Hydrogeit / www.h2-international.com / Issue 2 / May 2022 / 10 $

H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

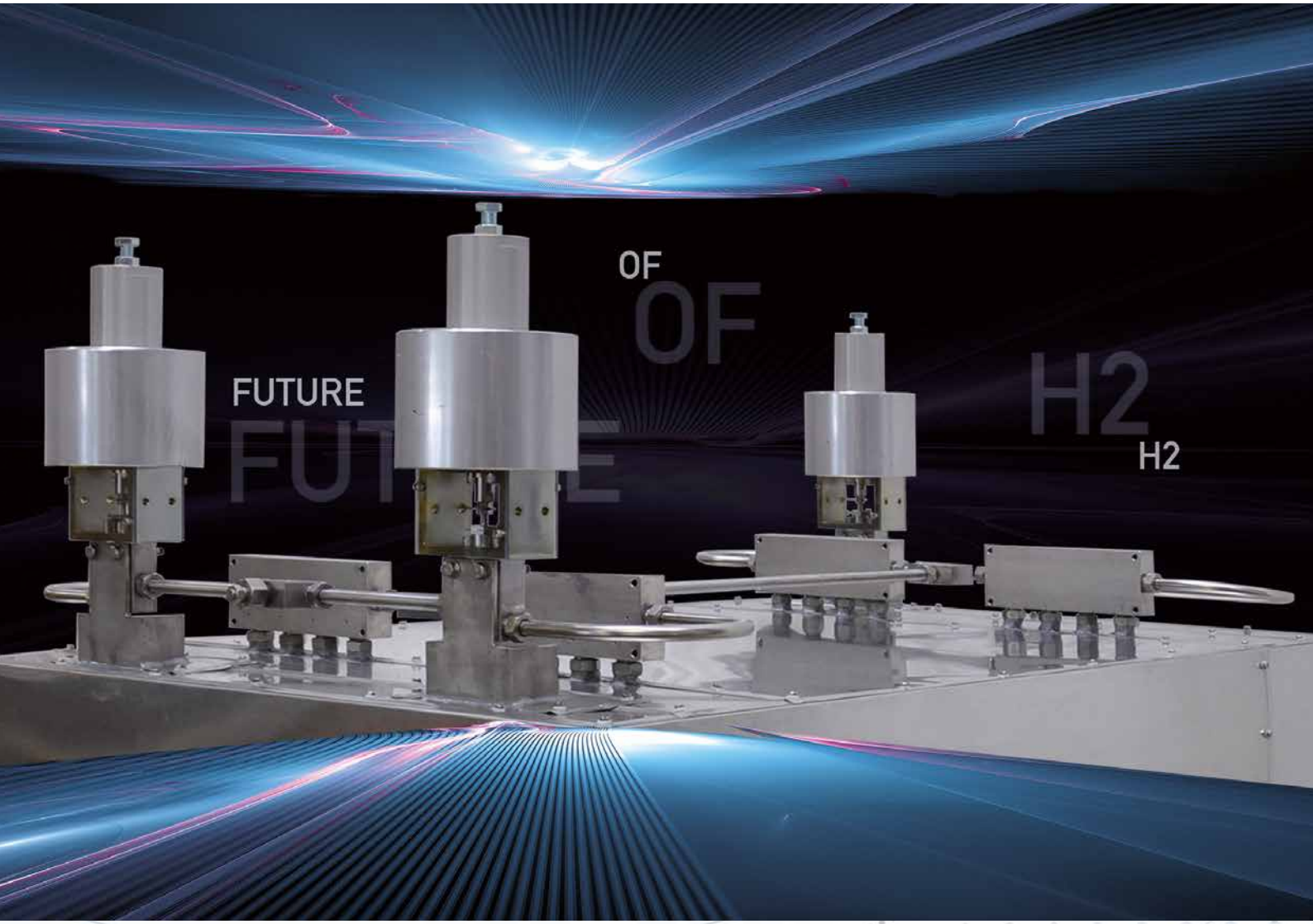
→ WATER DEMAND FOR THE MANY ELECTROLYZERS

→ E-FUELS – DO SYNTHETIC FUELS MAKE SENSE?

Hydrogen Regions, Part VIII: Real-World Lab Schwarze Pumpe

www.theisen-gmbh.de

THEISEN
SMART SOLUTIONS



INDIVIDUAL SOLUTIONS

H2 High-Pressure Coolers tested and approved. In use since 2015.

When refuelling fuel cell vehicles with gaseous hydrogen, the hydrogen needs to be cooled down during the filling process in line with SAE specifications. We manufacture high-pressure coolers for this application with an operating pressure of up to 1400 bar.

Cooling takes place via a secondary circuit with a heat transfer fluid or directly with a refrigerant. In use since 2015. Certified according to PED 2014/68/EU.

Personal. Individual. Efficient.
We look foward to meeting you!

WINNING FACTS:

- Mass flow rate: 60g/s (216 kg/h) or 120 g/s (432 kg/h)
- Weight: Approx. 1100 kg or 2200 kg
- Highest flexibility for the use of different refrigerants
- Excellent cold storage effect for the use of small, or constantly running refrigeration systems

Theisen GmbH & Co. KG I Deipenbrook 17 I 48607 Ochtrup I Germany I fon +49.2553.97010 I info@theisen-gmbh.de

TIME TO DO RIGHT BY FUTURE GENERATIONS

Dear Readers!

We could have had it so much easier. Everything we need today, we could have built and prepared long ago. But we knew, or at least suspected, that it might eventually come to this. The Club of Rome had prophesied exactly this scenario already fifty years ago.

Would've if? Apparently, we wouldn't have it any other way. It appears that other things have been more important to the key decision-makers over the past decades. Instead of planning for the long term and looking ahead, the focus was on short-term successes and particular interests. We've indeed discussed sustainability a lot, but then went on to change nothing, or too little.

And we voters agreed and diligently participated. We have consistently given our vote to the very people who have vehemently pursued profit maximization and the supposedly good allies with their fossil fuel reserves. Despite sufficient reminders, repeated and unceasing, to instate more energy self-sufficiency, more decentralization and more long-term planning.

We have all agreed, sometimes silently, to the previous way of doing business, or at least have not done enough to bring about substantial change. We have tolerated decades of investment in nuclear energy, although this technology is expensive for the long term and in no way fair to future generations.

We have accepted that once again huge sums of money have been invested in coal and gas while the future-looking technologies solar and wind went bankrupt in our own country, when over 300,000 people had been employed in this sector.

We have put up with years of the automobile lobby playing for time, lying and cheating, and continuing to receive millions in state subsidies and make huge profits despite the diesel and emissions scandals.

So don't complain now. Don't whine now that energy prices are supposedly "suddenly" unexpectedly high. We knew it was bound to happen at some point. We just didn't want it to be true.

Don't complain now about anyone else making wrong decisions in the past. We have all looked the other way and done too little to make sure that the economy was being managed differently, more sustainably. To blame others is easy but not honest. What's true is that at least those who are now older than 25 could have acted more responsibly – with more attention to the needs of the general public and less on our own wallets.

The good thing is that the current situation offers plenty of opportunities to make changes – and they are sorely needed. Changes are absolutely always associated with uncertainty of a favorable outcome, but they also hold the chance of being able to improve something.

We in Germany have not only the opportunity, but the duty really, to make the best of the current situation. Because we have the knowledge, the resources and the money.

Certainly, it is difficult for many citizens at the moment to keep the big picture in mind while we're in a state of emergency and to participate with sincere hope in saving the world. That's why it is necessary to swiftly take appropriate measures now to cushion social and financial hardships to come.

All others are also called upon at this point to finally act. There are enough privileged people who have the means to contribute to suitable solutions for a clean, sustainable future – on the large as well as small scale. Be it at the political level or in your own household, everything has significance.

Many of the companies that have been busily researching hydrogen and fuel cell technologies in recent years can now actively contribute to the rapid implementation of the long-heralded clean energy transition. The Energiewende, which has so far been nothing more than an empty phrase, must finally be filled with content. Must be realized and lived.

For this is needed all of the technologies that have been lying dormant in laboratories, still waiting for their market entry. Instead of just being researched and developed, future-looking products must now be brought into circulation and scaled up. When if not now?

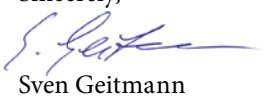
The positive news is that there are already numerous good examples. In February 2022, the US engine manufacturer Cummins put its first European fuel cell factory, in Herten, into operation. Mid-March, another North American publicly listed company, Plug Power, followed with a production site in Duisburg.

Nearly the same time, Intel declared that it wants to invest 17 billion EUR in a chip factory in Magdeburg. Meanwhile, in the nearby city of Zerbst, approval was given for construction of a 3,000-square-meter production site at which green hydrogen, with the help of solar, wind and biogas, is to be generated – an investment volume of 75 million EUR.

More such projects with partners from different regions are needed so that we can be more independent and better help others. The way is thus prepared for a socio-ecological transformation.

Even if the occasion – the war in Ukraine – is despicable, it has made it all the more important to get on the right wagon now and finally create an economy that is fair to future generations. ||

Sincerely,



Sven Geitmann
Publisher of H2-international

CONTENTS

08 Plug Power chooses Duisburg as production site

20 Use of seawater for electrolyzers

WILHELM MOVES TO THE DVGW

Fig.: Tilman Wilhelm [Source: DVGW]

Since April 2022, the former head of communications at the German national organization for hydrogen and fuel cells (Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie GmbH, NOW) has been working at the German association for gas and water standards (Deutscher Verein des Gas- und Wasserfaches e.V., DVGW). Tilman Wilhelm, who had been responsible for the public image of NOW since 2008, henceforth works as head of regulatory policy, press and public relations at the trade association. Dr. Gerald Linke, managing director of the DVGW, said, "With Tilman Wilhelm, a proven hydrogen and mobility expert with excellent political connections in Berlin and on the EU level is taking over responsibility for communications at the DVGW."

Wilhelm said: "The pace at which we are developing our energy supply and driving forward the integration of renewables in all sectors will continue to accelerate. The coming years hold great legislative and communication challenges in store. The DVGW has a central position in this change process. The objective: an energy system that is ecological and economically successful." He is succeeding Dr. Dennis Rendschmidt, who had left the association last year. ||

ALINA HAIN BECOMES NOW COO

Fig.: Alina Hain [Source: NOW]

NOW GmbH (Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie), the German organization for hydrogen and fuel cells, is getting a new head of business. On April 25th, 2022, Alina Hain is taking over the position of managing director and chief operating officer (COO). Spokesman of the managing board remains Kurt-Christoph von Knobelsdorff.

