be used for the assembly of both vehicle types. ||

Category: Electric transportation | **Author:** Uta Willim

HYDROGEN MOBILITY IN FOCUS

Region Series: HyExperts – Region Emscher-Lippe

The region Emscher-Lippe lies at the heart of Nordrhein-Westfalen (NRW) and consists of District Recklinghausen along with the district-free cities Bottrop and Gelsenkirchen. The two rivers Emscher and Lippe give the region its name. Nearly 1 million people live there, in an area of about 966 km² (373 mi²). It is one of the most densely populated areas in Germany, made up of large cities, rural areas and intermediate spaces. The companies there are mainly small and medium-sized enterprises, but global players are also present, a mix characteristic of NRW.

Fig. 1: Left to right: Bodo Klimpel (District Recklinghausen chief executive), Karin Welge (Gelsenkirchen chief executive), Dr. Hanno Butsch (BBH Consulting), Sabine Wißmann (Bottrop economy office), Peter Haumann (District Recklinghausen management) [Source: Mucha/RDN]

The economic restructuring in this former coal and steel region has motivated a local expansion of future-forward energy sources. Of particular benefit was the decades-long experience of chemical companies there in the industrial handling of hydrogen that could be built on. Some are now pioneers in H_2 production and processing. For example, the hydrogen technology center in Herten, h2herten, has been focused on H_2 applications since 2013. And Hydrogenics GmbH, a subsidiary of Cummins Inc., produces fuel cell systems in Herten that can be used in rail transport, buses and trucks as well as in stationary applications.

The region might also serve as a model for hydrogen mobility. The public H_2 station in Ewald Colliery, Herten, that was erected in 2018 has been expanded to be able to fill larger FC commercial vehicles at 350 bar. The waste removal company Abfallentsorgungs-Gesellschaft Ruhrgebiet mbH (AGR) is currently implementing an ambitious project of building electrolyzers and an H_2 station. This high-impact project will enable fleets to convert to regional hydrogen. Other waste removal businesses are planning to operate hydrogen vehicles. In 2023, Vestische Straßenbahnen GmbH will procure five fuel cell buses to be used in public transportation.

With the initiative GETH2, a nucleus for an H_2 infrastructure from Northern to Central Germany will be realized. The first step is bringing green hydrogen to Marl and Gelsenkirchen, in the Emscher-Lippe Region. There are also other high-impact projects along the entire value chain, from generation, storage, transport and use, up to demonstrations.

This means that the economic restructuring following the closure of mines and coal-fired power plants is far from complete. Further measures to modify the existing economic and energy structures are needed. At the same time, the necessary climate protection requirements, which have increased, must be complied with.

AIM With the implementation study "HyExperts Region Emscher-Lippe," the existing competences and the resulting unique structure of local actors for the provision and use of hydrogen in mobility should be concentrated and everything should be transferred into an overall concept for hydrogen mobility. The focus was on two main objectives:

1. Climate protection: reduction of CO_2 emissions through the use of H_2 technologies along the entire value chain
2. Regional value creation: for the region undergoing strong economic restructuring, Emscher-Lippe, a value chain needs to be made that encompasses all aspects of the new technology

Due to the contrast between urban and rural areas with different population densities and requirements for infrastructure, the Emscher-Lippe Region offers optimal conditions for demonstrating the technical feasibility of hydrogen mobility concepts and establishing the region as an active nucleus for true hydrogen-driven mobility.

The HyExperts implementation concept with focus on hydrogen mobility is thus a further building block of the national hydrogen strategy and the hydrogen roadmap for the region published in the summer of 2021.

IMPLEMENTATION During the 12-month project period, from Sep. 2020 to Sep. 2021, the potentials for hydrogen demand in the transport sector and for H_2 generation were determined to compare demand against need and to formulate derivations for the distribution of hydrogen in the region. Existing active groups, projects and project formulations were identified, evaluated and transferred into structured profiles. These serve to make individual projects visible to potential business partners and, through the specifications "I offer" and "I'm looking for," enable other projects to be linked up quickly.

From the analyses presented as well as consultations with the stakeholders, challenges and opportunities for the region on the path to an integrated hydrogen economy were derived. These resulted in recommendations for action and descriptions of how the region can drive forward the breakthrough of hydrogen mobility.

RESULTS In total, 65 projects and activities were identified for all value creation stages, that is, hydrogen generation, distribution, refueling and use, but also development of components and knowledge. The large number of projects in the

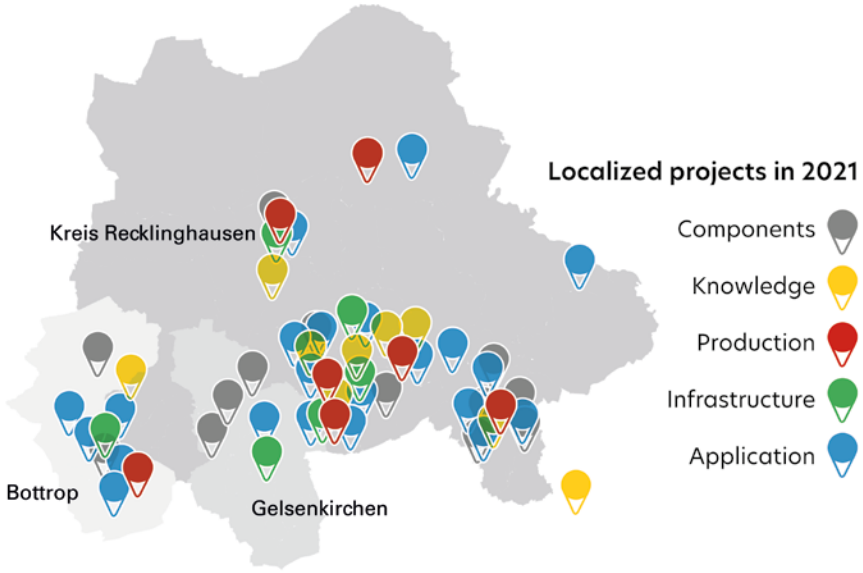

Fig. 2: Project chart [Source: HyExperts Region Emscher-Lippe]

area Generation and Knowledge is verification of the strong hydrogen knowhow in the region.

In Emscher-Lippe, hydrogen can be produced in several, very different ways. The projects cover technologies ranging from biogas reforming, electrolysis and thermolysis, to the utilization of hydrogen generated as an industrial byproduct. Some project concepts are already well advanced and their implementation is envisaged to be within the next one to two years. The current production volumes presumed by actors in the region amount to 3,268 tonnes of hydrogen per year, which is significantly higher than the estimated H_2 production potential of almost 2,500 tonnes for the year 2030. The H_2 generation potential from renewable energies, such as wind and PV, identified in the potential analysis could be used as a building block for the initiation of further projects.

Accounting for the demand in transport, the region will have a short to medium period of production surplus of 550 to 2,850 tonnes of hydrogen per year. This ensures the supply for vehicles foreseeable in the future and may incentivize the operation of more hydrogen-powered vehicles.

The network of refueling stations will be expanded. In addition to the already existing H2 Mobility station in Herten, six further locations are in planning, including four publicly and two privately owned stations for public transport.

For the use of hydrogen in mobility, more than 30 projects and project concepts have been identified. In particular, FC waste collection vehicles and buses for use in public transport are the focus of attention. In all three areas of the region, local actors can already be found in the value creation stage Components, in particular suppliers of fuel cell passenger cars, which often have several branches for the distribution of these vehicles. However, there is still the problem of the availability of such vehicles.

Concepts for the training and further education of future industry specialists are being further expanded. For example, the local automotive professions guild, Vestische Innung des Kfz-Gewerbes Recklinghausen und Gelsenkirchen, already offer inter-company training in high-voltage and hydrogen technology.

OUTLOOK The next step for the development of a regional hydrogen economy is to link the projects along the defined value chain, building on existing structures to support this process and the people involved. The H_2 user group (H_2-Anwenderkreis) established for this purpose will support each project concept individually, according to the progress made, and leverage synergies between the activities and the value creation stages. The group is cross-sector, covering all regional actors and value creation stages.

Actors should be supported according to their needs in order to be able to implement projects efficiently and to pass on experiential knowledge. The user group is divided into two levels: H_2 user (H_2-Anwender) and H_2 starter (Startplatz Wasserstoff). A so-called Projektfilter decides to which level a project belongs.

The task of establishing, implementing and further developing the H_2 user group has been assigned to the hydrogen coordination office of the region's economy support network WiN, that is, Wasserstoffkoordination Emscher-Lippe. The first meetings of the H_2 user group have already taken place, to support the regions participating as HyExperts during and also after completion of the study. A concept for the HyPerformer application is to be developed with other interested actors, including those outside the region, because it is also a goal of the region to take the next step in the HyLand program: to set up and establish itself as a HyPerformer region. ||

→ www.regioklima.de/klimaschutz/wasserstoff

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With the project HyExperts Region Emscher-Lippe, a study of the implementation of hydrogen technologies in the cities Bottrop and Gelsenkirchen and the district Recklinghausen has been launched. The special focus on mobility was set together with the strategic partners Wirtschaftsförderer-Netzwerk Emscher-Lippe (WiN E-L) and h2-netzwerk-ruhr eV. The service consortium with Becker Büttner Held Consulting AG, Emcel GmbH and motum GmbH was commissioned as part of the planning. The concept has been given 300,000 euros by the federal ministry for transport through the hydrogen promotion program Nationale Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie (NIP 2). It was coordinated by NOW GmbH and implemented by Projektträger Jülich (PtJ).

Fig.: Opened in March 2021 after a considerable delay: The hydrogen station in Neuruppin was no. 92

Category: Electric transportation | **Autor:** Sven Geitmann

TIME TO SWITCH UP NOT TAKE DOWN

Efforts to expand hydrogen infrastructure are stalling

New hydrogen refueling stations continue to spring up but Germany has yet to pass the 100-station mark. How can that be? The reason for this apparent stagnation lies in the dismantling or renovation of old filling stations. A number of stations that were built several years ago as demonstrators for the first stage of Germany's national hydrogen innovation program are showing their age. Consequently, some are no longer economical to run and are being taken down or – at widely varying expense – upgraded.

The original target of 100 German hydrogen refueling stations should have been reached by the end of 2018 – then the timeline was pushed back to mid-2020. Next came the announcement for 2021, with an adjusted goal of building 10 to 15 new forecourts a year. That figure was indeed met, the only thing being that some of the stations were disassembled or decommissioned in the previous year meaning the actual number as the year closed out was 91 – similar to the year before (February 2021: 90).

Because of the emphasis placed by the first hydrogen innovation scheme, NIP I, on research and development, each demonstration project had to be a technical one-off. Therefore all the hydrogen refueling stations constructed at that time were different and intended for testing out a range of technologies. Components that did not meet the grade are now being removed or replaced.

EXTENSIVE MODIFICATIONS NEEDED By contrast the second phase, known as NIP II, is all about market ramp-up. This is the stage in market development when tried-and-tested technology is scaled up, thereby lowering the price. The need for extra hydrogen filling stations, though, is still rather small since the number of fuel cell cars is growing at a slow pace due to a lack of supply and long lead times. That's why the fuel station operator H2 Mobility, which is responsible for establishing Germany's hydrogen refueling network, is focusing on developing medium-sized hydrogen stations for commercial vehicles. Running in parallel to that is work to upgrade older stations to 350 bar.

H2 Mobility said: "The location stays the same and we reuse most of the components. Only outdated or defective equipment is replaced. The exception to this is the Sachsendamm station: It's the only "real" deconstruction happening and that's due to the site moving to Tempelhofer Weg." When asked about why the total number of hydrogen refueling stations appears to be stagnating, the response was: "Because the work involves extensive modifications and you can't fill up for several months, we remove the HRS from the map and change it back to blue." On the H2.Live map, blue stands for "in progress."

Refueling stations for buses and trucks have a much higher flow rate and therefore need to be a larger size than previous versions so they can pump more hydrogen in a shorter amount of time. This means the compressor has to be more powerful which in turn leads to higher costs (around EUR 1.5 million instead or EUR 1.1 to 1.5 million). The greater amount of space required for the compressor unit could become an increasing problem since the cost of land can be sky high especially in large cities. In Munich, a square meter of land would set you back about EUR 4,000,

MULTITRACK APPROACH TO INFRASTRUCTURE

Kurt-Christoph von Knobelsdorff, managing director of Germany's National Organisation Hydrogen and Fuel Cell Technology, or NOW, said during an event in Berlin: "We need two infrastructure systems." The theory that funding for electric vehicle charging infrastructure would be freed up if support were no longer given to the development of hydrogen stations was met with denial by the NOW chief. In his opinion, the amounts of funding provided are poles apart, so any shift from one to the other would hardly be noticeable.