Hain follows in the footsteps of Wolfgang Axthammer, who had been with NOW since 2008 and was commercial director of the company from 2012 to 2021. She is continuing the supervision of the currently over 150 employees across four operating locations. Hain was born in Poland and has a law degree from Poland and from Germany. She is currently the head of administration at Leibniz IGZ (Leibniz-Institut für Gemüse- und Zierpflanzenbau), which is a research institute for plant cultivation, and before that worked for a chamber of commerce as well as the government of the state of Brandenburg.

Hain declared: "The goal of a climate-neutral society inspires me. I am convinced that it can be achieved if everyone makes their contribution. NOW GmbH is, in my view, a key player for the energy transition in the transport sector. That is, the employees play an important role in advancing emissions-free technologies and sustainable mobility." ||

FÜLLENBACH REPLACES PICHLER

Fig.: Martin Füllenbach [Source: SOLIDpower]

The SOLIDpower Group came under new leadership at the end of 2021. On Dec. 1, Martin Füllenbach took over the reins from Andreas Pichler who stepped down after his term of office expired following three years of service at the fuel cell equipment manufacturer.

Füllenbach has previously worked in management roles at companies such as Oerlikon, Voith Turbo and EADS and most recently oversaw the four-year restructuring of Semperit AG Holding, a publicly listed company of long standing headquartered in Austria which develops, produces and distributes rubber products for the industrial and medical sectors. A doctor in finance, Füllenbach is now tasked with accelerating the global rollout of SOLIDpower's BlueGEN technology as well as its industrial production. ||

NWS GETS A NAVIGATION POST

Never before has there been so much talk about hydrogen. And, accordingly, many questions. In order to be able to answer at least some of these questions, the German government has now established a Lotsenstelle Wasserstoff (hydrogen navigation post) to inform inquirers particularly about the support offers of the federal government.

The respective support needs are determined through an initial consultation with the federal funding advisory service for research and innovation (Förderberatung "Forschung und Innovation"). They find out who needs what kind of help for what in order to precisely direct the person to concrete offers.

The H_2 navigation division of the advisory service aims to contribute to implementation of Germany's national hydrogen strategy (NWS, Nationale Wasserstoffstrategie) by informing about the various support and funding opportunities that are already available from the many different government programs of Germany and the EU. ||

→ lotsenstelle@nationale-wasserstoffstrategie.de
Hotline: +49 30 2019 9420

H_2 AND LNG TERMINAL IN WILHELMSHAVEN

The search for alternatives to Russian natural gas is in full swing. Even before the march into Ukraine, some stakeholders had been advocating the import of liquefied natural gas (LNG) from the USA – as an alternative to Nord Stream 2. However, since the US exports gas obtained by fracking, which does not have a positive image in Germany, the German government is currently also trying to reach out to other source countries, for example in the Middle East, particular Qatar and the United Arab Emirates.

So far, however, Germany does not have a port where LNG tankers can unload their cargo. Efforts are therefore currently being made to create the appropriate conditions in Wilhelmshaven, the major port on the North Sea in Niedersachsen. The hydrogen project company Tree Energy Solutions (TES) together with Belgian investor group Atlas Invest are modifying plans for a hydrogen processing facility with power station there to also accommodate liquefied natural gas.

TES has been working to import green hydrogen from countries with plenty of solar and wind power since 2019. Initially, an import station for this and an export station for CO_2 were to be built in Wilhemshaven. The planning is now being expanded to include a terminal for bringing liquefied natural gas ashore, an investment volume of nearly 25 billion EUR until 2045.

TES manager Otto Waterlander told the Handelsblatt, "The German government has asked us to integrate an LNG terminal into our planned hydrogen factory to reduce dependence on imports from Russia as quickly as possible." TES founder and managing director Paul van Poecke said, "We're now planning further work to greatly ensure the start of phase 1 operation by winter 2025." ||

HYDROGEN FROM LANDFILL GAS

Bioenergy is not talked about as much as solar and wind energy in the context of H_2 production, but biogas, for example, is perfectly suitable for the production of green hydrogen. To bring some more light into the bioenergy darkness, the waste management association of Nordrhein-Westfalen (Bergische Abfallwirtschaftsverband, BAV) and the Austrian energy startup Rouge H2 Engineering (RGH2) put a research reactor at the Leppe dump site in operation in February 2022. There, in a test operation lasting several months, a decentralized production of high-purity hydrogen from landfill gas is to be tried and further developed.

At this landfill located in Lindlar-Remshagen, likewise to other dump sites, landfill gases with average methane content of 45 vol% develop. These gases, which issue from organic waste as a result of anaerobic decomposition processes, are collected and converted into electrical energy in a combined heat and power unit. BAV and RGH2 now want to investigate what effects the waste composition has on hydrogen production.

In addition, the :metabolon Institut, the waste recovery research facility of technical university TH Köln, is checking whether the RGH2 reactor is suitable for connection to the pyrolysis unit at its thermochemical research center. After a successful test operation, the project partners are aiming at a large-scale demonstration plant for the conversion of landfill gas to hydrogen. ||

Fig.: New H_2 research reactor at Entsorgungszentrum Leppe [Source: RGH2]

FC FACTORY FOR HERTEN

Cummins has opened a location in Europe. On March 3rd, 2022, the US engine manufacturer put its new fuel cell factory in Herten into operation. Cummins had taken over the Hydrogenics Corp. and with it the German branch Hydrogenics GmbH in the summer of 2019, which had been located in Gladbeck and is now in the HTVG (Gesellschaft für Technologieentwicklung und Vermögensverwaltung der Stadt Herten mbH) technology development center H2Herten.

Fig.: New Cummins production site in Herten [Source: Cummins]

In the virtual presence of Nordrhein-Westfalen's Minister-President Hendrik Wüst, the vice president of Cummins, Amy M. Adams, stated: "Europe is an important region for the global hydrogen economy, in which many governments are pursuing hydrogen strategies and creating incentives for the decarbonization of the transport sector and other industries. We are further expanding our presence in Europe to bring more fuel cells into use and to ease the transition to zero-emission vehicles for our customers."

The new 4,200-square-meter (45,000-square-foot) production center at the site of the former coal mine Ewald has an initial capacity of 10 MW available for the PEM fuel cell modules, which will primarily be for Alstom's Coradia iLint trains. According to information provided by Cummins, the building was erected by HTVG in only ten months. HTVG, as a subsidiary of the city of Herten, supervises, among others, the center for hydrogen projects H2Herten and is now leasing the new building to the US company.

Dr. Bernd Pitschak, managing director of Hydrogenics GmbH, was pleased that the site had only been moved 20 km to the east so the good, established relationship with the region could be maintained. ||

PLUG POWER EXPANDS TO EUROPE

Fig.: Chris Suriano opened the new facility in Duisburg, Germany

The US corporation Plug Power opened its European headquarters in Duisburg, Nordrhein-Westfalen (NRW) on March 18th, 2022. The new production site of Plug Europe lies at the center of Duisburger Hafen, the world's largest inland port. CEO Andy Marsh had really wanted to make a special trip from the United States to make the opening speech, but he was unable to because of a corona infection. Chris Suriano stepped in for him. Suriano declared, "Our local presence is very important in our key markets." He smugly added, "We have only just begun."

So far, the two halls are actually still empty. But by the end of the year, a service and support center with technical laboratories as well as logistics and training rooms is to be built on the approx. 6,500 square meters (70,000 square feet). In addition, an electrolyzer with the infrastructure for production of green hydrogen is to be installed at the site.

Plug Power, which builds not only FC systems for powered industrial trucks but also electrolyzers, aims to produce 17 t_{H2} per day by the year's end, and more than 500 tonnes by 2025. Green hydrogen, no less. Prof. Andreas Pinkwart, the economy minister of Nordrhein-Westfalen (center in photo), added, also in English, "NRW will have a huge demand on green hydrogen in the future. A rapid switch to renewables is a crucial necessity."

Plug Power has had a presence in Europe for over ten years, among others through its joint venture Hyvia with Renault. Not least from the acquisition of the Dutch company Frames did its number of employees in Europe recently jump from 16 to 225. Hyvia is expanding as well and opened a fuel cell factory in Flins, France at the beginning of this year, where the Plug Power FC modules conceived for Europe are to be assembled and tested. ||

HYDROGEN POSTER COMPETITION

Hydrogen is now also making its presence felt in cultural quarters thanks to two associations based in Hamburg, Germany: The hydrogen society Wasserstoff-Gesellschaft Hamburg has organized a hydrogen-themed poster competition in partnership with the Kulturaustausch Hamburg-Übersee, an arts charity with its own gallery and publishing house. The 19th edition of the poster contest, which always has a contemporary theme, had previously been delayed by the pandemic. As a result, the exhibition opened on Oct. 30, 2021, and the award ceremony finally took place at the end of February 2022.

Invited to compete in the event were children aged between 10 and 14 years who live in the metropolitan region of Hamburg. They were tasked with producing a creative artwork to express their visions and views of hydrogen. Twenty posters were selected by the judging panel to form part of an exhibition, the patron of which is Michael Westhagemann, Hamburg's senator for the economy and innovation. Six of the pictures will also be awarded a prize and incorporated into the charity's global touring exhibitions.

Jutta Wiegert, executive board member of Kulturaustausch Hamburg-Übersee, was delighted that one of the posters had been picked to illustrate the cover of the current edition of H2-international. The chosen artwork was created by Liliane L., born in 2009, who attends Waldörfer Gymnasium in Hamburg.. ||

→ www.galerie-kam.de/kpw2020/

Category: Trade shows and conferences | **Author:** Sven Geitmann

DIGITAL OPPORTUNITIES

Commentary on the changing face of the events sector

In a repeat of previous years, 2022 was also unable to escape the turmoil of rescheduling as, once again, many exhibitions and conferences originally planned for the start of the year were delayed at least until the summer. For most organizers, it's still unclear which events it will be possible to hold in person. Among those affected is Hannover Messe, which has postponed its opening from April to the end of May: At the time of writing, uncertainty remained as to what form the trade show would take, if, indeed, it goes ahead at all. Hence the popularity of digital formats in recent months. So what does this trend mean for the hydrogen sector? Should we pine the loss of face-to-face events or do online shows offer an adequate alternative – and perhaps even harbor new potential? If any real-life events are planned, should they be held in the summer and then everything shifted back online in the fall?

I mused once before on digitalization in the events industry in the February 2021 edition of H2-international. At the time, we didn't know how much longer the pandemic would keep us in its grip. What was already foreseeable, however, was the increasing pace and importance of digitalization within the events sector.

It's now been two years since COVID-19 began rocking the events calendar; the previously predictable annual lineup is now barely discernible. Except at Mission Hydrogen, that is. The digital events agency has now run numerous webinars, some of which were attended by hundreds of participants. In addition it has started organizing two large events a year – the Hydrogen Online Workshop (HOW) in spring and the Hydrogen Online Conference (HOC) in the fall. Further dates extending into 2027 have already been set and are timed to be exactly half a year apart.

MISSION HYDROGEN SHOWS THE WAY This agency, led by Silke Frank and David Wenger, provides the perfect example of the kinds of changes that greater digitalization could bring and the opportunities it could offer:

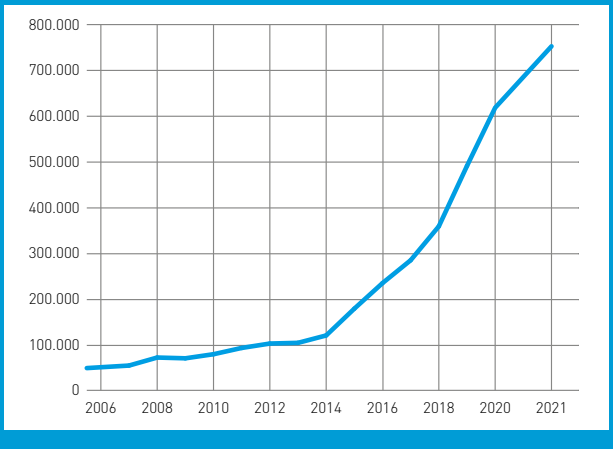
The first HOC in 2020 attracted 77 exhibitors, with more than 5,600 visitors from around the globe joining the conference during its 24-hour-long opening (see H2-international, February 2021). By way of comparison, the first Hydrogen Technology Conference & Expo in October 2021, which drew positive reviews, played host to 130 booths and 2,700 participants (see H2-international, February 2021). Here it's worth pointing out that, according to the classifications of the German FKM society that voluntarily verifies trade fair statistics, one delegate at a trade event is counted twice if that person attends on two separate days – and three times if they are present for three days.

These figures are testament to the fact that the internet has a far greater reach than is possible in real life. But how many virtual attendees are really present over a long duration? And how valuable can these online encounters be? Can this approach also give rise to new business opportunities?

In my H2-international commentary in early 2021 I wrote, somewhat skeptically: "I suppose only [...] Frank and Wenger could give an accurate account of the HOC's actual size. [...] I feel I have yet to develop a sense for how well (or not) attendees receive these offers, for the prevailing mood among exhibitors and speakers." I can only assume that the same must be true for everyone else sitting alone at their computers. Real transparency is not something readily associated with digital events. While a quick look around the exhibition halls tells you all you need to know about the footfall, by contrast, a visitor or press representative to an online show has no real way of gauging the busyness or the general mood.

For this reason Silke Frank, who worked for many years at the Peter Sauber agency before founding Mission Hydrogen with David Wenger serendipitously at the start of 2020, has granted an insight into the company's reporting. The

Hydrogeit Verlag's statistics make for a useful comparison: In the past year around 750,000 visitors in total have viewed its various websites (www.hydrogeit.de, www.hydrogeit-verlag.de, www.hzwei.info, www.h2-international.com) – a trend which is increasing sharply.



decision to share a large swath of data is Silke Frank's way of trying to create some transparency. This is where Mission Hydrogen's key figures table comes in. Compiled on a monthly basis, the data reveals how many newsletter subscribers, Twitter and LinkedIn followers, webinar participants and homepage visitors that the company has racked up over the preceding weeks.

Noticeable, here, are the number of registered webinar users (260,000) and webinar participants (52,000) for the whole of last year. Even if the data happens to include a large proportion of "repeat offenders," the reach is far higher than anything an in-person event could hope to achieve.

The interest in webinars or online conferences is only one part of the picture. Mission Hydrogen's other focus is virtual exhibitions. Whether online exhibitions are actually a good idea – from either an exhibitor's or an organizer's perspective – is still hard to judge, making it difficult to give a straight answer.

You could be forgiven for supposing that, for many visitors, the prospect of navigating to a webpage depicting a trade booth so as to search out information or pick up contact details would have only limited appeal. Nevertheless, there are digital events where you can visit and book virtual exhibition booths – be it Hannover Messe, the HOC or the HOW. Why? And how come other organizers are much more reticent to divulge their statistics?

As Silke Frank explained to H2-international, the broad reach is key for Mission Hydrogen. On March 3, 2022, a total of 5,340 people from 112 countries took part in the HOW. According to Frank's information, the average number of contacts at one of the event's virtual booths is around 450. "Try to collect that many business cards at a physical trade fair – it would be a difficult ask," she stated confidently.

If the quantity is matched by the quality of the contacts, there's no doubt this would help encourage acceptance. For now, we will just have to wait to see whether or not Hannover Messe can go ahead as an in-person event. Should it be canceled for the third year in a row, then there may well not be enough booth builders and caterers left standing by the time the show rolls around again. The next HOC will take place on Nov. 8, 2022. ||

BACK IN HALL 13 FOR HANNOVER MESSE

Hydrogen + Fuel Cells Europe, according to the current status, will take place May 30th to June 2nd in person on the Hannover Messe fairgrounds. There, industry representatives will be able to network in the dependable corporeal format again. That's the assumption of Tobias Renz anyway, the organizer of this trade fair. The space booked for stands may be similar to the last time, in 2019, before the corona pandemic. Renz hopes to be able to present around 200 exhibitors once again.

Tobias Renz told H2-international: "Remarkable this year is the high number of exhibitors who are exhibiting for the first time with us, alongside big names like Bosch, ElringKlinger, Emerson, Siemens, Eberspächer, Saint Gobain, Heraeus and Hyvia (JV of Renault and Plug Power). As in previous years, electrolysis will be one of the main themes, but there is also a lot to see regarding fuel cells/components and hydrogen storage."

For example, Celeroton AG will be coming over from Switzerland. This year, the manufacturer of miniaturized turbo compressors is presenting its latest product: an air supply system for fuel cells with a net power of 30 to 60 kW. The CT-2000 is, according to the manufacturer, an oil-free, air-bearing-based compressor designed for the highest speeds. Along with the new convertor CC-2000, this system is specially conceived for automotive requirements, especially in the commercial vehicle sector. As Celeroton distributor Peter Terstappen shared with H2-international, its predecessor is already in series production and currently delivered in small quantities to big customers, for example in the Rhine-Main region.

REFUGEES ON THE FAIRGROUNDS

Since March 2022, the train station in Laatzen, just south of the city of Hannover, has served as a shelter for refugees from Ukraine. Some will be accommodated on the exhibition grounds. As Tobias Renz assured H2-international, they will be accommodated in hall 27, which will not be used for the fair, so this will have "no effects on Hannover Messe."

BACK TO OLD HAUNTS This year, the former joint stand for hydrogen and fuel cells, which developed into its own trade fair over the years, will be in Halle 13, Stand A50. Long-time visitors of the fair will remember that H2FC had already been placed there for years before it was a guest in hall 27. This move means that this time "only" eleven halls on the south and east sides of the exhibition grounds are occupied. In pre-pandemic times, there were a few more. The fair also used to be longer. This year, the Friday, when mostly private, non-industry visitors would come, has not been included.

The partner country for 2022 is Portugal. For the more than 100 exhibitors expected from the Southern European country, hydrogen is an important topic, since Portugal is determined to reduce energy consumption, use resources more efficiently, achieve more sustainable mobility and greater security of supply and diversify their renewable energy sources. ||

FREE TICKETS FOR INDUSTRY PROFESSIONALS

Like usual, there will be Fachbesucher-Tickets (trade visitor tickets) in 2022. Industry business professionals who want to enter the exhibition grounds free of charge can request these tickets from Hydrogeit Verlag. Simply contact the editorial team.

Category: Trade shows and conferences | **Author:** Sven Jösting

EVERYBODY'S TALKING ABOUT HYDROGEN

Commentary on the Handelsblatt Energy Summit

Fig.: Dr. Andrew Forrest, CEO of FFI, reported about his activities in Australia [Source: Fortescue Future Industries]

Hydrogen was a dominant feature at this year's Handelsblatt Energy Summit, which took place online and in Berlin from Jan. 17 to Jan. 20, 2022. The discussions covered its many production-dependent colors and possible applications and underlined the major role the energy carrier has to play in successfully transforming the planet's energy ecosystem.

The price explosion in fossil fuels such as oil and coal but, above all, natural gas presents the energy industry with an array of problems. In particular, the conflict between Russia and Ukraine as well as the issue surrounding the use of the new Nord Stream 2 pipeline are also helping drive up the price. The provision of energy and its price are two key location factors for industry, especially in an industrialized nation like Germany. The question therefore arises as to where all the hydrogen – ideally green – will come from and what the infrastructure will look like.

Germany does not have enough sites for the generation of solar and wind power in order to facilitate sufficient hydrogen production, according to the apparently unanimous view expressed by representatives of all the main energy suppliers. It was therefore felt that a large proportion of the necessary hydrogen will be sourced in the form of imports from regions where the conditions are much more favorable than in Germany. And it's worth noting that Germany already imports over 70 percent of its primary energy.

Then, of course, there is the tricky business of precisely how to define green hydrogen. Given that the European Union's taxonomy also classifies energy from nuclear power plants and natural gas as "sustainable," this goes to show there is still a need for further debate.

AGENCY NEEDED TO TRANSPOSE AND DELIVER ENERGY TRANSITION A large part of the discussion during the summit centered on regulation – be that at an EU, national or local level. Here, the view was that things need to be tackled more pragmatically and at much greater speed as otherwise the highly ambitious climate goals of Germany's coalition government will not actually be achieved. It's therefore a matter of getting the framework right in order to ramp up the energy transition and the hydrogen economy. It's clear that nothing can happen without hydrogen, at least that was the consensus of almost all speakers.