He calculated that in Germany up until fall 2021, approximately EUR 56 million in grant money had been put toward 43 hydrogen refueling stations. On the other hand, the program for installing wall chargers has, he suggested, swallowed up EUR 800 million, with each charging unit subsidized to the tune of EUR 900. A total of 900,000 units had been fitted, far exceeding the number of filling stations installed. The chargers, however, are generally used by a single electric car while the hydrogen refueling stations are publicly accessible and will be able to serve many more people if more fuel cell cars come onto the road one day. At the end of November a further EUR 320 million was made available for wall chargers in commercial settings.

It's always been the case that Germany has had several infrastructure systems running side by side: Along with filling stations for gasoline and diesel, there is a nationwide network of CNG and LPG stations, and to a more limited extent stations for LNG and biofuels.

The coalition agreement set out by Germany's new government likewise proposes financial support for the development of a hydrogen infrastructure network.

according to gas company Linde; in Tokyo you're looking at EUR 300,000 a square meter.

As a result, the growth in the number of medium-sized filling stations is progressing more slowly compared with 700-bar stations for cars, although commercial vehicles refuel at "just" 350 bar. Therefore H2 Mobility's original aim of reaching 400 hydrogen refueling sites in Germany by 2023 would appear unachievable.

In November 2021, however, Daimler Truck and French company TotalEnergies, formerly known as Total, announced that they would be stepping into the hydrogen refueling sector. Their cooperation primarily revolves around the sourcing of hydrogen and its delivery to fuel stations. TotalEnergies explained that it intends to operate up to 150 hydrogen filling stations in Germany, the Netherlands, Belgium, Luxembourg and France by the year 2030.

HYDROGEN DEPOT FOR FUEL CELL TRAINS In summer 2020, work began in Bremervörde to construct what will be Germany's largest hydrogen filling station. But it won't be cars lining up to refuel in the future, but Alstom's hydrogen trains. From 2022 the rail fleet will increase to a total of 14 regional trains that will each have a range of 620 miles (1,000 kilometers). To meet the high amount of hydrogen that will be required, the depot will have a capacity of around 1,600 kilograms of hydrogen a day, making it nominally one of the biggest hydrogen refueling facilities in the world. In the meantime, a mobile refueling solution has been used to supply sufficient fuel for two hydrogen trains during their eight-month trial as well as over the course of their assessment period.

In relation to this, Alstom has claimed that the rail sector could be a major buyer of hydrogen in the medium term. According to its argument, this would also benefit road transportation as it would make filling stations more profitable to run and bring down the price of fuel. On average, trains need around 300 times more hydrogen per day than cars and 8 times more than buses.

100 PERCENT GREEN But H2 Mobility, which has also been operating four of the five hydrogen fuel stations in Austria since 2020, is not the only company putting up hydrogen filling stations. In fall 2021, GP Joule brought into service two of its own hydrogen refueling facilities for fuel cell buses. Unlike the H2 Mobility consortium, however, the company eFarming, which is responsible for the sites in Niebüll and Husum in northern Germany, is only using green hydrogen.

This is also the case for the Ellhöft community wind farm enterprise. Wind energy pioneer Reinhard Christiansen, who arranged for a filling station to be built at his wind farm on the Danish border at the end of 2021, had previously remarked to H2-international: "We are immensely excited that soon we will be able to fill up our Hyundai Nexo vehicles at a refueling station where the chain is 100 percent green." Christiansen continued: "After 20 years, Ellhöft has recently dropped out of the EEG subsidy scheme. Without our wind-generated gas project we would have been forced to take down a perfectly functional wind farm which would have been a great loss for the energy transition. In our fight against the climate emergency, we have to make use of every last green kilowatt-hour."

Switzerland also saw the opening of a green hydrogen station in Müntschemier at the end of November. The station, built by Maximator, was commissioned by the company Schwab-Guillod which needed its own means to refuel with hydrogen. It can also be used by members of the public to fill up commercial vehicles and cars. The medium-sized business, located in the Bernese Seeland area of Switzerland, has been supplying fruit and vegetables with a Hyundai XCIENT Fuel Cell truck since December 2020. Hans-Jörg Vock from H2 Energy, who advised on the filling station plans, confirmed to H2-international: "Green hydrogen produced at run-of-river hydropower plants is used for refueling. And the whole ecosystem works without subsidies for hydrogen production and filling stations." ||

In Switzerland in September 2021, Rolf Häusermann revealed high aspirations for his company H2 Energy Solutions GmbH which was founded in July 2021. The company aims to "play a significant role" in driving forward the "establishment of Swiss filling station infrastructure so as to enable the refueling of cars and trucks with hydrogen." An electrical fitter and service technician by training, Häusermann has backed up this ambition by citing his past experience, notably the founding of Petrol-Service Euringer & Häusermann in 1992 which was responsible for renovating 300 filling stations in the 1990s. This business was liquidated some time ago, as was Freeway 26 – another venture led by Häusermann. He himself has admitted to having, as yet, no appointed office or business address. Häusermann also explained that, due to confusion with H2 Energy AG – another Swiss-based organization – he renamed the company H2 Solutions GmbH. There is otherwise no connection at all to H2 Energy, he said.

Category: Development | **Interview Partner:** Stephan Reimelt

BLOOM EXPANDS INTO EUROPE

Interview with Dr. Stephan Reimelt, German branch leader of Bloom Energy

The enormous interest in hydrogen and fuel cell technology has brought a lot of attention to the publicly listed companies in this field. Fuel cell producers like Bloom Energy, however, are finding it difficult to benefit to a comparable extent from the upswing in the H_2 sector because their plants are still dependent on fossil gases for the time being. H2-international talked to the head of business development at Bloom Energy Germany, Dr. Stephan Reimelt, about some challenges involved in supplying decentralized energy through fuel cell plants.

Photo: Stephan Reimelt [Source: Bloom]

H2-international: Dear Dr. Reimelt, It seems that you joined Bloom Energy in April 2021. How did you come to lead the German branch of a US fuel cell manufacturer?

Reimelt: Before joining Bloom Energy as a strategic advisor, I was the CEO of GE Germany. A number of former GE executives are part of Bloom's leadership and management team, including previous GE CEO Jeff Immelt, who serves on Bloom Energy's board, and Greg Cameron, who held a number of officer and leadership roles at GE and who is Bloom's CFO. Through our previous work together, Bloom reached out to me to see if I would be interested in helping to lead its next phase of growth as the company expands into new international markets.

Before, you worked as the CEO and President at General Electric Europe. What parallels do you see between your previous and your new job?

Both GE and Bloom Energy are pioneering energy companies who are leaders in the industry, with missions to bring innovative solutions to help the world think differently about where our energy comes from and the equipment needed to produce and consume energy in new ways.

How are your first months at Bloom going?

The demand for our fuel-flexible, non-combustion Energy Servers is strong, and as Europe faces an unprecedented energy crisis, we are seeing demand from a number of organizations here. We are achieving record acceptances and revenue quarter over quarter. We have started to ship our high-temperature, high-efficiency solid oxide electrolyzers internationally. We are making great progress on our technology roadmap to deliver our new products to market, and we are building out our manufacturing capacity needed to meet both current and future demand. The demand for Bloom's solutions is growing dramatically, and it's an incredibly exciting time to be a part of Bloom.

As a member of the international management team, you will also be responsible for the expansion of the company's activities into Germany. What approach are you taking to achieve this?

Our mission is clear – we bring clean, reliable and cost-predictable energy. And to bring high efficiency energy solutions to the local market, there is not one silver bullet to solve this energy crisis – it's critical that both public and private sector work together to solve the energy challenges we face. A partnership ecosystem is also important – radical collaboration unlocks solutions to the world's most pressing energy problems. We are working with potential partners to tailor solutions to the needs of Germany's energy transition. There are a number of opportunities and challenges related to power availability, reliability, sustainability and costs, and this is exactly what Bloom is tackling.

In terms of geographic area, where do you see Bloom Energy being most active in the future?

Bloom Energy is the world's leader in delivering stationary fuel cell technology, and we have begun expanding into onsite hydrogen production through our electrolyzer technology. Our Energy Servers are fuel flexible, allowing organizations to use an abundant, lower-carbon fuel source. Bloom has a strong presence in Korea, as well a number of other markets such as India and Japan. It's exciting to be a part of this journey as Bloom expands into Europe. We're engaged in multiple high-profile discussions across Europe, Southeast Asia and South Asia for partnerships, projects and pilots. And we're looking forward to sharing more details about those projects and partnerships in the months ahead.

I imagine that such decentralized energy supply systems make sense especially in regions with poor network coverage. In Europe, electric grids are generally considered to be quite secure with a high level of coverage. Are your Bloom Boxes coming to Germany primarily as a substitute for diesel generators for emergency power supply, or are they really only designed for continuous operation?

When talking about energy, it's important to address both the causes and consequences of climate change. And clean energy and resilient energy can, and should, be discussed simultaneously as one solution, not independent of one another. We need a pragmatic approach that will reduce carbon emissions and dependence on carbon-heavy fuels. On our journey to net-zero, we also need to ensure the world's energy needs can be met until renewables are available at scale. Solar and wind represent a mere 1.4% of the total global energy mix. By 2030, the world energy needs are expected to be about 10% larger than pre-COVID levels. The increase in demand alone represents a whopping 714% of current wind and solar energy capacity.

Experts are recognizing that responsibly deployed natural gas is critical in our energy transition. During COP26, the EU Climate Chief stated that investment in natural gas infrastructure would be included in the green transition. We are a partner of choice to net-zero for resilient, predictable and zero-carbon solutions.

The solid oxide fuel cell (SOFC) that can be used with a variety of energy sources, where do you see its future?

Hydrogen is attractive because it can be produced from various resources, from fossil fuels to wind or sunlight, and can be imported from anywhere. But a fully formed hydrogen market is years away, especially green hydrogen, and will take trillions of dollars. The journey to net zero will be long, and there are many practical solutions needed today that can help us on that journey. Bloom Energy Servers are fuel flexible, and ready to adapt to biogas and hydrogen fuels in the future.

So how are you trying to distance yourself from these fossil fuel industries?

I addressed this in the question above, but to make the hydrogen economy a reality, we need to accelerate hydrogen deployment and advance hydrogen production. We need an "all of the above" approach:

1. Policies by various governments must be in place to grow the hydrogen economy.
2. We need to ensure hydrogen can be made and used as efficiently as possible.
3. We need to focus on decarbonizing the industrial sector.
4. We need to make hydrogen economically viable.
5. We need realistic, interim solutions.

Your Bloom Energy Servers are known so far as being primarily for stationary applications. Now, it seems, Bloom is looking to develop FC systems for maritime applications. How far along are you? Are there already initial demonstration projects?

In 2020, we announced our collaboration with Samsung Heavy Industries (SHI) to power engineless fuel cell-powered ships with our technology. We recently announced the achievement of two key milestones. In conjunction with Samsung Heavy Industries, the companies' initial design for an engineless, fuel cell-powered liquefied natural gas (LNG) carrier received Approval in Principle (AiP) from DNV, a premier international maritime classification society. Bloom Energy also received verification as an alternative power source for vessels as part of the American Bureau of Shipping's (ABS) New Technology Qualification (NTQ) service. This progress is a testament to Bloom Energy's industry leadership.

In addition, we have a strong pipeline of marine projects, partnerships and collaborations that are in discussion, and we look forward to sharing more information about these marine developments in the months ahead.

It seems that competitors also don't have it easy. Dr. Reimelt, your scope of duties also includes improvement of Bloom's market position. How will you achieve that?

There is not one company or country alone that is going to solve the climate crises and energy challenges this globe faces. There is no one silver bullet. It's going to take a lot of hard work across both public and private organizations, working together, to make the hydrogen economy a reality, collaborating closely with partners, building an ecosystem, and educating. It's like a rowboat. Many different people in the same boat need to work together in sync to move forward and make traction. We view partnerships and collaborations as key to unlocking the potential of a net-zero energy future. Bloom Energy is collaborating with a number of industry-leading organizations to enable and empower the global hydrogen economy.

Now we come to your second area of activity: electrolyzers. SOEC (solid oxide electrolyzer cell) technology has been too expensive and not as mature as PEM or alkaline electrolysis. Where is your technology at today?

Bloom's high-temperature SOEC electrolyzer produces hydrogen up to 45 percent more efficiently than PEM and alkaline electrolyzers, which operate at low temperatures. Because Bloom's electrolyzer operates at high temperatures, our technology requires much less energy to break up water molecules and produce hydrogen. Electricity accounts for nearly 80 percent of the cost of hydrogen production from electrolysis. By using less electricity, hydrogen production becomes more economical. In addition, the ability to use heat as an energy source, which is a much lower-cost source of energy than electricity, further improves the economics of green hydrogen production.

That's key to unlocking the hydrogen economy – we have to bring the cost of hydrogen production down to make hydrogen economically viable at scale. If we can reduce the amount of energy and electricity needed through high-temperature electrolysis, combining with a number of energy sources, not grid electricity alone, that energy input flexibility and reduction in input can unlock low-cost hydrogen production.

Is it true that you want to install 1 GW of electrolysis capacity by 2025?

Yes, we have set ourselves ambitious goals and will be launching a commercial product next year. The first test facilities are in operation. The target is ambitious at 1 GW.

Can you also tell us about your activities in the area of carbon capture? Are there already concrete plans?

Here, we have built our first plants and determined that our carbon dioxide is extremely pure and well suited for reuse, in the food industry for example. Here, too, we are working on a standardized solution for the future.

Briefly regarding SK ecoplant, will Bloom Energy now be more active in South Korea? What can we expect there?

SK ecoplant has been a formidable partner since we commenced our initial joint venture three years ago. South Korea has a strong focus on enabling a hydrogen-powered and fuel cell-powered economy. Our expanded partnership includes:

1. SK ecoplant contracting a minimum of 500 MW of power from Bloom Energy, representing USD 4.5 billion in equipment and future service revenue.
2. Co-creating Hydrogen Innovation Centers in the US and South Korea to significantly accelerate global market expansion for Bloom's hydrogen-powered fuel cells and electrolyzers, reflecting our shared commitment to a zero-carbon future.
3. SK ecoplant targeting an equity investment of approximately USD 500 million in Bloom.
4. Expanding business cooperation in global markets.

Author: Sven Geitmann

Category: Development | **Author:** Sven Geitmann

THE END OF THE INTERNAL COMBUSTION ENGINE...

or the the debut of stationary hydrogen engines?

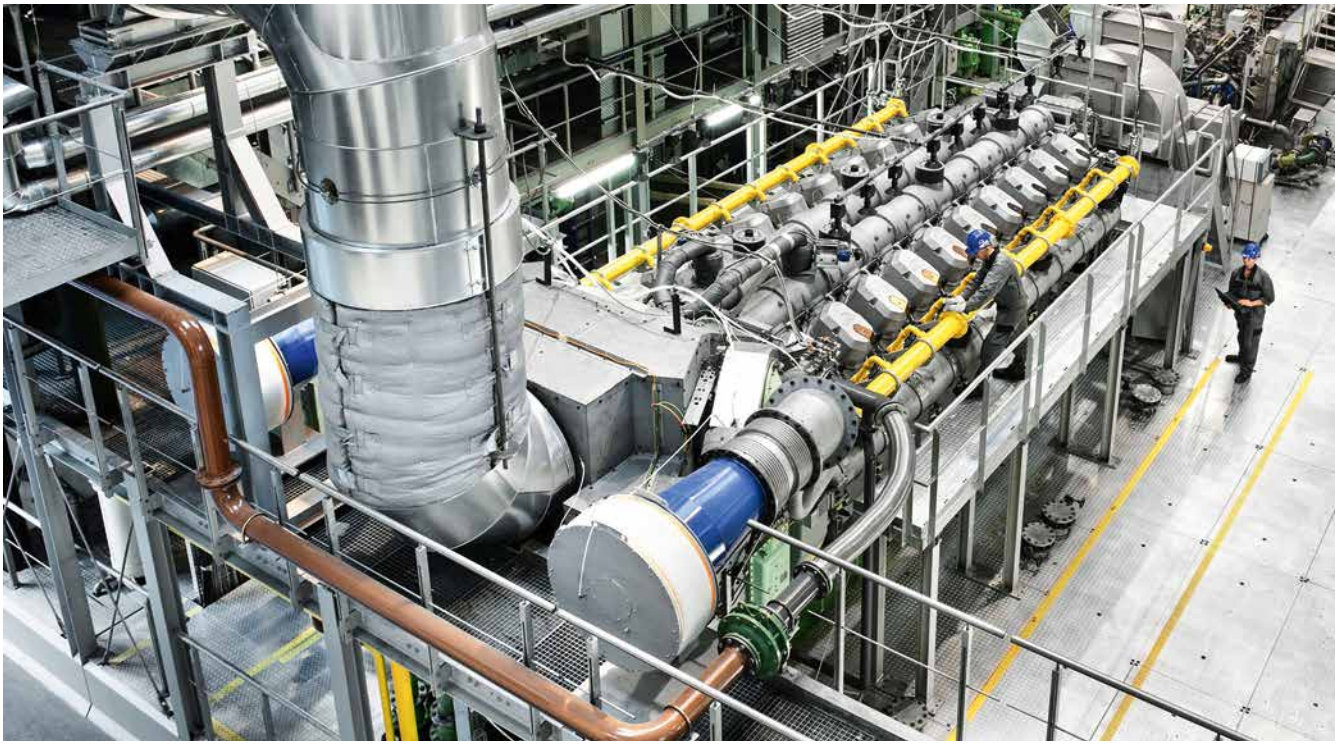

Fig. 1: Such large engines can already be operated with up to 25 percent hydrogen [Source: MAN]

The whole world is talking about the imminent end of combustion engines, on possible bans on oil and diesel combustion engines. But what about hydrogen motors, especially for stationary applications? In the German-speaking domain, companies such as 2G and Innio are particularly active in this sector. Globally, companies like Wärtsilä and MAN are also pushing for this technology route.

Gas engines have long been used in stationary applications. Up to now, however, most systems used as combined heat and power (CHP) units have been operated with natural gas or biogas. Hydrogen use exists only in isolated cases.

In March 2021, Innio Jenbacher reported that initial tests had been successful, which is why the joint testing with HanseWerk Natur will be continued. After the Austrian engine building company had first successfully tested a 12-cylinder engine in Jenbach, it retrofitted the 16-cylinder gas engine of the northern German heating supplier. The 1-MW engine that runs a CHP unit in Hamburg-Othmarschen supplies the 30 residential buildings, sports center, day-care center and leisure park Othmarschen Park there with 13,000 MWh per year of local heating.

Dennis Binder, project manager at HanseWerk Natur, explained, "Our CHP unit ran during the test with different mixing ratios of natural gas and H_2. Operation with 100 percent hydrogen, in compliance with the highest safety requirements, was also successful." The technical business manager Thomas Baade added, "We demonstrated how a CHP system can be operated with green hydrogen and can be used for climate-friendly heat and power supply. The costs to convert or retrofit existing units to run on hydrogen are manageable." Baade admitted, however, that "the fuel costs are currently still too high for economic operation of such a unit."

According to Innio Jenbacher, the Austrian company now has five series that can be operated with a high hydrogen content of up to 100 percent. According to Dr. Klaus Payrhuber, starting January 2022, the Jenbach-based company will offer all customers buying an engine from them an H_2-ready option. However, Payrhuber also thinks it will probably take until 2030 before the performance details of H_2 engines match those of natural gas engines.

The company 2G has also been active in this sector for some time now and already installed a system in 2013 in the Total Tankstelle fueling station at Berlin Brandenburg Airport (see H2-international Jan. 2013 and July 2014). Since 2019, 2G and Siemens have been jointly operating an H_2-CHP unit in Haßfurt (see H2-international Jan. 2020) as well as one in Dubai. A 115-kW H_2-CHP system went into operation in Rostock April 2020 (see H2-international July 2020 and Fig. 3).

For Christian Grotholt, CEO of 2G Energy (see Fig. 2), hydrogen-capable CHP systems are "important for climate protection and preservation of capital." Accordingly, the white paper released by the Heek-based company in March 2021 states, "A 2G natural gas CHP unit installed today can be converted to run on hydrogen at any time, thus avoiding stranded investments." In addition, a 2G spokesperson assured H2-international, "Fortunately, the idea is gathering momentum, albeit slowly, and we have recently received two more hydrogen unit orders."

Fig. 2: Christian Grotholt with 2nd place award from Nordrhein-Westfalen's environmental-economic awards Umweltwirtschaftspreis.NRW 2020 [Source: 2G]

HYDROGEN USE IN THE POWER PLANT SECTOR The Finnish company Wärtsilä is working on stationary gas engines for the megawatt sector. After it was said in 2020 that mixtures of up to 60 percent hydrogen with natural gas had been successfully tested on their 34SG engines, the development work towards 100 percent H_2 gas has been progressing along.

An early adopter of this technology is Keppel Offshore & Marine's (Keppel O&M), who in December 2020 ordered two 34SG engines from Wärtsilä that could be run with hydrogen/natural gas mixtures. They will be used at the Floating Living Lab (FLL), a floating offshore testing station in Singapore. Initially, only three percent can be added to natural gas, but according to Wärtsilä, after some modifications to the gas engines, up to 25 percent hydrogen should be feasible.

WTZ ROSSLAU

Wissenschaftlich-Technische Zentrum Roßlau (WTZ Roßlau) is working on a stationary hydrogen engine as well, but their H2 DI Zero is a closed-loop engine (see H2-international Apr. 2020). The team leader Manuel Cech explained to H2-international, "Our 20-kW CHP unit is a demonstrator of feasibility, proves that the argon power cycle works and has a significantly higher efficiency." In principle, this concept is also suitable for large engines, according to Cech, however, some basic research is still required before a partner can be approached for commercialization.

In July 2021, according to the technology company, Wärtsilä started testing its Balancer models with pure hydrogen in the engine laboratory in Vaasa and expects to be able to provide a 100% hydrogen-capable engine and power plant concept by 2025.

In December 2021, Caterpillar Energy Solutions announced that its MWM generator sets, which have power outputs ranging from 400 kilowatts to 4.5 megawatts, are now suitable for use with blends of up to 25 percent hydrogen. This applies to the stationary gas engine models TCG 3016, TCG 3020, TCG 2032 and TCG 2032B, for which retrofit kits will also be offered. The Mannheim-based Caterpillar Energy Solutions was founded in 1871 by Carl Benz and is now owned by the Caterpillar Group, which is headquartered in the US.

100 PERCENT HYDROGEN FROM 2025 MAN Energy Solutions, which until 2018 operated under the name MAN Diesel & Turbo SE, are also increasingly engaged in the hydrogen sector. The Augsburg-based machine builder reported that their gas-powered four-stroke engines (models 35/44G

Fig. 3: Structure of hydrogen power plant with an H_2-CHP unit from 2G at Apex

Fig. 4: How Wärtsilä sees the future
[Source: Wärtsilä Energy Business]

"The world is on the path to 100 percent decarbonization, and Wärtsilä continues to support this trend with our research and development of future fuels such as hydrogen. The market for hydrogen-fueled power plants will emerge together with regulations restricting the burning of fossil fuels."

Marco Wiren,
President of Wärtsilä Energy Business

TS, 51/60G and 51/60G TS) are H_2-ready, meaning that they can be run for stationary applications with, so far, a hydrogen component in the gas mixture of up to 25 percent by volume. An adaptive combustion control (ACC) should enable more efficient operation, as combustion is fully automatically adjusted when the hydrogen content in the mixture with natural gas is varied. According to the company, it is possible to upgrade gas engines on site or retrofit them with ACC sensors without any problems. The gensets will also be adapted to run on 100 percent hydrogen by 2025.

Dr. Gunnar Stiesch, head of engine development at MAN Energy Solutions, said, "Flexible and decentralized gas-fired power plants play a crucial role in ensuring a secure supply of electricity on the way to one hundred percent renewable energy." However, he also cautioned that green hydrogen is "still a scarce commodity." However, his company is working on future concepts that will make "H_2 contents of up to one hundred percent possible, as soon as it is available in large quantities."

His colleague Marc Grünewald also announced ammonia engines for 2024 (see also reporting on ammonia in last and next issue of H2-international). He is also advocating the use of liquefied natural gas (LNG) sourced, with the aid of H_2 and CO_2, from biogas plants, in order to be able to use this liquid fuel in the mobility sector, in particular in marine engines, and thus decarbonize maritime applications at an early stage.

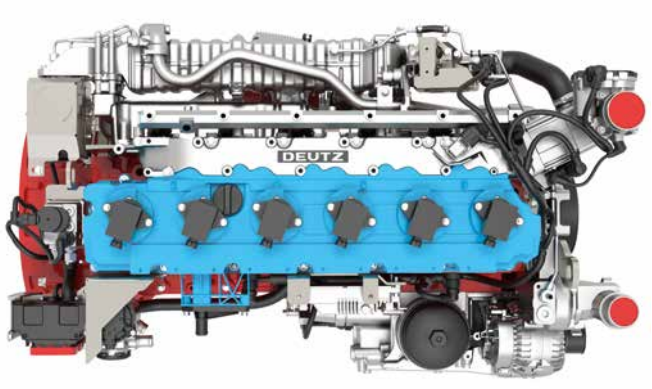

Fig. 5: The TCG 7.8 H_2 will first, beginning of 2022, undergo practical tests in a stationary application [Source: Deutz]

MAN is driving forward development of H_2 engines, for stationary as well as mobile applications, particularly at its "hydrogen campus" in Nürnberg. Since fall of 2020, the diesel engine plant there has been open to Hochschule students as well as those studying at the university Friedrich-Alexander Universität Erlangen-Nürnberg (FAU) and the technical school Technische Hochschule Nürnberg (THN), in order to jointly advance research into hydrogen technology in the laboratories and on the test benches. The president of FAU, Prof. Joachim Hornegger, explained, "Our society needs new, sustainable forms of mobility. Only if science and industry work closely together can such a revolution in transport succeed."