If faster action can be taken and bureaucracy minimized, the more rapidly the required energy will be obtainable. There were also calls for current planning procedures, which can often take up to 10 years, to be accelerated drastically. Some authorities and state institutions (e.g., the Federal Network Agency) should have their remit redefined and take a proactive approach rather than act obstructively. The suggestion from the summit was that there needs to be a greater degree of planning expertise in engineering law at the responsible bodies instead of them being just a juridical authority.

CLIMATE POLICY IS INDUSTRIAL POLICY Positive noises were heard about Germany's renewable energy law EEG finally coming to an end and the introduction of a market-based regulatory system that takes account of climate change through carbon dioxide certificates and carbon dioxide pricing. Now all that remains is to make sure that the conditions in EU member states are comparable. In this regard, it's long been the case that other countries have enjoyed clear competitive advantages because they are more flexible and act more quickly and pragmatically.

Without government support programs to initiate a ramp-up in hydrogen, it simply wouldn't happen – was the general opinion – with the recommendation that any subsidies should have a clear time limit. This is where investment incentives, in particular, have a meaningful and also necessary role to play. Transforming heat has a key part in this, since this area of the economy accounts for a good 40 percent of energy demand. Electric heat pumps will come increasingly to the fore, but so too will hydrogen as a substitute for natural gas in the heating sector as well as for power generation.

There are many existing buildings that can't be upgraded to the latest energy technologies overnight. Indeed, dis-

trict heating isn't a feasible option everywhere. Hence summit participants spoke of the need to dramatically expand existing gas power plants with a view to running them on hydrogen instead of natural gas. In short, the energy transition – propelled primarily by exploiting the potential of hydrogen – will come and it will succeed. But a) it won't happen overnight, and b) it needs some serious cash.

PLANNING WITH THE FUTURE IN MIND The current way of going about things is to look at how much energy will most likely be available in 2030, 2040 or 2050. A much more sensible approach is to start in the future and work back to today. What needs to be done now in order to reach the desired targets? That's when totally new forms of energy consumption come into play, if you take electric transportation, for example. Other important factors are Germany's standing as an economic powerhouse and issues such as the digitalization of energy markets, decentralized production and on-site consumption. This requires joined-up thinking.

While policy provides the framework, it's industry that translates these measures into action. That's why industry should be given greater freedom, business representatives at the summit urged. Too much "false" regulation could lead to companies investing elsewhere, they claimed, adding that too many investments are still being blocked. Furthermore, it was mentioned that other parts of the world are taking more resolute and concerted action, and in some cases in a more cavalier fashion.

10 NOT 5 GW BY 2030 The new government and the German economy minister Robert Habeck have not only recognized the potential of hydrogen but are now also encouraging its scale-up. For instance, the intention is to increase hydrogen-based energy production from the planned 5 gigawatts to 10 gigawatts in the run-up to 2030.

As for the color of hydrogen, some industry players are now being more open minded and are accepting that the blue variety (produced via the reforming of natural gas) is a sensible option in the transitional period until green hydrogen can take over, during which time biogas-derived yellow hydrogen should also be deployed. The expectation now is that hydrogen-purchasing deals will be negotiated around the world. For example, there's an agreement with Ukraine as well as a private-sector project between the Australian concern Fortescue and the German company Covestro, equating to 100,000 metric tons of green hydrogen per year. Special attention should also be given to the promotion of electrolysis research.

The conclusion that can be drawn from this highly informative, content-heavy congress is that hydrogen is not just an option, it's a necessity in order to turn around the climate crisis. For this to succeed, it's important to up the pace of implementation. Hydrogen will become available in ever greater quantities at ever better (lower) prices and its importance as a tradeable commodity on the world's energy markets is set to increase massively. ||

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

IS THE GAS SECTOR REALLY H2-READY?

Yes, but H_2 is far from being established

The heating sector is still seen as the "sleeping giant" that needs to be awakened in order for the energy transition to be reached. A major problem is the lack of alternatives to heat generation with fossil fuels. A major beneficiary of the phase-out of coal and nuclear energy is likely to be the gas industry, which is already advertising the replacement of natural gas by green hydrogen, although so far hardly any carbon-free-generated H_2 gas is available. Nevertheless, suppliers of fuel cell-coupled heating systems are currently having a hard time profiting from the upswing in the H_2 industry, because their units are still dependent on fossil gases for the time being.

Fig. 1: Gas pipes – also suitable for hydrogen [Source: Mannesmann Line Pipe]

"H2-ready" – The gas industry is fixed on this label. As soon as the criticism that like oil, hard coal and brown coal, natural gas is a fossil fuel, reference is made to hydrogen and how blending turns gray natural gas green. But how quickly does this color change take place? From what point does fossil-sourced gas become a green gas? From what blending rate and what year?

According to Ronald Aßmann, test site manager at Gastechnologisches Institut gGmbH Freiberg (DBI), their registered assurance label "H2ready geprüft" (H2-ready tested) certifies that "the products are for the indicated percentage of hydrogen (usually up to 20 vol% H_2 in natural gas or up to 100 vol% H_2) operational/capable." Therefore, "H2ready geprüft" does not mean that all of the units thus marked can tolerate pure hydrogen, but rather that they are at least suitable for partial H_2 admixing. The volume percent of hydrogen for which suitability exists is usually documented in the certification documents. To date, fossil gas is still the main gas in the fuel in most cases.

CHICKEN-OR-EGG PROBLEM IN STATIONARY SECTOR AS WELL The manufacturers of fuel cell heating appliances are therefore faced with extra challenges. Their units, despite subsidies, cost many times the price of a fossil gas-run boiler. They also offer no CO_2 savings in the short term. It's quite to the contrary. The modules also generate electricity from the gas, which is not yet really green, and in doing so may displace the green electricity that would have been drawn from the grid, therefore causing a worse CO_2 balance.

Heating, of buildings and for industrial applications, accounts for over 50 percent of Germany's end-use energy consumption, and it is still strongly dominated by fossil fuels. Carbon emissions from the heating market account for around 40 percent of Germany's total carbon emissions.

Only when pure hydrogen is used in FC devices can the modern energy converters demonstrate the advantage of a comparatively high efficiency. But as long as there are no H_2 grids, there is a similar chicken-and-egg dilemma in the stationary sector to that in the mobile sector. Without an H_2 infrastructure, the introduction of FC products is not worth the expense; but if there are no such products in use, no one will invest in the networks for them.

DRY SPELL FOR HEATING DEVICE MANUFACTURERS For the producers of fuel cell heating devices, this means that the marketing of their units will be further delayed. Anyone who is building today and has a limited budget usually decides in favor of a gas boiler, because it is proven, affordable and can be installed quickly. It does not seem to concern many home builders that these devices will expectedly to be in operation for the next twenty years and thus will not contribute to the decarbonization that is required in the near future. But a rude awakening could come soon, as gas prices are already rising dramatically.

Markus Dönges, Head of Product Line Management at Viessmann Deutschland GmbH, has stated that for the operator of the proprietary FC device Vitovalor, "energy costs are up to 40 percent lower than for the usual solution of electricity from the grid and a conventional boiler." In response to H2-international's inquiry as to which prices this percentage is based on, Alexander Dauensteiner, Product Line Owner Fuel Cells, explained, "The savings refer to average energy costs and do not include the currently significantly higher gas and electricity prices for new customers." Therefore, it is advisable for homeowners to recalculate in view of the currently rapidly rising prices for natural gas and to plan for further developments in fossil fuel costs.

Heat pumps are currently very popular as an environmentally friendly alternative. Most choose the more cost-friendly option of an air source heat pump because of the price. But their efficiency, the annual performance factor, is quite low at our lat-

In a short study for the foundation Stiftung Klimaneutralität, Prognos AG investigated whether heat pumps or hydrogen heating systems are more efficient. The study shows that heat pumps can contribute significantly to flexibility of the electrical grid, while the use of hydrogen-powered fuel cell heating systems leads to a significantly higher H_2 and also electricity demand, which would be more inefficient. The authors therefore recommend, instead of electricity generation, rather the use of hydrogen produced on the basis of renewable energies in backup power plants. In the building sector, heat pumps should be promoted as the main technology for achieving the climate targets.

Prognos; Dezentrale Wärmeversorgung in einem klimaneutralen Deutschland; Kurzstudie im Auftrag der Stiftung Klimaneutralität; 2022

itudes, and they are unsuitable for poorly insulated, old buildings. More efficient, but also more cost-intensive, is a ground source heat pump.

Stationary fuel cell devices are currently attracting only very limited interest. It is currently quiet in this segment, because heating device manufacturers hardly advertise this technology. Instead, they are waiting for better times, when H_2 networks are established. This has quietly been confirmed by the employees. It almost seems like the marketing departments are relieved that there are hardly any hydrogen-related fairs taking place at the moment.

Fig. 2: Schuck gas house-transitions HSP – suitable for H_2 gas [Source: Schuck]

Also the stationary sector is at this time virtually excluded from the political debate on hydrogen. While in the mobility sector there is still a dispute whether hydrogen should only be used in the commercial vehicle segment or also the passenger car segment, it is clear that the most important thing is to first decarbonize industrial activities. Based on the current perspectives regarding utilization of H_2, the heating market is going to be last on the list.

PREPARATIONS FOR THE MARKET RAMP-UP Nevertheless, some companies are trying to position themselves to get going as soon as enough green H_2 gas is available. For example, SOLIDpower, an FC manufacturer based in Germany and Italy, announced mid-2021 the start of a cooperation with the GC Group. The GC Group is made up of approximately 15,000 employees, 100 specialist wholesalers at more than 850 locations. It is said that they will be helping in the distribution of SOLIDpower's BlueGEN CHP devices.

In addition, the Heinsberg-based FC company parted ways with its managing director for the past three years, Andreas Pichler (see p. 6), and instead appointed a proven economics and organization scientist to head the company. Martin Füllenbach had previously restructured the rubber specialist Semperit and brought about there "an impressive increase in profitability." Which is why the SOLIDpower Group has entrusted him with leading the business in the hoped for market ramp-up.

Panasonic, which has a cooperation in the fuel cell sector of Europe with Viessmann, an Allendorf-based German boiler manufacturer, already has extensive experience from its home market, Japan. There, a total of 400,000 FC systems are already in the field, and half of them are Panasonic's. There is expected to be 5.3 million in the island nation by 2030, corresponding to a quarter of all households. If comparing only the heat generation, according to the manufacturer's statement, each of these systems saves about 1.4 tonnes of CO_2 per year in comparison to a gas boiler. In Germany, Viessmann sold its 10,000th fuel cell-powered heating unit mid-January 2022.