Two others researching hydrogen engines for use in buildings and transport are the Belgian engine builders ABC and CMB. They are working together, with their joint venture BeHydro in Gent, on a dual-fuel engine for locomotives, ships and power generators that can use hydrogen or diesel to deliver 1 megawatt of power. In addition, among others, the British company ULEMCo is working on a dual-fuel hydrogen-capable engine.

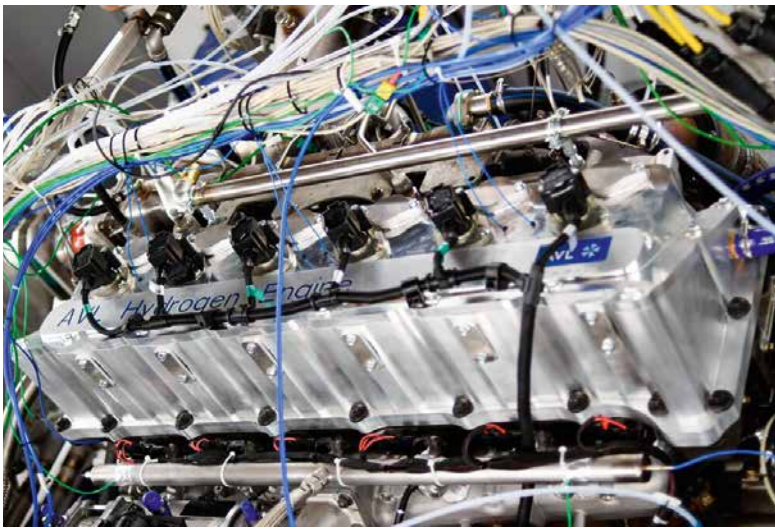

Fig. 6: Former natural gas engine now runs on hydrogen
[Source: AVL]

H_2 ENGINES ARE ALSO IN THE MOBILITY SECTOR In October 2021, a message fluttered across the desk saying that in China, the Guangzhou Automobile Group (GAC) had developed its own hydrogen engine for mobile applications. It is a three-cylinder engine, which, according to its own specifications, should have a thermal efficiency of more than 44 percent, which is unusually high. GAC's interest in hydrogen was demonstrated in August 2020, when the automobile manufacturer presented the fuel cell vehicle Aion LX Fuel Cell.

In the German-speaking domain, Keyou in particular is working on hydrogen engines, which primarily will be used in trucks (see H2-international Apr. 2017). The company has been working with Deutz since 2019 (see H2-international July 2019). In August 2021, Deutz reported that the model TCG 7.8 H_2 was "ready for the market." Although that sounds like it was ready for commercialization, it initially only meant that the H_2 engine meets the CO_2 limit set by the EU for zero emissions. Series production is not planned until 2024.

Fig. 7: The HydraGEN unit at IAA Nutzfahrzeuge 2018 in Hannover

Chief Technology Officer Dr. Markus Müller explained, "The six-cylinder TCG 7.8 H_2 builds on an existing engine concept. It runs not only CO_2-neutral, but quietly, and already delivers 200 kW of power. In theory, the engine is suitable for use anywhere Deutz currently is, but because of the available infrastructure, it is likely to be used first in stationary plants and generators as well as in rail transport."

To secure exclusive distribution and service rights, in October 2021, Deutz brought in Blue World Technologies, the Danish manufacturer of methanol-fueled high-temperature PEM fuel cells, as a 10 percent partner. Dr. Frank Hiller, CEO of Deutz, clarified, "Fuel cells that run on green methanol offer an ideal solution here. Deutz is thus consistently pursuing the path towards new technologies beyond the classic engine to also enable climate-neutral mobility and applications in the off-highway sector and in stationary applications."

In Austria, AVL is working in this sector and affirmed in February 2021 that it was working on a hydrogen engine that is specially designed for use in heavy-duty vehicles with payloads exceeding 3.5 tonnes. Since 2019, work is being carried out jointly with the Institute for Internal Combustion Engines and Thermodynamics at Technische Universität Graz to develop a former 12.8-L natural gas engine into a hydrogen-capable engine that can provide 350 kW of power.

QUESTION MARKS AROUND DYNACERT And then there's still dynaCERT. The Canadian company repeatedly causes a stir with promising-sounding announcements, including or especially on investor platforms on the internet. Since shares in dynaCERT are listed on the stock exchange, the Toronto-based company is benefiting from the current great interest in everything to do with hydrogen.

Instead of hydrogen combustion engines, company executive Jim Payne is set on their HydraGEN product (see Fig. 7). This is an additional unit to be integrated in commercial vehicles to, as promised, improve the combustion process of diesel engines and reduce emissions. The only requirement is the installation of this compact box (price: EUR 8,000), which would neither affect the vehicle warranty nor require a complicated installation procedure. The HydraGEN then produces hydrogen and oxygen by electrolysis, which are subsequently fed into the engine's intake manifold.

In August 2019, the North American company advertised that it had "after a 26-month verification and test phase, received the general operating permit from the German Federal Motor Transport Authority (KBA) for the innovative hydrogen technology HydraGEN" and subsequently certified their own technology as having "billion-dollar potential." In addition, dynaCERT advertised that according to tests by TÜV Nord with the product, fuel consumption was reduced by 8.9 percent, CO_2 emissions by 8.7 percent, NO_X emissions by 88 percent and particulate matter by 55 percent.

According to dynaCERT, its team has been working since the beginning of 2018 to build a worldwide dealer and distributor network. Among other things, the Canadian company presented their technology with their subsidiary based in Lahr, Germany, dynaCERT GmbH, during IAA Nutzfahrzeuge 2018 (see Fig. 7) as well as Hannover Messe 2019 and other exhibits in Deutschland.

In answer to the press release from dynaCERT in 2019 that the former Head Engineer of TÜV Süd in Lahr, Michael Mayer, had "after monitoring four times the strict and successfully completed tests at TÜV Süd," switched sides and has since been working as sales manager of dynaCERT in Germany, a TÜV-Süd representative told H2-international that the Munich-based certification group "has had done nothing so far for dynaCERT." ||

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Category: Market | **Author:** Sven Jösting

THE RAMP-UP OF A GLOBAL HYDROGEN ECONOMY

Sven Jösting's stock analysis

At the start of 2021, we were still seeing a real hype around hydrogen stocks. Then came a powerful backlash. I see this as a healthy correction to a short-term overheating that is now clearly bottoming out. Despite prices retreating recently, it will result in a stable upward trend in the long run for these stocks in 2022. Still, the plans being announced across the world at present to expand the hydrogen economy are triggering a kind of gold rush. And it is not just the many conferences, strategies and projects that are contributing to this picture but the specific intentions of numerous countries and companies to use technology to combat climate change too.

Large financial intermediaries, i.e., major institutional investors like BlackRock, want to invest massively in hydrogen. This means that for the companies and stock prices mentioned in this report a floor is gradually being established that might serve as the basis for strong prices in the medium to long term. Temporary setbacks are not unusual in these situations. You simply need the key attributes of a professional investor: time and patience.

This industry will not ramp up overnight but it will certainly occur. First of all, production capacities must be built up to be able to respond to demand for any components – different types of electrolyzers or the many and varied fuel cell stacks for various uses and products – starting with deployment in buses, trucks and other commercial vehicles, then in ships and rolling stock, and ultimately aircraft and drones, but also in passenger cars. Fuel cell cars will not appear overnight either but be increasingly likely in five to 10 years' time because companies like Toyota and Hyundai are pressing ahead and have also clearly identified this market for the future. At the same time, it is a question of expanding delivery capacities for hydrogen, whether that is using pipelines or ships – via green methanol and ammonia or liquid hydrogen – and, of course, expanding the infrastructure needed: hydrogen refueling stations with varying pressure levels for each type of vehicle used.

Anyone investing in individual securities is, of course, also at the mercy of individual stock price fluctuations and ever-changing prices – depending on how the relevant companies position themselves and the news they release (key performance indicators, orders, collaborations, technological breakthroughs, stakes, mergers, etc.). The more sensible investment for conservative investors is a fund that perfectly reflects the area of interest. Although if you buy a good mixture, you'll not only achieve risk diversification similar to that possible in a fund but also better reflect the different fuel cell/hydrogen areas.

As we are clearly dealing with a new megatrend here, people will arrive at great success with these investments in the coming years, I believe. But overall, follow the advice of the legendary investor Warren Buffet and invest in what you know. Here, you will therefore find plenty of background, analysis and opinions plus interpretations and sources of information so you can assess the companies thoroughly yourself and make up your own mind.

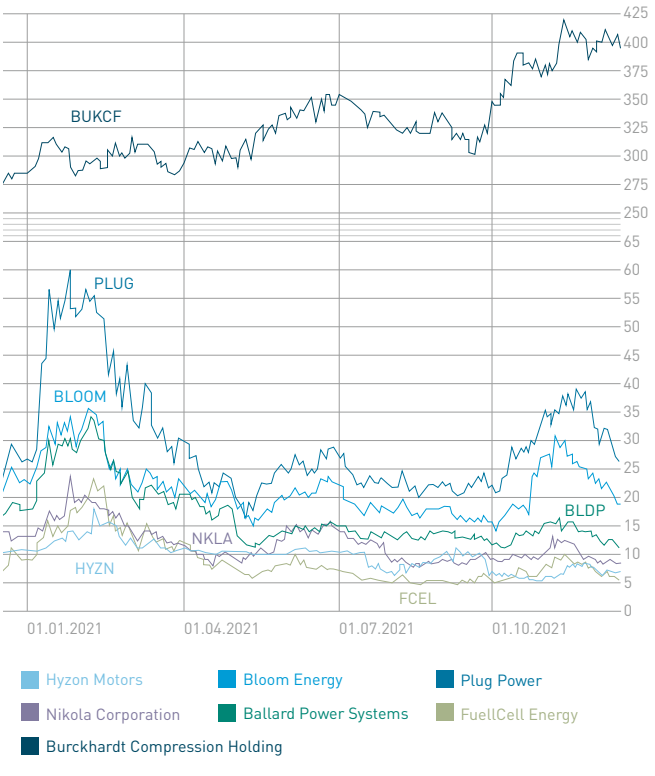

Fig. 1: Stock price performance of the companies discussed [Source: www.wallstreet-online.de] Prices as at Dec. 21, 2021

BALLARD POWER – LARGE REVENUE AND PROFIT GROWTH EXPECTED

Ballard Power, as one of the significant market leaders in PEM fuel cells, is quietly working on positioning the company in various fuel cell markets. With the increase and expansion in stack capacities come huge investments in R&D, the rise of joint ventures and the development of numerous prototypes with strategic partners. Added to that, new deployment areas, such as electrolysis and associated technologies, are emerging – aimed at delivering products that perform well and are competitive, increasingly cost-effective and enjoy long operating lifetimes and a compact design. These all form the foundation for future orders and, of course, the transition to sustainably and vigorously growing profits. The stock market factors all of this into stock prices long before the facts are on the table. Remember when Ballard's price stood at USD 1, USD 2 and USD 3? That was only two years ago.

China has announced big plans since then. There, unlike here in Germany, they are not spending ages on meaningless discussions about the color of hydrogen. That's because until you achieve green hydrogen, it will also be about blue and yellow hydrogen. In China, more than 100,000 commercial

vehicles are due to be powered by hydrogen in the next three years, and a total of 1 million automobiles, including passenger cars, by 2030. Sinopec, a state-owned petroleum corporation, is itself planning 1,000 hydrogen refueling stations by 2025 while the megacity of Beijing alone wants to bring 1,500 hydrogen filling stations online. I therefore forecast there could be a total of 5,000 refueling stations in China by 2030 and many times this by 2040.

Individual Chinese provinces are pressing ahead and entering into talks with Ballard/Weichai. That's because so far the central government has not announced any subsidy figures to support the ramp-up of the hydrogen economy. Meanwhile, the joint venture has released a statement saying it intends to optimize the stacks and modules produced in China and improve the sourcing of many components. CEO Randy MacEwen stated in a telephone conference that everything will progress very smoothly in 2022.

It could be that 2023 is the year when Ballard can expect extremely rapidly increasing order books and above-average revenue and profit growth – and expect that sustainably and for the long term. You need to bear in mind this forecast. You can already see significant acceleration in certain areas. So far, Ballard has deployed about 150 fuel cell buses in Europe. Recently it received a single order for more than 40 modules. According to the CEO, we can now expect individual orders for bus stacks to take off, with orders for 100 or even 1,000 units anticipated in the future.

To take another example, California alone is planning that by 2025, zero-emission buses will make up 50 percent of its long-haul transit vehicles. This is also clearly playing into the hands of fuel cells compared to battery-electric mobility. And, increasing numbers of perfect strategic partners are being brought on board to help with this, e.g., Mahle, Linamar, CP, Hexagon Purus, Quantron, Siemens, ABB and Norled.

AUDI PROGRAM COMES TO AN END I regard it as a (very) big mistake by Audi to ignore the fuel cell segment in passenger cars, although that is merely my personal opinion. VW boss Herbert Diess is just planning to rely on batteries in mobility – he only sees fuel cells as useful for ships. Hence he is dropping the development program with Audi in August 2022 and consequently the VW subsidiary will undertake no further work in this area. MacEwen explained: "So I don't expect to see any developments there for the passenger car market with Audi in the near term."

I have my own interpretation of this situation that just might be dynamite. How would it be if another automotive group jumped on the bandwagon and accomplished what, in my opinion, Audi is missing out on – or even, is shutting its eyes to? After all, Ballard has great expertise around fuel cell-powered passenger cars and the associated technology. Added to that, Ballard has regained from Audi the rights to deployment in cars. I would not be surprised to see another corporation as a partner – possibly Apple even – which might seize this opportunity.

STAKE ACQUIRED IN FORSEE POWER Forsee Power, the French battery specialist, has gained Ballard as a strategic partner and major shareholder. They have many customers in common – bus and commercial vehicle manufacturers but also those in railway transport (MacEwen: "a very strong position in the rail market"). Forsee and Ballard want to work together on the integration of batteries and fuel cells so they can offer these technologies to customers as a one-stop solution for commercial vehicles.

TAKEOVER OF ARCOLA ENERGY IN THE UK Ballard paid EUR 40 million (a mixture of cash, shares and milestone payments) to take over the British systems integrator Arcola Energy. The two have already been working successfully together for 10 years. It will add about 80 staff. Arcola, according to the press release, possesses specialist expertise in integrating fuel cell systems into commercial vehicles and rolling stock, and is one of the strongest growing hydrogen companies in Britain. So that makes it the perfect strategic acquisition at an excellent price.

MULTI-MW POWER PLANT WITH HDF ENERGY HDF Energy, aka Hydrogène De France, has teamed up with Ballard to develop the world's first multimegawatt hydrogen power plant in French Guiana: CEOG Renewable. It will use hydrogen obtained via renewable energy. A total investment of USD 200 million will also develop a solar park with subsequent hydrogen production, i.e, electrolysis, backed up by short-term energy storage via batteries as a buffer. This will supply 10,000 households with clean energy and zero emissions. Ballard will provide FCgen-LCS stacks. Beyond that, HDF intends to further develop plans of this kind in a production facility in Bordeaux, using this first project as a blueprint.

PARTNERSHIP WITH SIEMENS MOBILITY So far, Siemens Mobility has held out for a USD 3 billion order for 73 trains – a further 140 trains are said to be an option. Now we hear we can expect further orders from US company Amtrak. The Biden government's infrastructure plan is making funds available for this. Even if it only runs as a hybrid or battery-electric version at the start, it is clearly linked to the prospect of fuel cells and of hydrogen coming on board, literally, in the next generations of trains. Forsee Power (see above) is well placed to be the perfect battery supplier – for Alstom too, incidentally, which together with Cummins likewise supplies fuel cell systems for trains. Ballard will then provide the fuel cell stacks for the locomotives.

RESEARCH PROJECT FOR BACKUP POWER SYSTEMS Diesel engines still persist in data centers because they offer an uninterrupted power supply. Ballard's PEM fuel cells should now be introduced. Data centers not only require a vast amount of energy (Bloom Energy is perfectly positioned here, see fig. 3 and the interview on p. 46), power cuts must also be ruled out. For numerous companies, such a catastrophic event would be equivalent to a major nuclear disaster. Ballard can really offer something here. At Microsoft and Caterpillar, the company is starting a three-year test run in a few data centers, supported by funding from the US Department of Energy. For Ballard, this is another market with excellent growth potential.

Conclusion: Ballard is positioning itself, through a series of collaborations, strategic partnerships and acquisitions, etc., to be a perfect partner later on (from 2023 onward) for the integration of fuel cell systems into various products and markets, and also to be set up well in terms of capacities. The ramp-up of orders for stacks and components is therefore only a matter of time. Randy MacEwen commented: "We're putting the customer at the heart of our strategy and our investments."

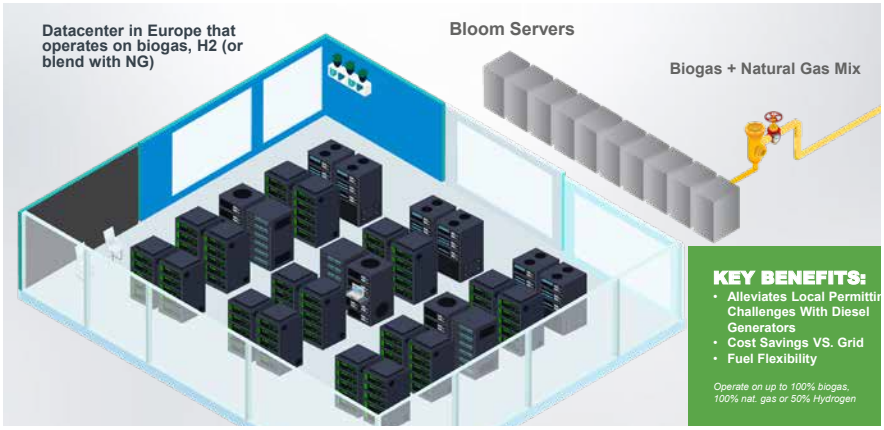

Fig. 2: Data centers like this are already under way [Source: Bloom]

BLOOM ENERGY – BILLION-DOLLAR DEAL TRIGGERS PRICE EXPLOSION

Bloom Energy gained its South Korean customer and corporate partner of many years, SK ecoplant, as a shareholder and, thanks to the existing good working relationship, has even bagged a USD 4.5 billion order – for hardware and software and also service revenue – for 500 megawatts for the time being. This order should only be the start though and so ought to have further potential. SK ecoplant, part of the SK Group, is the largest energy corporation in South Korea and is planning to invest multiple billions in fuel cells and hydrogen, said to be about USD 25 billion.

This investment fits with South Korea's strategy to become a global leader in this area. By 2040, it plans to have over 6 million hydrogen vehicles on its roads. The stated aim is 15 gigawatts via hydrogen and 1,200 hydrogen refueling stations also by 2040. SK alone is planning to equip 1,600 of its more than 3,000 filling stations with hydrogen fuel pumps. Since SK is also active in many other markets, Bloom may envisage many other great developments.

Both companies want, for example, to bring two research laboratories online – in the USA and South Korea – that can improve and expand their own expertise alongside external partners using new business models. Bloom's high-performance electrolyzer technology, due to be launched on the market from 2022, also plays a critical role in this.

SK ecoplant will also become the biggest single shareholder in Bloom Energy, holding up to 15 percent of the capital stock. The first USD 255 million tranche of the planned and reported USD 500 million investment flowed in during December 2021.

The upshot of all these developments was an increase in the Bloom share price from USD 18 to USD 37 although that retreated back to USD 24. An ideal price again for new and additional acquisitions. We might even be seeing a 50 percent degree of reaction here, as often occurs after a very large price increase where half of the price gain evaporates again as day traders, i.e., very short-term investors, secure their gains. After that though, the trend for the future is likely to be up again, especially if the news is decidedly positive.

Short sellers will have tracked and exploited this trend too. At the time the SK deal was announced, they had still short sold more than 18.4 million shares, with the short interest then decreasing to 14.4 million shares, hence obtaining cover. In my view, the outlook could not be better.

FIGURES AND OUTLOOK The third quarter turned out to be reasonable on various grounds, with revenue up

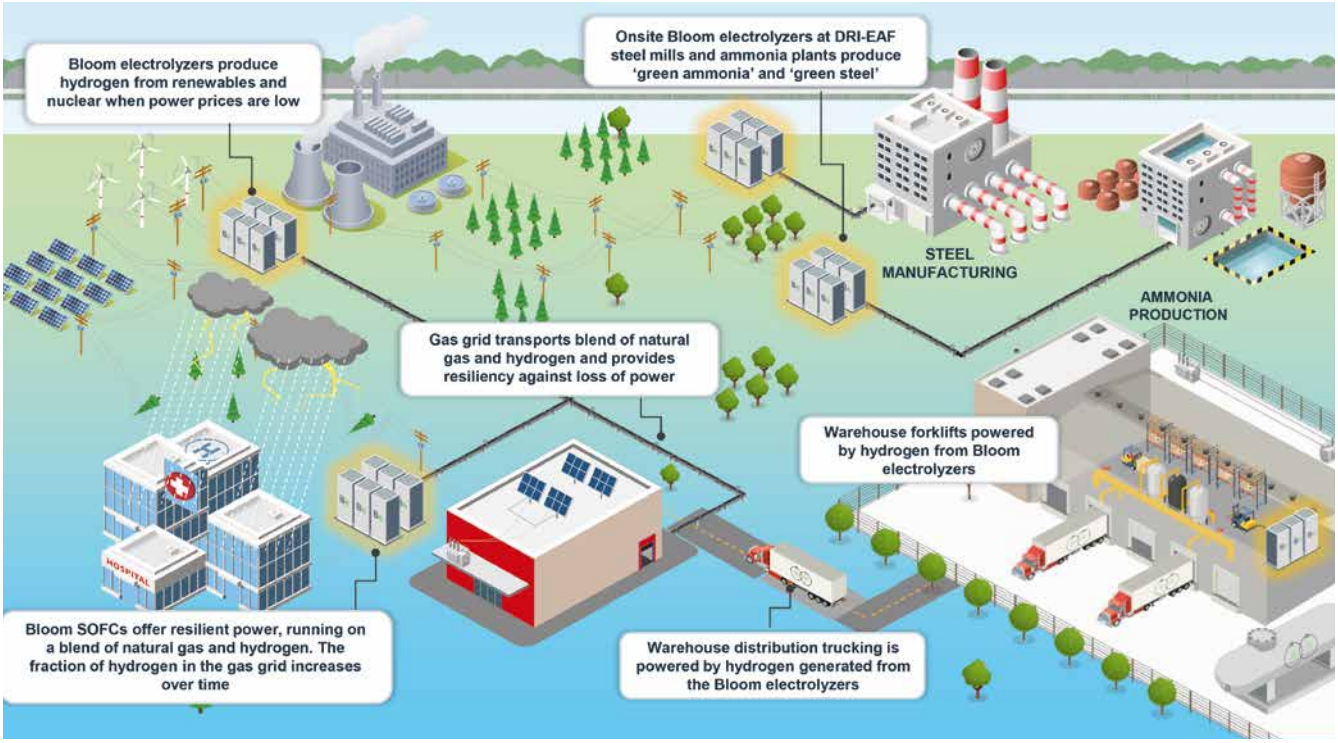

Fig. 3: Bloom's energy supply concept [Source: Bloom]

11.4 percent to USD 207.2 million. However, revenue shifted by USD 20 million in the fourth quarter although needing to be adjusted by USD 14.2 million for accounting reasons to recognize nonrecurring revenue recorded in the third quarter of 2020. The non-GAAP loss was USD 22.9 million in the third quarter of 2021. The forecast is more important though, with Bloom massively expanding the capacity of its 5.0 and 7.5 energy servers and electrolyzers.

Problems with supply chains needed to be resolved along with increasing raw material prices and higher general costs although Bloom dismissed these negative effects as temporary. Cash and cash equivalents stood at USD 320 million in the black as at Sept. 30. The first tranche of USD 255 million from SK ecoplant's stake will be on top of that. However, revenue is said to be set to increase less strongly now. This is primarily due to Bloom tendering strongly to subcontractors for contracts, including for installations. This type of business typically has narrower margins. Bloom therefore sacrificed revenue in favor of margins meaning that it would either not achieve, or would only just miss, its target of about USD 1 billion revenue in 2021. In my mind, the profit margin is much more important than the revenue.