The conventional condensing boilers installed today from Viessmann are suitable at least to a limited extent for the use of hydrogen. Dr. Frank Voßloh, the managing director of Viessmann Deutschland, stated, "Our devices today can already operate with 20 percent hydrogen." In addition, the company is developing H_2-ready gas condensing boilers that will be suitable for operation with natural gas, with natural gas-hydrogen mixtures and with pure hydrogen. It is said that to convert the network to a pure H_2 network, only the burner assembly would need to be replaced in these units. They should be ready for the market in 2025, according to the chief technology officer Dr. Markus Klausner.

Fuel cell units that can run on pure hydrogen are also expected to come onto the market in 2025. Designed for this, the Panasonic module named Kibou, the Japanese word for hope, outputs 5 kW with an electrical efficiency of 56 percent. Several of these modules reportedly are being installed in the 100% renewable energy factory RE100 in Japan that has been in construction since October 2021. The 570-kW photovoltaic plant in Kusatsu, Shiga Prefecture is supplying the electricity, which can be stored in the 1.1-MWh battery as well as the 78,000-liter hydrogen tank. The 100 FC modules installed there can together generate 500 kW, which can be used to supply the factory in which the ENE-FARM home fuel cells are to be built all year round, a total energy demand of 2.7 GWh annually.

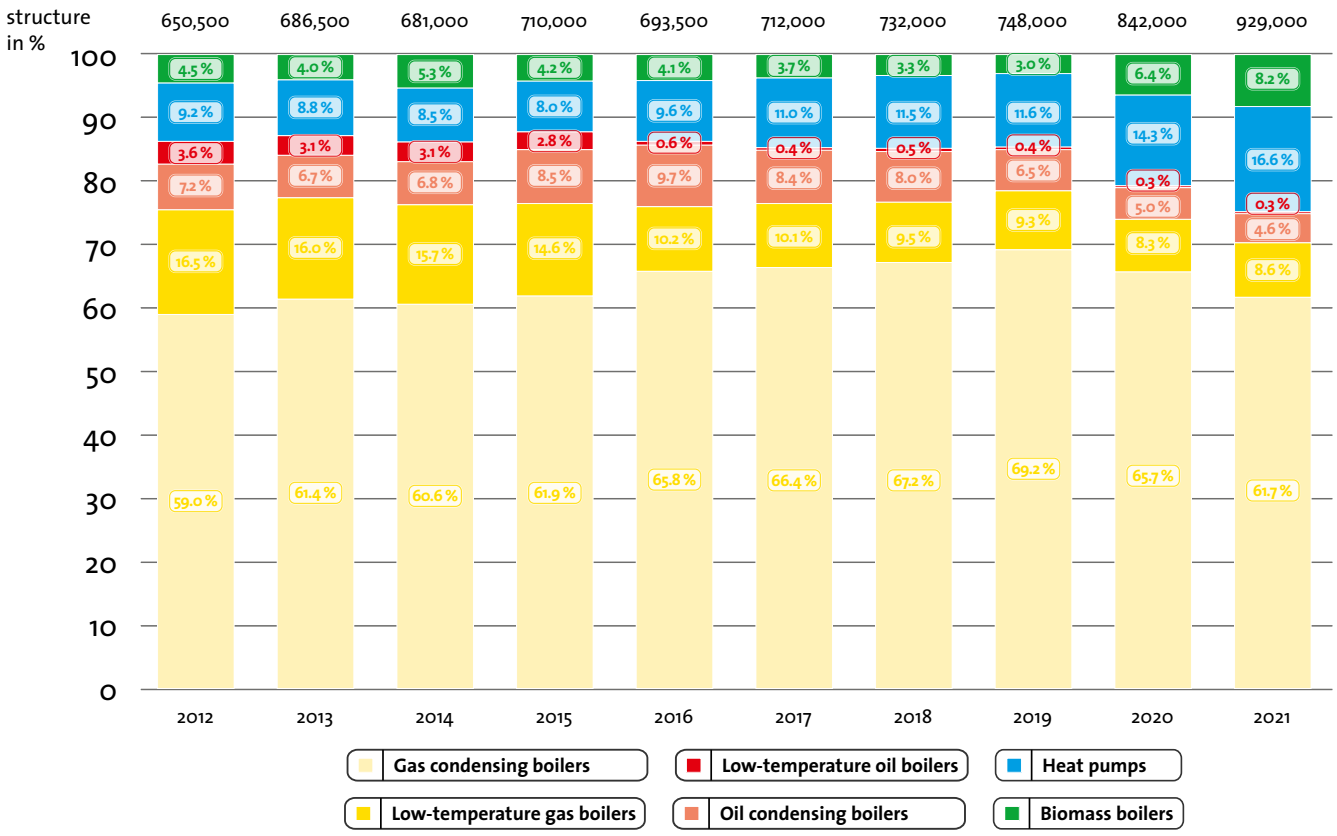


Fig. 3: Heating Systems in Germany [Source: BDH]

COMPONENTS ARE H2-READY The trend towards hydrogen solutions has meanwhile swept up more and more component suppliers, who are now offering the appropriate parts. Franz Schuck GmbH, a supplier of connecting elements for piping systems, already offers a complete array of components. Talking to H2-international, the principal engineer Andreas Dobsch reported that since the beginning of 2020, Schuck has been installing products that are "durably suitable for pure hydrogen".

The Steinheim-based company has been installing around 200,000 gas piping systems per year to supply energy to houses. The parts originally designed for natural gas have been tested and certified for suitability for H_2 gas and are already being installed in series at no extra cost. In this way, the gas infrastructure is already getting upgraded where individual operators think that introduction of H_2 makes sense, and the future switch from fossil to green gas can easily take place.

The product manager at Schuck, Robert Bartle, pointed out that the conversion from natural gas to hydrogen would probably initially take place via micro-grids, that is small, isolated grids. There will probably be a choice of admixtures, for example 30 percent H_2 gas, which will later include pure hydrogen as well. In all likelihood, however, there will hardly be more than three levels of mixing ratio, thinks Bartle. Sabine Augustin, head of corporate development at Open Grid Europe, said in February 2022 in an acatech online conference that the transmission network is "one hundred percent" H2-ready, with the exception of a few "little darlings."

According to Andreas Dobsch, the distribution network, when small pressures and small nominal pipe sizes are concerned, can handle hydrogen without much issue. At higher pressures, however, the type of steel for example is much more important, since especially alternating stress and chemical transformations in the pipes can lead to hydrogen embrittlement with subsequent crack growth. Dobsch explained, "Because of these influences, it is important to use suitable materials and to create construction requirements that ensure proper operation."

Another challenge is insulation, because the very small size as well as the high permeation ability of hydrogen molecules places increased demands on the fittings. There is a need for action in this area as well as in the regulatory framework, which so far has primarily been oriented around natural gas. "Hydrogen is only addressed in a few guidelines, materials standards or materials studies. Which is why extensive work on norms is still necessary," stated Dobsch.

Schuck sees itself well positioned here. Through close cooperation with DBI Gas und Umwelttechnik GmbH Leipzig, they have gained extensive experience in the area, and the first components were able to get DBI's "H2ready-geprüft" label. ||

TRADEMARKED PHRASES

Their hidden potential is shown by, among other things, the current efforts of various players to trademark terms. DBI has already filed "H2ready-geprüft". On the other hand, Mannesmann Line Pipe GmbH has claimed "H2ready®" for itself. The subsidiary of the Salzgitter Group calls its steel tubes for hydrogen conduction "Mannesmann H2ready®."

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

DISPROPORTIONATE GROWTH REQUIRED

H_2 industry must grow faster than PV by 2030

The realization that we need a lot of green hydrogen very quickly, not only in Germany and Europe, but also worldwide, is becoming more and more widespread. Germany has already made the decision to phase out nuclear energy and coal. And after Putin's attack on Ukraine, natural gas is also under examination. The plan was to make the gas grid greener and greener. Now, there is discussion about a much faster ramp-up of the hydrogen economy. Which scenarios are conceivable for this?

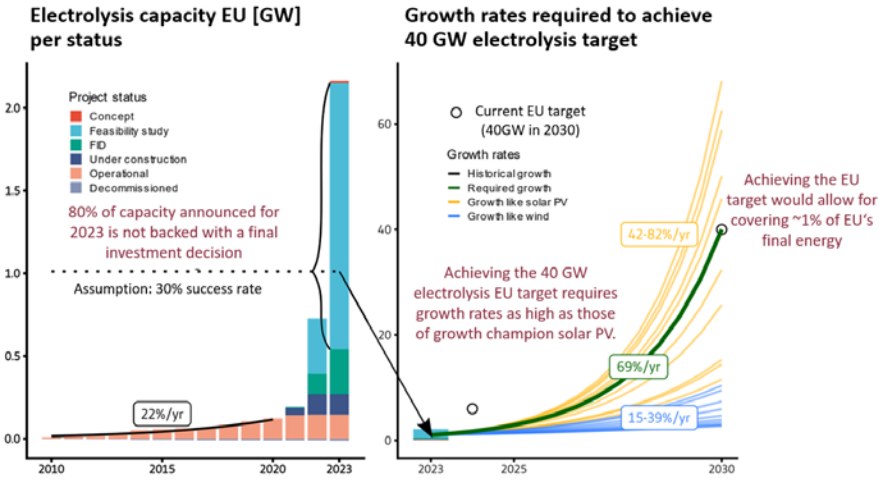


Fig. 1: Expected exponential growth in electrolysis capacities by 2023 (left) and by 2030 (right) [Source: IEA, Ueckerdt]

In a paper by the climate research institute PIK (Potsdamer Institut für Klimafolgenforschung) presented at the H2-Kompass conference in Berlin February 2022, it is shown how the market ramp-up of hydrogen electrolysis might look. The authors, Gunnar Luderer, Falko Ueckerdt and Adrian Odenweller, determined that in the short and medium term (by 2030), green hydrogen will remain scarce, because a ramp-up of the production capacities needs to first occur. In the long term, however, hydrogen and e-fuels (see p. 25) will play a leading role in achieving climate neutrality.

Among other things, the many scientists involved in this analysis have calculated what the growth rate in the electrolyzer sector should be to achieve the EU target of 40 GW electrolysis capacity by 2030 (see Fig. 2). This would require a similarly rapid market ramp-up to that which took place years ago in the photovoltaic sector. That corresponds to a 42 to 82 percent annual growth. An increase of 15 to 39 percent, the case with wind power, would not be nearly enough.