BIDEN'S US GOVERNMENT INFRASTRUCTURE PLAN The USD 1.1 trillion plan revealed and approved by the Biden government to modernize the creaking infrastructure in many parts of the US has positive consequences for Bloom, as it does for the entire hydrogen industry. Investments are to be made not only in electricity grids and their resilience – Bloom is even building off-grid fuel cell power plants – but there are also plans to subsidize the price of green hydrogen so it is competitive at USD 3 per kilogram compared with natural gas. Besides, USD 9 billion will go into R&D so green hydrogen can be produced for under USD 2 per kilogram in five years' time or USD 1 per kilogram in the long term even. That's positive for Bloom on so many levels.

BREAKING INTO EUROPE VIA THE UK In England, Bloom Energy is planning a partnership with Conrad Energy and Electricity North West. Conrad is the prime contractor and financier whereas Electricity North West is responsible for servicing and installation. Bloom will provide its Energy Server and servicing. Electricity from the fuel cell power plants is intended to be sold by Bloom through PPAs, i.e., Power Purchase Agreements. Both partners possess a large customer base and wide-ranging expertise. Electricity North West stated: "We want to be a UK leader in the race to reduce carbon emissions and help our customers to achieve energy cost security, whilst preparing for the hydrogen economy. This technology offering manages to do all three in one go."

For me, this confirms that it is only a matter of time until Bloom begins collaborations with local partners in other European countries to deploy its technology there too. The venture in Great Britain should receive orders shortly, according to their press release.

Conclusion: By my reckoning, Bloom Energy is the best organized fuel cell company with a proven business model, the technology, and a positive front-runner image with very large growth potential. Perhaps Bloom will become the first company in the industry to sustainably enter profitable territory. The price decrease we just saw again is an opportunity for investors to move into new stocks and increase their stake provided they are able to give their investment two to three years to work.

NIKOLA MOTOR POSITIONS ITSELF IN THE GLOBAL MARKET

At first glance, the news seems to be negative. Nikola Motor has already stated it will settle with the US stock exchange regulatory agency, the SEC, for USD 125 million regarding the misdemeanors of its founder and former CEO, Trevor Milton. On the other hand, however, Nikola plans to claw back this money since Milton probably still owns at least a 10 percent stake in Nikola although he is likely to have sold some of his shares and transferred them to relatives. Nikola cannot simply seize these shares but perhaps it will freeze them until an agreement has been reached.

The SEC filing stating that Trevor Milton reportedly registered and sold shares worth USD 317 million in recent months (which also partly explains the recent price decrease) will not in my opinion prevent a settlement if part of this money flows back to Nikola, although that is only my theory – for which I accept no liability.

The free float, i.e., the number of freely tradable shares will therefore increase. This may give short sellers the right to short sell these shares which must number at least 60 million (as at November 2021), that is, about 30 percent of this free float. Critics like to object that the settlement with the SEC could give some the impetus to start a class action lawsuit as that could be seen as a sort of admission of guilt. Here, too, I will argue that a way to end this chapter will surely be found using the shares that Milton may still directly hold – although that is my own theory – for which I accept no liability.

Nikola itself is calmly implementing its business plan which can be seen in various collaborations and the expansion of the factory in Coolidge, Arizona. Together with TC Energy, a major Canadian gas pipeline corporation, Nikola is planning to produce in the region of 150 metric tons per day of green hydrogen. New orders were won for battery-electric and hydrogen-powered trucks and the latest filings revealed that the company's headquarters in Phoenix, Arizona was meantime acquired for USD 25 million.

Apart from that, Nikola is preparing to further expand its service network and is behaving in a similar way to Daimler Truck which wants to bring online a network of 150 hydrogen refueling stations in Europe together with the French petroleum company Total. At the same time, German vehicle manufacturer Daimler Truck is planning 25 hydrogen refueling stations with the British petroleum company BP to solve the chicken-and-egg problem whereby no logistics company will order a fuel cell truck if it is unable to buy the fuel or it is not widely available.

FINANCING SECURED Institutional investor Tumim Stone Capital, managed by 3i Management, promised Nikola up to USD 600 million through two financing programs and share-purchase agreements. Nikola can issue shares and place them with this major investor as it sees fit at the time and price of its choosing. I see this as a very smart move by this investor. Not only is it financing the implementation of the business plan but it is also succeeding in wielding an increasingly large influence over Nikola. I dare to forecast that this investor is ready with a lot more capital than the USD 600 million already announced to help Nikola to succeed and make the breakthrough. Tumim will ultimately – I suspect – hold a 15, 20, 25 percent or more stake in Nikola and, later, may pass on this large block of shares to a strategic investor with a lovely block markup. So, a perfect win-win situation – potentially.

Fig. 4: Nikola's head office in Phoenix, Arizona [Source: Nikola]

PLUG POWER – (TOO) MANY PROJECTS WORLDWIDE?

Plug Power is benefiting from the fact that a variety of analysts view the company to be a front-runner in an American hydrogen economy in 2023/24 and one that should be very well positioned to produce green hydrogen through the development of its own electrolyzer capacity in the longer term. In nine years' time, a revenue of USD 9 billion may even be possible. Until then, a hydrogen price of USD 1 per kilogram should be achievable, according to Evercore analyst James West.

The target price for the shares is between USD 42 and even above USD 70. It is clear that Plug will profit from the infrastructure program just agreed in the USA. A lot of money is flowing into R&D. Funds are also being channeled into subsidizing the price of green hydrogen (hydrogen tax subsidies/production tax credits) and supporting the expansion of the hydrogen economy along with associated applications. Plug still also has USD 4 billion in the bank underpinning its growth forecasts. So in 2022 a revenue of USD 900 to 925 million should be possible instead of USD 825 to 850 million.

On the other hand, it seems to me that it is far too highly dependent on individual key accounts like Amazon. Although it is seeing high billing levels (orders to convert forklift trucks), these do not allow it to achieve satisfactory profit margins. Some stacks are being exchanged. Ballard Power is probably still profiting from this as it was in fact Ballard that supplied Plug with stacks in the early years before Plug Power itself started production in "gigafactories" (see Ballard's last quarterly results).

Interesting news like the planning of a feasibility study for deployment in the aerospace industry with Airbus should surely be assessed in a very positive light – although in my view orders will not arrive overnight. Clearly positive news is that Plug Power and oil corporation Phillips66 are planning a joint venture to expand hydrogen infrastructure.

Conclusion: Plug's valuation at about USD 24 billion is entirely appropriate and has already factored many positives into the share price performance. The shares will track the positive sentiment which is expected to continue compared to the entire market segment of hydrogen and fuel cell stocks. I remain cautious because, to me, many of the words being uttered by companies seem like they are really meaningless. My view remains that Plug should take stakes in Nikola Motor and Hyzon Motors. This is a way that Plug could position itself in the commercial vehicle industry (in addition to the partnership with Renault for cargo and passenger vans) together with expanding the hydrogen infrastructure – although that is only a strategic observation of mine that I have expressed frequently here.

Fig. 5: Hyvia van by Renault and Plug [Source: Hyvia]

FUELCELL ENERGY – CAN EXXONMOBIL DRIVE UP THE PRICE?

With ExxonMobil, FuelCell Energy is already working nicely with regard to carbon capture. Now ExxonMobil has published a six-year plan that sees the corporation wanting to invest USD 15 billion in this area. As a result, I therefore believe that for FuelCell Energy there is potential for many a supplementary and major order.

The market capitalization of FuelCell Energy, which stands at more than USD 3.5 billion, is comparable with that of Bloom Energy at USD 4.5 billion. FuelCell Energy will achieve revenue of about USD 100 million whereas Bloom will cross the USD 1 billion threshold next year and, according to forecasts, could move into profit. What is also clear is that FuelCell Energy's shares are popular on platforms like Reddit and Robinhood as is reflected clearly in their daily transaction volumes ranging from up to through to more than 100 million shares. On the other side of the coin, you need to recognize that FuelCell Energy's balance sheet is obviously healthy with liquidity that probably exceeds USD 400 million.

My conclusion: suitable for traders although long-term investors should invest in Bloom instead, especially as both companies serve pretty similar sectors through fuel cell power plants, and of course, will profit from this megatrend and from the US Biden government's plans.

WIKIFOLIO BZVISION – BOTTOMING OUT HAS STARTED

The Wikifolio BZVision has gone the same general way as stocks in the fuel cell and hydrogen sector. Still up more than 50 percent per year, however, although seeing a sharp drop at the start of 2021, with the investment in Tesla put options suffering badly after the electric automobile manufacturer's share price rose to more than USD 1,200 or USD 1.1 trillion. I bought more put options in Tesla for my portfolio – partly as security/hedge against the general performance of the stock exchange but partly also to speculate on Tesla's plummeting price.

In October 2021, CEO and charismatic entrepreneur Elon Musk asked his approximately 63 million Twitter followers whether he should sell some of his shares. He received absolution from the majority (57 percent of respondents) which enabled him to sell. So USD 10 billion is likely to have already flowed into his personal account. Board colleagues have likewise followed suit and realized USD 1 billion. For me, that is a warning sign.

In short, around 5 percent of the portfolio is now reinvested in Tesla put options. Issuer: Société Générale, matures: 9.16.2022, strike price: USD 1,000. Ratio: 1:100, i.e., one share for every 100 put options. Purchased at about EUR 1.40/option and listed at EUR 1.90 as at the time of this report. Apart from that, a couple of Ballard shares were sold and reinvested in additional Bloom Energy and Nikola Motor shares to show a better weighting of individual securities. If the investment in Tesla put options bears fruit, the equivalent value will go into Ballard, Bloom and Nikola, and also into Weichai Power.

BURCKHARDT COMPRESSION – BOOM IN INCOMING ORDERS

The stocks in this compression market leader have performed extremely well since they were first mentioned here in our H2-international magazine, improving from about CHF 300 to more than CHF 400. Burckhardt Compression benefited from a boom in orders for compressors, but also from its service solutions. In the first half of 2021, Burckhardt achieved significantly greater incoming orders of about 80 percent, taking it to CHF 450 million. A "strong increase in hydrogen mobility and energy activities" is expected for the second half of the current year.

Conclusion: The company has a bright future ahead of it and will benefit from the worldwide ramp-up of the hydrogen economy by being active in China too – an acquisition was already made here some time ago. I imagine the company could be a target for a takeover by a large corporation which, as a global player, could seamlessly incorporate Burckhardt Compression's expertise into its own hydrogen product range. Continues to be suitable as a small admix.

HYZON MOTORS – END TO THE OBSERVATION ROLE

Hyzon Motors, a manufacturer of hydrogen-powered commercial vehicles founded in Singapore (IPO via special-purpose acquisition company, SPAC, in New York), saw its the share price crash after a hedge fund named Blue Orca (a short seller?) leveled various accusations, including that an order for 20 Hyzon trucks did not come from the named customer, Hiringa Energy, but from someone completely different. Moreover, it also prompted questions about an agreement (memorandum of understanding) concerning 400 trucks for a Chinese customer. Law firms simultaneously added a string of class action lawsuits whose aim and purpose is unclear to me, though. Did someone want to initiate a lower IPO price or make stock prices tumble by short selling?

The price fell from USD 10 to USD 5 in any event. Still, like Nikola Motor, the company continues to calmly implement its business plan so there are now production sites in Asia, Europe and the USA. Shanghai Hydrogen HongYun Automotive has placed an order for 62 trucks. TC Energy signed an agreement to supply hydrogen – Nikola even agreed this with TC Energy – to jointly provide hydrogen refueling stations and also hydrogen. Planning is in full swing on a joint pilot project with Zhangjiagang Haili Terminal, a subsidiary of the fourth largest steel corporation in the world, Sha Steel Group.

With Itochu, planning has started for the deployment of fuel cell systems made by Hyzon in mining vehicles. Added to that, its partner, Hiringa, in New Zealand obtained an investment from the Japanese corporation Mitsui to expand its hydrogen infrastructure. From Australia came the news that prototypes of heavy trucks made by Hyzon for Ark Energy in Queensland have won funding from two governmental agencies.

By the end of the year, a total of 85 vehicles should have been delivered and driving on the roads of the USA, Europe, Australia and Asia. Production sites in Rochester, NY/USA,

Fig. 6: Ark Energy, an Australian subsidiary of Korea Zinc, secured five heavy trucks for itself made by Hyzon Motors [Source: Ark Energy]

and the Netherlands, among others, will be expanding on schedule, according to reports. Hyzon had about USD 500 million cash in the bank as at Sept. 30, 2021. About 247.5 million shares had been issued up to this date, valuing the company at below USD 2 billion.

Conclusion: Hyzon is building on the experience it gained throughout 20 years in fuel cell technologies and hydrogen management for the deployment in commercial vehicles. Compared with Nikola, this Asian company is an interesting player in this sector that primarily benefits from fuel cells and hydrogen in heavy trucks (according to McKinsey, more than 70 percent of heavy trucks will be running on hydrogen by 2050). Interesting as a speculative investment even if class action lawsuits still make for uncertainty and may also give rise to costs. These costs must ultimately be paid for by their own shareholders, meaning that some class actions should be examined closely and treated with caution, at least that is my feeling.

SIEMENS ENERGY – STILL AN INTERESTING ENTRY-LEVEL STOCK

If you read about any of the major hydrogen projects underway, you will be unable to avoid Siemens Energy. Orders like the recent ones worth EUR 700 million should be on the agenda. Even the problems with its wind power subsidiary Gamesa seem solvable because – regardless of short-term problems (price increases in raw materials and component shortages) – the market is growing strongly. Here, I would venture to suggest to the company that it integrates wind farms into existing projects and offerings via Power Purchase Agreements, or PPAs, from the outset. Then you would be able to view a wind farm from a different return perspective and margin.

Siemens Energy is already, in my opinion, regarded as a major, experienced player that will win many a large order given the enormous plans by countries in the Middle East. The same goes for the USA where the corporation is represented strongly too.

The loss for the financial year ended September 2021 of EUR 500 million (EUR 673 million loss as a nonrecurring item) does, however, indicate the general trend if you compare these figures with the same period last year and the loss of EUR 1.9 billion (with large nonrecurring expenditure). Siemens Energy is building on a sustainable, achievable operating profit margin of 3 to 5 percent and can therefore feel pleased that its "H2ready" power plant concept has been certified by TÜV Süd – the first project of its kind and a blueprint for more of the same.

Conclusion: The company, as a one-stop shop partner offering relevant solutions as far as clean energy and production and processing/use is concerned, will benefit from the enormous growth in all hydrogen economy and renewable energy segments. Just by themselves, the multi-100-billion investment plans of Middle Eastern countries, such as Saudi Arabia, the United Arab Emirates and Qatar, are playing into the hands of Siemens Energy. Classified as a buy. Investment horizon: medium-term – two to three years with the aim of exceeding the current peak price for this stock.

Fig. 7: Silyzer 200 PEM electrolyzer in Werlte, Germany [Source: Siemens Energy]

WEICHAI POWER – A TURNING POINT

Although the price of Weichai Power fell away steadily in recent months, it has bounced back very strongly in recent weeks by more than 35 percent. Weichai, as a leading producer of diesel engines in China, is the perfect counterpart to the American corporation Cummins, which is very aggressively expanding its hydrogen and fuel cell activities, and as such is hedging Weichai's future strategy. For Cummins, the acquisition of Canadian firm Hydrogenics was its ticket into the world of hydrogen. For Weichai, it was its stake in Ballard Power (probably currently standing at about 15 percent) and the joint production of commercial vehicle stacks in a joint venture (51:49).

Conclusion: Weichai Power is for me a seismograph for fuel cells in China with its more than EUR 20 billion in annual revenue and good profits, and should be seen as a blue chip of the industry. The joint venture with Ballard might even be floated on the stock exchange. Its stakes in Kion and in Ceres Power and Ballard are alone valued at more than EUR 5 billion. ||

RISK WARNING
Share trading can result in a total loss of your investment. Consider spreading the risk as a sensible precaution. The fuel cell companies mentioned in this article are small- and mid-cap businesses, which means their stocks may experience high volatility. The information in this article is based on publicly available sources, and the views and opinions expressed herein are those of the author only. They are not to be taken as a suggestion of what stocks to buy or sell and come without any explicit or implicit guarantee or warranty. The author focuses on mid-term and long-term prospects, not short-term gains, and may own shares in the company or the companies being analyzed.

Category: International | **Interview Partner:** Stijn van Els

INITIATIVE FOR H_2 EXPORTS TO GERMANY

Interview with Stijn van Els, Director of Port of Rotterdam

Rotterdam is not only the largest port in Europe, it is playing a key role in the German hydrogen strategy. Stijn van Els has been working since January 2020 as director of commercial delivery at the port, which belongs 70 percent to the municipality of Rotterdam and 30 percent to the Netherlands. After studying at a German Hochschule, van Els studied physics in Delft and then started as an engineer at Shell. He's been working around the world for 30 -years and in Hamburg as head of Shell Germany. H2-international spoke with him about the role of the port for the European hydrogen economy.

Fig. 1: View of the Port of Rotterdam
[Source: Danny Cornelissen, Port of Rotterdam]

H2-international: Rotterdam is the hub for energy imports in Europe. Where is the port in the overall H_2 strategy of the Netherlands?

van Els: The task of Port of Rotterdam will be to import hydrogen from countries where the sun shines or the wind blows for longer. The Netherlands, like Germany, is an importer of energy, whether it be gas, LNG or oil. This will not be so easy to change in the future either, because the potential for local production of hydrogen has physical limitations. Making these imports possible, including for Germany, will be our task. The energy source will change in the future, but the distribution of the green hydrogen, or even green LNG or ammonia, will still be necessary. Another fact is that the distribution of blue hydrogen will also increase by 2030.

How much H_2 is currently produced in the port per year?

About 1 million tonnes of H_2 is currently produced by natural gas reforming. That corresponds 10 to 15 gigawatts of electric power. In 2050, 20 million tonnes of H_2 will be processed and 90 percent imported. For comparison, we currently process around 100 million tonnes of oil in the port per year. Rotterdam is the largest energy port in Europe. Around 14 percent of the energy required by all sectors in the whole of Europe arrives here. So for electricity, heating and vehicles. By 2050, this energy should come almost entirely from renewable sources, as envisaged by the EU's New Green Deal.

How's the acceptance for the clean energy transition and green hydrogen?

On paper, according to surveys, the acceptance is very high. The situation is different when it comes to implementation. That's not going as quickly as we'd like, as operators of Port of Rotterdam. After all, we are no longer just talking in this country, we have now entered an implementation mode. Politicians would like to accelerate this further, but as of the end of October 2021, we are still in the middle of coalition negotiations in Holland as well, which have been dragging on for over half a year already.

The energy corporation Shell wants to build a 200-MW electrolysis plant in industrial port Maasvlakte II in Rotterdam. What does this mean for Port of Rotterdam and its future strategic direction?

There are various plans. Shell's plant will probably be the first giant electrolyzer, but BP and other companies also want to invest. The reason is, among other things, the planned expansion of offshore wind energy in the Netherlands to 50 GW. This electricity should also flow into electrolyzers to produce green hydrogen. On the one hand, it can serve as a flexible electricity buffer for renewables. On the other hand, through power-to-X, it can also be used or further processed for heating and as fuel. We want to install electrolyzers for 2 GW in total in the energy park of Rotterdam by 2030. The first plant should be in operation in 2025.

As port operators, will you also invest in the hydrogen infrastructure?

In electrolysis itself, we will not invest. That is being done by private businesses. We're a public entity, but we're owners of the areas, so we rent these out. We will also invest revenue into the hydrogen infrastructure. Among others, a new 40 kilometer long pipeline between Maasvlakte und Pernis is planned, which will supply several hydrogen consumers.

As port operators, what plans, targets and strategies do you have to become climate neutral by 2050?

The national so-called Dutch Climate Accord for 2030 also applies to us. It plans a 49 percent reduction in CO_2 emissions, and as an industrial location, we can make a particularly efficient contribution. The dense concentration of industrial activities makes it possible to reach up to 40 percent of the total national CO_2 reduction target in Port of Rotterdam alone. Compared to normal households, we're much larger consumers and thus larger emitters. In addition, we are currently implementing a CCUS project. That's about the use or the underground storage of carbon. CCUS is a new acronym in German and stands for Carbon Capture, Utilisation and Storage.

CCS is a controversial issue, with or without CO_2 utilization. In Germany, these plans have been abandoned for years. Vattenfall has buried its pilot project.

The coalition agreement and the climate agreement in Holland underline the importance of CCUS for the energy transition. We, as the port operators, as well as Gasunie and the state-owned company EBN developed the project in order

to transport CO_2 from the industry at the port and to store it in empty gas fields under the North Sea. Construction of the project could start in mid-2022. The facility should be in operation starting 2024. Carbon capture will occur at the hydrogen producers and refineries in the port. The four companies Air Liquide, Air Products, Exxon Mobil and Shell are also partners in the project.

How is the project and the expansion of renewable energy being funded?

The funding scheme for us is different from Germany's. It's called SDE++ (Stimulation of sustainable energy production and climate transition). It's what's called in neo-German a "Contract for Difference." The CO_2 reductions will be compensated with an EU Emissions Trading System certificate with the monetary value. In addition to wind and solar parks, this also includes CCS projects and many other CO_2 reduction technologies. In Germany, there's a guaranteed compensation for generating green energy for the grid, as set out by the EEG law. We don't have that.

Do you also produce green electricity or green heating in the port itself?

There are plans for 350 megawatts of wind power to be built in the port area. In addition, we already use some of the excess heat from the industry there for heating. There is enough waste heat to heat 600,000 homes. For the roofs, photovoltaics is a natural choice. We plan to install more than 100 MW worth.

For the H_2 infrastructure, is there a cooperation with Germany?

In several places. Port of Rotterdam is a part of the German-Australian HySupply study, among others. The northern German ports are not. The initiative is trying to promote hydrogen imports to Germany. Then, there's the Delta Corridor planned. This is a pipeline to connect Port of Rotterdam, the industry park Chemelot Limburg in Maastricht and Nordrhein-Westfalen. It will transport in addition to H_2 also CO_2, propylene and LPG. An advantage is that most of the route can be covered by an existing pipeline that has been transporting tens of millions of tonnes of raw materials like oil and gas between Rotterdam and Nordrhein-Westfalen every year since the 1960s.

That makes the construction and planning easier. How do the current plans for the development of the "European Hydrogen Backbone" look?

As far as I know, there's still no concrete plan for the establishment of a European hydrogen network. The Delta Corridor, which will connect Nordrhein-Westfalen to Rotterdam and the industrial town Geleen, should be ready for operation by 2026 and will likely be one of the first new cross-border hydrogen pipelines. Private cross-border pipelines for relatively small quantities of hydrogen already exist in Europe, but with the expected imports in northwestern Europe and production in southern countries such as Portugal and Spain, further pipeline initiatives can be expected. The companies operating the European natural gas network are considering reusing this network, but we believe that the capacity of the natural gas network is too small to meet demand. Hydrogen is not only a substitute for natural gas, but also for a large part of the currently used oil products and coal. The EU should help fund these new international hydrogen pipelines, because they are necessary to achieve the climate targets of the EU and the individual countries.

Fig. 2: Stijn van Els
[Source: Port of Rotterdam]

And what does the infrastructure for crude oil to Germany look like today?

There are two pipeline systems with a total length of 457 kilometers (284 miles) for the transport of crude oil from Rotterdam to refineries in western Germany. The plant has a transport capacity of around 25 million tonnes of crude oil per year as well as 10 million tonnes of other products.

You have already mentioned the Dutch Climate Accord. How much green hydrogen could the Netherlands provide?

The goal is 20 million tonnes of H_2 in 2050, of which 2 million will be produced locally and 18 million will be imported. Of these volumes, I expect 12 million tonnes will be transported over to Germany. To guarantee that we meet the increasing demand for hydrogen, Rotterdam has established several partnerships with other countries, including Portugal, Iceland, Morocco, Oman, Australia, Chile, Brazil, Norway and Canada. This import function of the port also secures Rotterdam's future position as an energy port in northwestern Europe. Incidentally, the amount of green ammonia needed to get the same amount of energy from H_2 is by a factor of 7. So we would need to import 140 million tonnes of fuel. But that would still be less than what we process today. Currently, 200 million tonnes of oil go through our port.

Where do you stand on blue hydrogen? Is green hydrogen better for the climate?

The discussion about the color is unfortunately always a bit too simplistic. Now we're in the middle of the European debate on what can actually be certified as green hydrogen. France is promoting low-emission generation of hydrogen with nuclear energy. From my point of view, what's important is that for every tonne of H_2 produced, the carbon footprint is also reported. That would be transparent and a real step forward. In a study commissioned by us, an H_2 change purse with a CO_2 backpack is likewise proposed. Right now, there is no price on green hydrogen. That has to change.

Where will we see the first commercial markets for hydrogen?

In the field of mobility, for trucks. We can already see it today for example in Switzerland, because the zero-emission requirements for environmental protection areas in the Alps demands it. Also very soon in steel production, where green hydrogen will replace furnaces fired with coal. This will happen in the chemical industry as well. The driving force behind this is the EU Renewable Energy Directive, RED II. In our opinion, the entire value chain for imports and infrastructure needs to be taken into account. As port operators, we also moderate exchange between all parts of the chain, which sometimes equates to a difficult balancing act.