It is considered problematic that for the H_2 projects announced for implementation by 2023, no final investment decision has yet been made. Even a 30 percent success rate would make no visible contribution to achieving the 2030 climate targets, since only 1 GW would be installed by 2023 (see Fig. 1).

According to the study, which was compiled as part of Ariadne, a Kopernikus-Projekt funded by the German education and research ministry (Bundesministerium für Bildung und Forschung, BMBF), the ramp-up dynamics in the hydrogen sector should therefore be vigorously supported, for example through establishment of lead markets, a hydrogen infrastructure, and strengthening of trade across Europe. The talk continues to be of a gradual broadening of H_2 use with dependence on markets and technological developments, for which an adaptable hydrogen strategy is needed.

The authors furthermore claim that direct electrification, especially in areas where there are no market-ready alternatives to fossil energy sources as of yet, such as transport and heating for buildings and low-temperature processes, must be massively accelerated. ||

Literature:

Ueckerdt et al. (2021) – Ariadne Kurzdossier, Eckpunkte einer anpassungsfähigen Wasserstoffstrategie, Markthochlauf der Wasserstoffelektrolyse und Implikationen für kurz- bis mittelfristige Importpotentiale, H_2-Kompass-Konferenz, Berlin, 22.02.2022

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

ENERGY REQUIREMENT DOWN, PRODUCTION VOLUME UP

H2-international survey of electrolyzer manufacturers

The developments in the electrolyzer sector are continuing in great strides. Particularly in costs, where most manufacturers have been able to achieve substantial price reductions in the recent months, even if this has not been reflected in a reduction of the final price in all cases. In addition, both stacks and whole systems are becoming increasingly more compact and efficient.

As part of the market overview that H2-international published in the January 2022 issue, we asked manufacturers about improvements and changes over the preceding 24 months. The presented developments revealed that all the suppliers have made significant progress and are well on the way to establishing an electrolyzer market.

Fig.: The EL 4.0 will be built first in Pisa and then Saerbeck [Source: Enapter]

For example, H2V reported that their energy requirement for H_2 generation (kWh per Nm^3_{H2}) was able to be significantly reduced. H2 Core Systems succeeded in reducing costs by 30 percent just from a switch to series production. Through F&E measures and process optimizations of its own, the partner company Enapter, in the model change from EL 2.0 to EL 2.1, reduced the size of its electrolyzer by 4.5 cm, which was accompanied by a five percent reduction in energy consumption. Meanwhile, EL 4.0 came into being as the the fourth generation of the patented and ISO 22734 certified AEM (anion-exchange membrane) electrolyzer. In March 2022, so before the official market launch this summer, more than 400 orders had been placed.

Sebastian-Justus Schmidt, cofounder and CEO of Enapter, said, "The EL 4.0 will be a building block for system integrators that will allow them to quickly introduce H_2 production and realize the necessary global market ramp-up. We are certain that the future mass production of these AEM electrolyzers will fundamentally change the production of green hydrogen." Mass production of more than 10,000 modules per month is to take place next year at the site currently under construction in Saerbeck, Germany.

In view of upcoming major projects, Sunfire started development of a semi-automated process in order to better exploit scaling effects in the future. In addition, the Dresden-based company succeeded in reducing costs by redesigning its SOEC model. On the other hand, Nel Hydrogen reported an increase of the size as well as efficiency of its stack, along with a containerized solution in the megawatt range.

The US competitor Plug Power made major changes while moving the location of acquired electrolyzer manufacturer Giner ELX to Concord, MA and expanding the production capacities tenfold. In addition, Plug is building a gigafactory in Rochester, NY with an initial capacity of 1,500 MW and an eventual capacity of 2,500 MW after completion. A further site, Düsseldorf, is being created (see p. 8).

Green Hydrogen Systems went public on Nasdaq Copenhagen in June 2021. The Danish company wants to invest the collected investor money in expansion of production capacities (series production of the A series) and development of a next generation of devices (X series) as well as in organizational growth. ||

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

GRID-SERVING ELECTROLYZERS FOR SURER SUPPLY

Decentralized H_2 plants can be economically operated

Source: Elogen

Up to now, Germany has had an energy supply system that's as centralized as possible. Large power plants generated electricity and heat, which was then distributed nationwide by means of an extensively branched infrastructure. With the emergence of renewable energies two decades ago, the idea of decentralization became increasingly widespread: since local solar and wind power plants or biogas plants generate electricity or heat on site, this energy can be used locally, without the need for loss-ridden transports. This basic idea is now also being pursued with hydrogen production by electrolysis. Whether such an approach might be sensible was investigated by the Reiner Lemoine Institut in its newest study "Netzdienliche Wasserstofferzeugung" (grid-serving hydrogen production). The results were presented in an online press conference March 10th, 2022.

The study focused on concrete recommendations for the shaping of Germany's national hydrogen strategy (NWS). The NWS was presented in the summer of 2020, but detailed measures for its implementation are still missing so far. In light of the new global situation with the war in Eastern Europe, there are currently numerous efforts to quickly pave the way so that a secure and mostly independent energy supply can be guaranteed for Germany in the future.

For this purpose, the Reiner Lemoine Institut (RLI), on behalf of Green Planet Energy (formerly Greenpeace Energy), analyzed whether, and how, the use of decentralized electrolyzers could be sensible and economical. As Dr. Kathrin Goldammer showed, electrolyzers with a peak output of up to five megawatts are particularly suited for this purpose. The managing director of RLI explained: "Such electrolyzers can react flexibly to the fluctuating supply of wind and solar power and signals from the distribution grid operators. In this way, they make an important contribution to grid stability and security of supply. The energy system thus becomes more efficient, resilient and cost-effective."

Also Marcel Keiffenheim, leader of the policy and communication division of Green Planet Energy eG, stated that "decentralized electrolyzers offered security of supply, resilience and optimization of solar and wind utilization." Keiffenheim therefore demanded that decentralized electrolyzers be taken into account in the national hydrogen strategy and that clear capacity expansion targets be defined, as not only large electrolyzers are needed. He said, "Instead of just dribbling, we should also drabble. We should do one thing without abandoning the other."

Specifically, he set the power output from decentralized electrolyzers that could be put to good use in the distribution grid at 5 GW by 2030. A part of it (max. 3 GW), he says should be funded through CfDs (Contracts for Difference) so that the current price difference between gray and green hydrogen can be compensated for – for example through a tender for 375 MW per year between 2023 and 2030. This way, up to 13.7 TWh of green hydrogen in total could be produced per year, which corresponds to half of the domestic production planned by the German government by 2030.

To H2-international's question on what basis the economic analysis was carried out, Goldammer explained that the calculations were made in the second half of 2021, when the current trend in prices for electricity was not yet foreseeable. Nevertheless, she assured that the calculations were "still current." ||

> "The government is currently relying mainly on large electrolyzers. We strongly advise supplementing them with small electrolyzers. Such decentralized electrolyzers use local surpluses from wind and solar power to produce green hydrogen, which is beneficial for the national economy. They can be economically operated in many grid areas throughout Germany."
>
> *Green Planet Energy*

Literature:
Schalling, A.; Arnhold, O.; u. a.; Netzdienliche Wasserstofferzeugung, Green Planet Energy & RLI, Febr. 2022

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

WATER NEED FOR A GREEN H_2 ECONOMY

Forward thinking in site selection required

Source: NorthShoreSurfPhotos – Fotolia

For the production of the 14 TWh of green hydrogen capacity the German federal government expects by 2030, no more water is needed than what a city with around 200,000 inhabitants consumes. This was the calculation of the DVGW (Deutscher Verein des Gas- und Wasserfaches), the German association for gas and water standards, in the study "Klimaschutz und Resilienz" (climate protection and climate resilience) from April 2021. According to it, the use of electrolyzers with comparatively low input of water is feasible. Electrolyzers also perform favorably in comparison to coal-fired power plants. For example, the water demand of the energy industry today, which is primarily coal-fired, is more than 50 percent of the total water withdrawal of Germany for the year 2020, according to data from the federal environmental agency UBA (Umweltbundesamt).

With regard to the future energy supply, DVGW spokesman Lars Wagner said, "We assume that there will be a gap of around 70 TWh in Germany in the future, which can be filled with power-to-gas." Generation of the corresponding amount of H_2 would require a total of about 19 million cubic meters (205 million cubic feet) of water per year for Germany. Based on the approximately 24 billion cubic meters (258 billion cubic feet) consumed by all users in this country in 2016, this is a nearly negligible percentage, calculates Wagner. Thousandths of a percent.

IN PRINCIPLE NO WATER SHORTAGE The German trade association for energy and water industries BDEW (Bundesverband der Energie- und Wasserwirtschaft), which deals in both these topics, also does not recognize any deficit. Germany is a land rich in water, the opinion is. "In principle, there is no danger of water shortage from the increased production of hydrogen," expressed a spokeswoman in response to H2-international's inquiry. However, it is important to plan ahead. For example, the majority of German electrolyzers should not be concentrated in any one region.

"Due to regional differences in the availability of water, when planning electrolyzers, similarly to the construction of industrial plants, care should be taken that enough water is available in the region," the spokeswoman said. Otherwise, water could become scarce at certain locations and certain times during dry periods in the summer, as the agricultural sector and households would also demand more drinking water. An example is the result of Tesla e-car production activities in Brandenburg.

THE SHORTEST ROUTE IS THROUGH THE ELECTRICITY Environmental conservationist Arianna Ferrari has another perspective. She is the coordinator for new technologies at the wildlife conservancy organization NABU (Naturschutzbund Deutschland). "The climate footprint of hydrogen from electrolyzers in Germany greatly depends on the source of electricity. The water treatment as well as the building of the facility constitute a tiny fraction of the carbon balance," stated Ferrari. Electricity also plays the biggest role in other environmental impact categories, including impacts related to water systems such as freshwater eutrophication, freshwater ecotoxicity, marine eutrophication and relative water use.

The most efficient way to improve the sustainability of hydrogen from electrolysis in this country is through the electrical power. "For the water, work can be done on site selection and the desalination plant to make it even more sustainable," said Ferrari. In Germany, however, electricity from renewable energies is an important prerequisite for the production of low-emission hydrogen by electrolysis.

DIFFERENT REQUIREMENTS ABROAD Even more critical seems to be the topic of water outside country borders. For this, it's best to deal with one specific country at a time and see what the ecological impact of water use for electrolyzer operation is there, according to Ferrari. Currently, countries such as Namibia, Chile, Denmark, Russia, Tunisia, the Democratic Republic of Congo and Australia are important partners for Germany. There, the water situation is very different, expressed the NABU conservationist.