Interviewer: Niels Hendrik Petersen

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

ALL ROADS LEAD TO ROTTERDAM

The Netherlands is tipped to become a hydrogen gateway

Fig.: Among the port authority's plans is a new 25-mile (40-kilometer) hydrogen pipeline (Source: Eric Bakker, Port of Rotterdam)

All eyes will be on Rotterdam in March 2022 when the city will host its first-ever global hydrogen summit and exhibition. The Dutch region, which is home to Europe's largest port, has its sights set on becoming a hydrogen hub, at least that is the intention set out in the country's energy strategy. The Dutch government sees the international trade in hydrogen gas as a great opportunity – assuming that a pan-European pipeline project doesn't get in the way.

Given that Germany will not produce sufficient hydrogen from renewable energy sources before 2030, the German government is intending to supplement its own supplies with a high level of imported hydrogen from regions with copious wind and solar resources. Southern Chile, for example, was chosen as the site for Siemens Energy's Haru Oni hydrogen/power-to-x project. Here, hydrogen is produced using wind-generated electricity and combined with carbon dioxide captured from the air to make a carbon-neutral fuel.

Academics from the German economic institute IW, Fraunhofer UMSICHT and the Wuppertal Institute are pressing the new German government to give higher priority to all plans relating to hydrogen. "In doing so, however, we should not make ourselves too dependent on individual producer countries but look to establish a broad import portfolio from the outset," urged Malte Küper from IW. According to Küper, it is also vital that a joint European approach is taken – particularly with a view to setting global standards when it comes to matters of sustainability.

Germany and the Netherlands have already held talks on cross-border hydrogen networks. And it's clear that, whatever the final outcome, the Port of Rotterdam will have a significant role to play. What's more, the harbor is part of a bilateral cooperation project, dubbed HySupply, between Germany and Australia which will see hydrogen imports entering Rotterdam and being piped onward to Germany. "One of our tasks will be to facilitate this importation," said Stijn van Els, commercial delivery director at the port, in an interview with H2-international (s. p. 60).

In his view, the supply of oil and natural gas will change in future but the distribution of green hydrogen, or for that matter green liquefied natural gas or ammonia, will still be required. "In truth, however, it will increasingly involve blue hydrogen in the runup to 2030," believed van Els.

A WORLD-CLASS HYDROGEN VALUE CHAIN Describing its hydrogen strategy, the Dutch government stated: "Furthermore it is of crucial importance for the ports and particularly the Port of Rotterdam from a strategic standpoint that the current intersecting function within international energy flows is retained." It went on to say: "Hydrogen has the potential to become a globally traded commodity." The important part that the Port of Rotterdam has to play in that trade is not to be underestimated. The facility is to be the gateway through which hydrogen imports must pass and a sizable one at that, given Rotterdam is Europe's largest energy port. Around 14 percent of the energy required for power, heat and transportation arrives here.

Now Rotterdam has ambitions to become a hydrogen hub. The Dutch province of South Holland, Rotterdam's city and port as well as the Sustainable Energy Council, SEC, have decided to organize an international hydrogen summit and expo which will henceforth be held on an annual basis. The SEC arranges three such exhibitions and summit meetings every year: one in Asia, one in America and one in Europe. Rotterdam has now been selected by the SEC to be the location for the European event for the years ahead. The event will run from March 8 through March 10, 2022.

It is hoped this international platform will ensure that a global hydrogen economy is established in a way that is in keeping with the 2030 and 2050 climate goals. Included in the plans is the development of a world-class hydrogen value chain with projects such as the large-scale production of green and blue hydrogen, in addition to imports and infrastructure measures, all of which sit comfortably within the Port of Rotterdam's current remit. The country as a whole has set itself the target of becoming climate neutral by 2050, with the Netherlands aiming to cut carbon dioxide emissions by 49 percent by 2030.

23 GAS NETWORK OPERATORS – ONE PLAN The "Fit for 55 Package and Gas for Climate" study from the European Hydrogen Backbone initiative, which was released in November 2021, estimates that hydrogen demand in the European Union and the United Kingdom will reach 2,300 terawatt-hours per year by 2050. By way of comparison, that equates to around 45 percent of the natural gas consumed in these regions in 2019 and approximately 20 percent to 25 percent of the projected energy requirement in 2050.

The proposed infrastructure pathway to 2040 for a European Hydrogen Backbone, known as the EHB, is a vision put forward by 23 European network operators with long-distance gas pipelines across a total of 21 countries. The EHB timeline envisages a pipeline network initially covering 7,200 miles (11,600 kilometers) by 2030. Hydrogen infrastructure could then be gradually extended with the ultimate goal of creating a pan-European grid that is 24,600 miles (39,700 kilometers) long by 2040. With no concrete plans in place, however, the initiative remains purely speculative for the time being.

One thing that can make a hydrogen pipeline network joining 19 EU states and the UK a worthwhile endeavor is the cost: At EUR 0.11 to EUR 0.21 per kilogram and per 620 miles (1,000 kilometers), hydrogen pipelines represent the most cost-effective option for transporting large volumes of the gas over long distances. "They exceed transportation by ship for all reasonable distances – at least within Europe and neighboring regions," the Fit for 55 report stated. The calculation presumes future production costs will be between EUR 1 and EUR 3 per kilogram of hydrogen.

Whether or not the hydrogen backbone comes to fruition, there is no getting around the fact that hydrogen imports from Chile and Australia will need to be brought by ship and – in all likelihood – landed in Rotterdam. ||

MAJOR HYDROGEN PROJECT IN NAMIBIA

In November 2021, the Namibian government issued a notice of award stating its intention to appoint Hyphen Hydrogen Energy as the preferred bidder to develop a hydrogen project in the Tsau Khaeb National Park. The project, worth an estimated USD 9.4 billion, will produce 300,000 tons of green hydrogen per year and will see the installation of 3 gigawatts of electrolyzer capacity and 5 gigawatts of wind and photovoltaic generating capacity by the end of the decade. Hyphen is a joint venture between Nicholas Holdings and Enertrag South Africa, a subsidiary of German company Enertrag. This initiative is part of the H2Global program (see H2-international, October 2021). ||

COMPASS FOR THE H_2 WORLD

In October 2021, the association Hydrogen Europe unveiled its Clean Hydrogen Monitor 2021. This is the second edition of the paid-for guide which aims to give an overview of European hydrogen applications through an extensive array of facts, figures and analysis.

Jorgo Chatzimarkakis called the report, which can be purchased from Hydrogen Europe for EUR 299, a "compass for the hydrogen world." Among the information revealed by the Hydrogen Europe CEO at the guide's presentation was the insight that a photovoltaic plant in Chile, Namibia or Morocco produces around double the yield of a plant in central Europe. In North Africa, a 1-kW_{peak} plant generates 2,190 kilowatt-hours, while in European Union countries the average is 1,051 kilowatt-hours. If sunny regions use this solar power to produce hydrogen which is then transported to Germany to feed fuel cell cars, this would equate to the same amount of energy available for propulsion as when a battery car is powered by electricity from a German PV plant.

According to the analysis, current production capacity for hydrogen in the EU is 10.5 million metric tons a year, the main contributors being Germany (2 million t_{H2}), the Netherlands (1.6 million t_{H2}) and Poland (2 million t_{H2}). Thermal processes are still the predominant means of making the gas (95.5 percent, for instance via the steam reforming of natural gas); 3.9 percent comes about as a byproduct and only 0.1 percent is produced through power-to-hydrogen.

This comes as no surprise since electrolyzer capacity in 2021 "only" amounted to 135 megawatts – which compares with 90 megawatts in 2019 and 100 megawatts in 2020. Nevertheless, the EU's aim of achieving 40 gigawatts by 2030 could be exceeded. Currently it is estimated that 118 gigawatts will be reached by that date. Many countries want to expand their generating capacity: the Netherlands by 11 gigawatts, Spain by 7.3 gigawatts, Greece by 5.4 gigawatts and Germany by 5.3 gigawatts, for example. Governments are investing large sums of money to realize these ambitions: France: EUR 14.3 billion; Spain: EUR 9.4 billion; Germany: EUR 7.9 billion; Italy: EUR 7.8 billion; Romania: EUR 5.1 billion. ||

Hydrogen Europe, Clean Hydrogen Monitor 2021

NO HYDROGEN IMPORTS FROM MOROCCO

In 2020 there was much talk of low-cost green hydrogen being readily imported from Morocco. Mooted in the country's favor were its copious supply of solar energy, its connectivity to Europe via Gibraltar as well as its relative political stability. As of summer 2021 that has not been entirely the case. The sun is still shining but diplomatic relations have become frosty.

The German and Moroccan governments have recently been at loggerheads through a dispute over the sovereignty of Western Sahara. While the Moroccan monarchy lays claim to the desert territory, the German government insists that the United Nations must first clarify the issue before any energy plants can be installed there.

Germany's former development minister Gerd Müller had previously signed an agreement with the Moroccan ambassador Zohour Alaoui in June 2020 which envisaged a solar hydrogen industry being established in the northwestern African state. The original plan was for hydrogen to be produced in industrial quantities using the region's solar resources and German electrolyzers. The hydrogen could then be exported – in one form or another – to Germany.

According to the German government's national hydrogen strategy, EUR 2 billion in funding is set aside for this type of overseas project. Detractors continue to be critical of oil-exporting countries' dependency on hydrogen-exporting nations as a means of finding their salvation. There have also been repeated warnings against cooperating with regions that are politically unstable.

It remains to be seen whether diplomatic relations will settle down again and how soon that could potentially happen. ||

CLOSE COOPERATION WITH DUBAI

Despite dubious past experience with the countries of the Middle East and North Africa region, in November 2021 the German government signed a declaration of intent with the United Arab Emirates covering the establishment of an Emirati-German task force for hydrogen and synthetic fuels. The deal was given the seal of approval in Dubai by Andreas Feicht, the former state secretary to the German economy minister, and Suhail Al Mazrouei, the UAE energy minister. The agreement, which proposes greater collaboration between the two countries on green hydrogen, was preceded by an initial electrolyzer pilot project conducted by Siemens Energy and the Dubai Electricity and Water Authority in May 2021. ||

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f-cell 2022 | Hydrogen & Fuel Cell Conference and Trade Fair, 4-5 October 2022, Messe Stuttgart, Germany, *www.f-cell.de*

f-cell Canada 2022 | The Annual International Hydrogen & Fuel Cell Event, 25-26 May 2022, Edmonton, Alberta, Canada, *www.hyfcell.com*

f-cell China 2022 | International Trade Fair for Industrialization of Hydrogen and Fuel Cell Technology, 1-3 December 2022, Shanghai, China, *www.f-cell.com.cn*

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WS Reformer GmbH, Dornierstrasse 14, 71272 Renningen, Germany, Phone +49-(0)7159-163242, Fax -2738, *www.wsreformer.com*

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Resato International B.V., H_2-Pressure Testing, H_2 gas booster for refueling stations, high pressure technology, Duitslandlaan 1, 9400 AZ Assen, Netherlands,
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EVENTS

Please have also a look at the following homepage where you can find upcoming online and live events and eventually changes: www.h2-international.com/events

MARCH

HOW – Mission Hydrogen
HYDROGEN ONLINE WORKSHOP
March 3 2022 – online
www.hydrogen-online-workshop.com/

5th Hydrogen & Fuel Cells Energy Summit
Discount code: EHFe5Ahsan
16 to 17 March 2022, Porto, Portugal
www.wplgroup.com

FC Expo
Green Hydrogen Society –
Gigawatt Scaling for EU's CO_2 neutrality
March 16 to 18, 2022, Tokyo Big Sight, Japan
www.fcexpo.jp

APRIL

H2 Forum BERLIN
Green Hydrogen Society –
Gigawatt Scaling for EU's CO_2 neutrality
from April 4 to April 5 2022 – Estrel Berlin and virtual
www.h2-forum.eu

MAY

ees Europe
Messegelände Munich
Conference: May 10 to 11 2022
Fair: May 11 to 13 2022
www.ees-europe.com

European Hydrogen Energy Conference (EHEC 2022)
Organized by Spanish Hydrogen Association (AeH2)
rescheduled to 18 to 20 May 2022 in Madrid, Spain
www.ehec.info

f-cell Canada
4th Annual International Hydrogen and Fuel Cell Event
organized by Landesmesse Stuttgart GmbH
May 25 to 26, 2022, Edmonton, Alberta, Canada
www.hyfcell.com

Hannover Messe
Hydrogen + Fuel Cells Europe
May 30 to June 2, Hannover Fair, Germany,
Hannover Messe
www.h2fc-fair.com

JUNE

Hydrogen & P2X 2022
Organized by Spanish Hydrogen Association (AeH2)
June 15, 2022, in Copenhagen, Denmark
www.fortesmedia.com

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

LEGAL NOTICE

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Cover image: Screw connections typical of electrolyzer stacks [Source: Green Hydrogen Systems]
Photo on p. 3: derBildmacher, Rüdiger Tesch-Zapp

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