It is therefore worth taking a closer look at the issue. A study that precisely records the water demand of electrolyzers in Germany is still lacking, confirmed the BDEW. ||

Fig. 1: Pilot plant for producing hydrogen from seawater in the port of Texel island, the Netherlands [Source: Hydron Energy]

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

PURE HYDROGEN FROM SEAWATER

Desalination for future offshore wind farms

A consortium has shown that it's possible to extract climate-neutral hydrogen from seawater. Involved in the SEA2H2 project are automotive and industrial supplier Schaeffler, the startup Hydron Energy, which joined the Schaeffler Group in summer 2021, and Wageningen Food & Biobased Research, or WFBR for short, which is in turn part of Wageningen University.

The pilot plant on the Dutch island of Texel, situated in the North Sea, lies some 60 miles (100 kilometers) north of Amsterdam. The facility is already operational and treats seawater for use in membrane electrolysis. That's because electrolyzers need high-purity hydrogen. The water from around the island must therefore be desalinated as well as undergo laborious purification and filtering processes. What the SEA2H2 technology will do in future is allow green hydrogen to be produced using electricity from offshore wind farms and then transported via pipeline to the mainland.

INNOVATION FROM HYDRON ENERGY As part of Schaeffler, the Hydron team is already working on scaling up its technology. The aim is to fabricate filtering, desalination and membrane electrolysis components on an industrial scale. At the same time, costs are expected to drop and operational efficiency and longevity are set to rise if things go according to the corporation's plans.

"Hydrogen produced from green energy from offshore wind turbines will play a decisive role in achieving European climate targets," assured Sander ten Hoopen. He is one of the founders of Hydron Energy and currently heads up Schaeffler's system engineering. The experience gained thus far will now help toward further expanding Schaeffler's value chain and enabling the competitive manufacture of green hydrogen, ten Hoopen was pleased to state.

The production of green hydrogen from wind energy is a major growth area for Schaeffler. "Working in collaboration with our partners in the wind power sector, we intend to become one of the leading suppliers of system components in this field," confirmed Bernd Hetterscheidt, manager of Schaeffler's hydrogen division. "To this end, we are marrying Hydron's innovative development with Schaeffler's strengths." By this, Hetterscheidt means the understanding of the system as a whole and the know-how to rapidly scale products and projects – aspects he believes will allow the high quality standards of mass production to be quickly reached within the industry.

SCHAEFFLER USES MEMBRANE DISTILLATION Conventional desalination technology is based on reverse osmosis: a process in which seawater is forced through a semipermeable membrane. Ions and other constituents are held back and the seawater is purified. Schaeffler has made a con-

scious decision not to apply this traditional method in the SEA2H2 project. "We use the process of distillation, but in an ultramodern form, that of membrane distillation," explained Hetterscheidt. The process utilizes the waste heat from electrolysis to purify the seawater in an advanced membrane module.

"From a technical perspective, linking up the two systems of electrolysis and distillation was quite a challenge," described Hetterscheidt, adding: "Surprisingly, the search for a suitable site for testing the pilot plant also turned out to be pretty difficult." According to Hetterscheidt, finding an appropriate building plot was a real issue because the site needed to have access to a seawater extraction point as well as the necessary electrical infrastructure.

In addition, it was imperative to meet legal requirements for operating a pilot plant. "After much searching we finally found the right location: the port on the Dutch island of Texel, which is operated by NIOZ, the Royal Netherlands Institute for Sea Research," explained Hetterscheidt.

PEMWE STACK TECHNOLOGY Over the past several years Schaeffler has worked intensively on the industrialization of electrolyzers. "We are convinced that the technology we have developed as part of the SEA2H2 project will be used at scale in a few years and will help create a sustainable, carbon-free energy system for the future," confirmed the Schaeffler manager.

The first production line for PEMWE (polymer electrolyte membrane water electrolyzer) stacks and associated components is currently being configured and improved in terms of automation. What's more, the next generation of high-performance PEMWE stacks is already under development.

In Hetterscheidt's view, the biggest cost factor when it comes to hydrogen production from seawater is, however, the outlay for renewable power. Giving a rough estimate, he explained: "80 percent of the costs for hydrogen production are attributable to operating costs that are dominated by electricity costs. Only a low percentage of the costs are due to the desalination and purification of the water."

In the energy system of the future, many kilograms of hydrogen will need to be manufactured. And each kilogram of hydrogen requires 9 kilograms of water, in other words it's a 1-to-9 ratio (see p. 19). In essence, water treatment is highly dependent on the location and the quality of the water available – even if the expenses only make up a low proportion of the hydrogen production costs. ||

H2GIGA & STACK SCALE-UP

Hydrogen is an important strategic area of business for Schaeffler in terms of sustainability and mobility, hence the gas also forms part of the company's own strategy guideline: Roadmap 2025. An example of Schaeffler's other work on hydrogen includes involvement in the H2Giga project supported by the German education ministry. The company is the consortium leader of the subproject "Stack Scale-up – Industrialization of PEM Electrolysis" and is collaborating with nine partners from industry and research with the aim of making series production of the latest electrolyzer stacks a reality.

Fig. 1: Aerial view of the site in Hemmingstedt [Source: Raffinerie Heide]

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

FASTER AWAY FROM PETROLEUM

Green H_2 reduces CO_2 footprint of refineries

The trend is clear: refineries also need to become greener – recently also to limit the use of Russian oil and gas. In Germany, refineries are responsible for about a fifth of the CO_2 emissions by the sector. Green hydrogen can be integrated into existing production processes. Several refineries are currently making this transition.

Today, 30 percent of the demand for H_2 in Germany is coming from Nordrhein-Westfalen (NRW). In Wesseling, just south of Cologne, an electrolysis plant with 10 MW capacity just recently started operation. The industrial park where it is located, formerly Rheinland Raffinerie, now bears the neo-German name "Energy and Chemicals Park Rheinland." In the future, up to 1,300 tonnes of green hydrogen will be produced here every year. And the need will continue to grow – the NRW government estimates that demand will double by 2030.

Shell is already planning the construction of REFHYNE II, a 100 MW electrolysis plant (see H2-international Aug. 2020). The start of construction could still be in 2022. Crude oil processing at Germany's largest refinery is to stop in 2025. People want to get away from oil and gas, especially if it comes from Russia. The current war in Ukraine is now further accelerating the eco-ambitions.

Big Oil wants to go green as soon as possible – and must. Shell has announced its intention to become a net-zero emissions company by 2050 at the latest. As part of its Powering Progress strategy, Royal Dutch Shell announced at the beginning of the year that it will reduce the number of refinery sites around the world to five. In doing so, Shell's global production of fossil fuels will sink 55 percent by 2030.

"We want to become Germany's leading supplier of green hydrogen for industrial and transport customers," said Huibert Vigeveno at the opening of the plant. He is a board member of Royal Dutch Shell. Shell has the entire value chain in sight, from offshore electricity production on the high seas to the expansion of capacity to produce green hydrogen for all sectors, expressed Vigeveno.

HYDROGEN, TRASH AND BIOMASS INSTEAD OF PETROLEUM More and more sustainable chemical and energy products are also to be produced along the Rhine in the future. The raw materials for production would then rarely be petroleum but rather hydrogen, circular waste materials and biomass. Old facilities would be dismantled, new ones created and existing ones converted or repurposed. Therefore, in addition to the 100 MW electrolyzer REFHYNE II, a bio-PtL plant is planned, which will produce synthetic aviation fuels and naphtha from the green electricity and biomass.

Synthetic fuels (see also p. 32) are considered promising for reduction of CO_2 emissions, particularly in aviation. Both projects, according to Shell, are in the advanced planning stage. However, the final investment decision is not to be made until 2023. The engineering contract to build a bio-

LNG production plant for the heavy-duty transport market has already been awarded. Furthermore, a so-called Energy Campus is to be created in Wesseling, where companies, start-ups and research institutions will drive forward the development of technologies for the energy transition.

STORING GREEN H_2 IN CAVERNS During the inspection and maintenance activities at the end of August 2021, the refinery in Heide, on the coast of the North Sea in Schleswig-Holstein, was also assessed as to whether the cavern there is suitable for a planned storage of green hydrogen as part of the real-world lab project Westküste100 (see H2-international Nov. 2020). After the inspection, a green light was given by the LBEG (Landesamt für Bergbau, Energie und Geologie), the mining office for Niedersachsen and Schleswig-Holstein. "On basis of the findings, it can be concluded that the cavern is suitable for upgrading and repurposing for hydrogen storage," stated Sandra Niebler. She leads the division Commercial & Economics at Raffinerie Heide and is responsible for the energy transition projects at the refinery site in Hemmingstedt.

Currently, the caverns near the refinery are still being used to store oil and fuels as federal storage reserves. In the course of the suitability test, special inspection equipment was introduced into the underground tunnels, said Niebler. Through these, they were able to determine an overall good status for the conditions in the cavern. "This is an important result for us at Raffinerie Heide and especially for the future use of green hydrogen to decarbonize energy sectors such as aviation, industrial or chemical," she said. Now the refinery is in position to move on to the next phase of the planning process for storage of green hydrogen in the caverns.

The medium-sized company generates a revenue of more than 1 billion euros per year. Even though most of its products are still of fossil origin today, the company wants to move away from fossil raw materials in the future. The plans are very concrete.

30 MW ELECTROLYZER IS TO START UP IN 2023 Part of the project Westküste100 are plans to produce green hydrogen using electricity from renewable energy sources in an electrolysis plant. This green hydrogen will be used in the natural gas network for heat supply, in a hydrogen filling station for passenger cars and in industrial processes directly at Raffinerie Heide. In this way, the decarbonization of industry, mobility and the heating market is being implemented under real conditions in the pioneering project. Within the scope of this project, a 30 MW electrolyzer for the production of green hydrogen is to be built. Operation is to start in 2023.

Raffinerie Heide is planning the construction and start-up of the electrolyzer together with Ørsted Deutschland and Hynamics Deutschland in the joint venture H2 Westküste GmbH. The total investment is 89 million EUR. The German ministry for economics and climate protection (BMWK) is supporting it with 36.5 million EUR. Overall, the project is progressing well, expresses manager Sandra Niebler: "The project team has already completed the design stage of the electrolysis plant, including all connected ancillary structures and the corresponding approval aspects."

However, there is no concrete date for the start of construction yet. This is because the final investment decision depends to a large extent on the regulatory framework conditions, which have not yet, as was expected, been implemented, responded Sandra Spiering, spokeswoman for Raffinerie Heide, to H2-international's inquiry. Only once the delegated articles 27 and 28 of RED II (Renewable Energy Directive) have been adopted into national law will it be possible to schedule the construction.

Fig. 2: The PEM electrolysis plant REFHYNE I in Energy and Chemicals Park Rheinland [Source: Shell, REFHYNE-Projekt]

It's pretty certain that the German renewable energy law (Erneuerbare-Energien-Verordnung, EEV) and the 37th law to implement the emissions reduction law (37. Bundes-ImmissionsSchutzverordnung, BimSchV) will have to be modified. Because up to now, the only emissions taken into account when placing fuels on the market have been those emitted when the fuel is used. The emission reduction effect of using green hydrogen in the refinery process is lost on this.

MULTIPLHY PROJECT STARTING Not only in Heide, but also Neste's refinery in Rotterdam is green hydrogen to find use (see H2-international Aug. 2020). The catchy abbreviation MultiPLHY stands for "multi-megawatt high-temperature electrolyser to generate green hydrogen for the production of high-quality biofuels." The project has now been launched at Neste's renewable products refinery. Besides

E-CO_2MET – GREEN METHANOL FROM LEUNA

At Hydrogen Lab Leuna, climate-neutral methanol will be produced in the future from low-carbon hydrogen and captured carbon dioxide. This is an important approach to reducing climate-damaging greenhouse gas emissions, emphasize the project participants: TotalEnergies, Sunfire, Fraunhofer CBP (Fraunhofer-Zentrum für Chemisch-Biotechnologische Prozesse) and Fraunhofer IMWS (Fraunhofer-Institut für Mikrostruktur von Werkstoffen und Systemen).

TotalEnergies currently produces around 700,000 tonnes of methanol per year at Raffinerie Mitteldeutschland in Leuna, Sachsen-Anhalt, from fossil-based raw materials. This makes the corporation the largest methanol producer in Europe. The project e-CO_2Met wants to test the interaction of three innovative processes at the same time: the use of CO_2 captured from the refinery, the use of green hydrogen produced by high-temperature electrolysis and the subsequent methanol synthesis on the linked scaling platform Hy2Chem (see H2-international Sep. 2021).

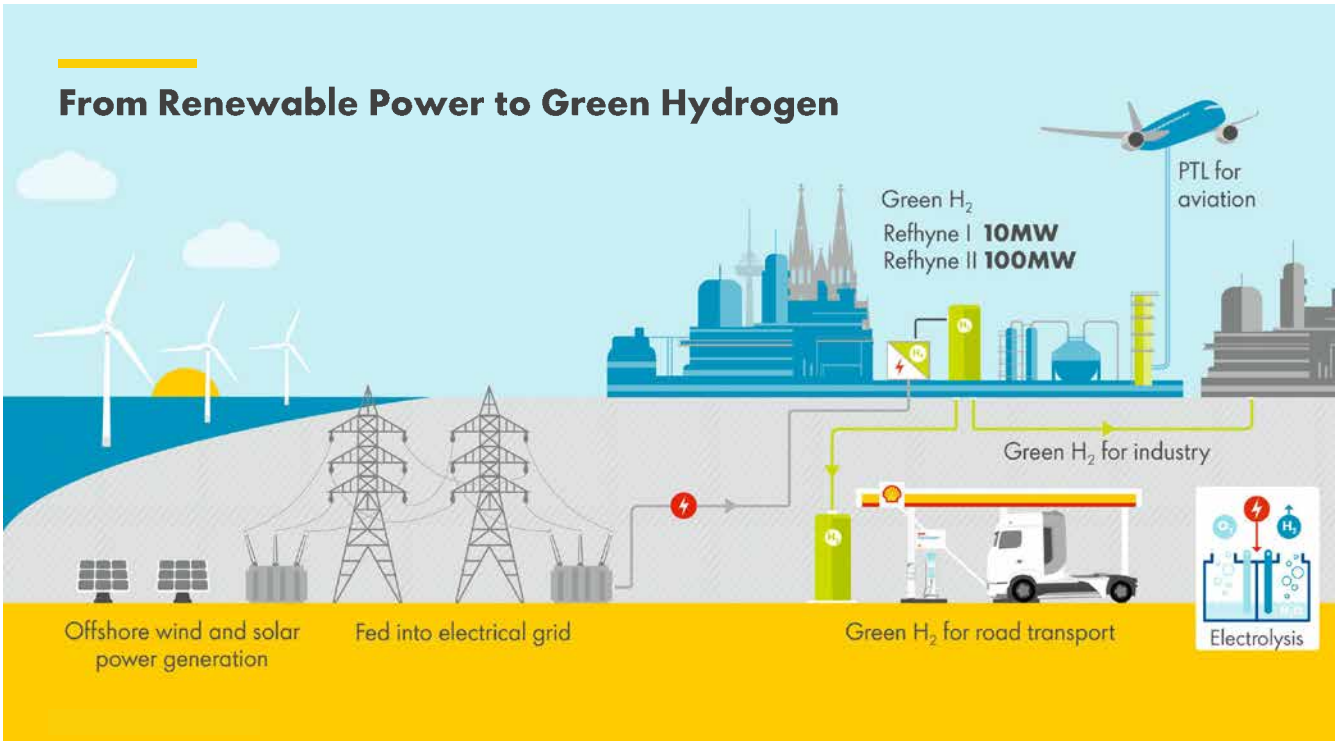


Fig. 3: Future energy supply with green H_2 [Source: Shell Deutschland]

Neste, the French research organization CEA and the plant builder from Luxemburg Paul Wurth are involved, as well as French energy supplier Engie and Dresden-based electrolyzer manufacturer Sunfire.

Led by CEA as project coordinator, the project consortium received 6.9 million EUR as part of the EU-funded program Horizon 2020 FCH2-JU. The consortium has built a high-temperature electrolyzer with a capacity of 2.6 MW. It is to produce 60 kg of H_2 per hour with an electrical efficiency of up to 85 percent in the industrial refinery process.

The electrolyzer is expected to run for at least 16,000 operating hours by the end of 2024 and have produced a total of about 960 tonnes of green H_2. According to Neste, 8,000 tonnes of greenhouse gases will be avoided. The project supports the Carbon Direct Avoidance (CDA) approach. In this way, fossil hydrogen from methane steam reforming is replaced with certified green hydrogen. Here too the aim is to scale up to 100 MW. There will certainly be no lack of demand. ||

Fig. 1: Viking Energy [Source: Eidesvik]

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

ACROSS THE SEA WITH AMMONIA

NH_3 can assume a key role in the energy transition

The production of ammonia for the fertilizer industry is, according to the IEA (International Energy Agency), the second most important area of hydrogen utilization. We therefore presented some concrete projects for the production of green ammonia in the July 2021 issue of H2-international. But what about the user side? Up to now, ammonia has hardly played any role as an energy carrier, although it could become an important source of energy, especially in transport by ship. The compound has numerous advantages over other energy mediums. At the same time, however, there are still many technical and logistical challenges to be solved, which are being addressed by, among others, the research projects ShipFC and Campfire.

Ammonia becomes liquid "already" down at -33 °C under ambient pressure or with just under 9 bar at 20 °C. This makes the compound much easier to store and transport than hydrogen. In addition, the energy density of liquid ammonia, 11.4 GJ/m³, is notably higher than that of liquid hydrogen, which is 8.52 GJ/m³.

The ship classification society DNV GL therefore presupposes that NH_3 rather than LH_2 (liquefied hydrogen) can play a role as a ship fuel. So in various research projects, scientists are looking for ways to use ammonia in engines and fuel cells.

FIRST AMMONIA FUEL CELL ON A SHIP The first ammonia-based FC propulsion system for ships is to emerge from the project ShipFC. Involved in the project are 14 collaborating partners from Europe. The majority of them are from Norway, including the coordinator, NCE Maritime CleanTech. However, the German research institute Fraunhofer IMM (Fraunhofer-Institut für Mikrotechnik und Mikrosystem) is also part of the group.

The goal is to test an SOFC (solid oxide fuel cell) with a power output of 2 MW on Viking Energy, a supply ship of the shipping company Eidesvik. Eidesvik wants to reduce their emissions to half by 2030 and be climate-neutral by 2050. It operates Viking Energy for the energy corporation Equinor.

For ammonia to be used, it must first be thermocatalytically split into nitrogen and hydrogen. "The often-used term cracking is not correct," said Gunther Kolb, head of the energy division and deputy institute director at Fraunhofer IMM. Since a trace of the caustic starting material always remains in this process, ShipFC has decided on a robust a solid oxide FC. This can, in contrast to the more sensitive PEM fuel cell, convert the ammonia directly into electricity for the ship's electric motor. The fact that the fuel cell changes its output more slowly than the engine is not a problem. "As with any fuel cell drive, a battery installed as buffer ensures that the engine receives the required power at all times," said Kolb.

Traces of ammonia, an irritant, are also still present in the exhaust gas. That is why Fraunhofer IMM is developing a downstream catalytic convertor. By 2023, all of the systems should be installed on Viking Energy. Test trips are planned to take place in 2024, according to the project website.

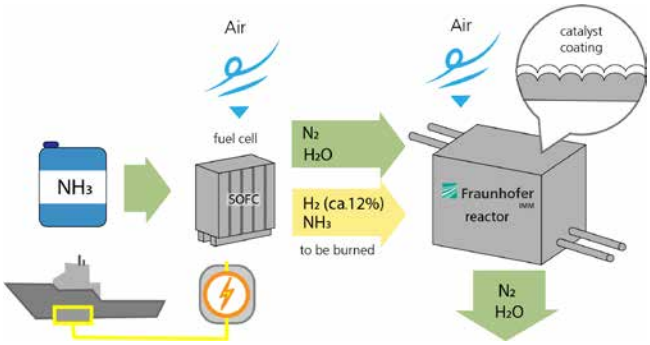


Fig. 2: ShipFC-Schema [Source: ShipFC]

AMMONIA ENGINES AS ALTERNATIVE TO DIESEL Ammonia engines might be used by ships faster than SOFCs. "The engine has a lead in terms of confidence from shipping companies compared to the fuel cell," says Angela Kruth, speaker and coordinator for the research partnership Campfire, and division director at the research institute Leibniz INP (Leibniz-Institut für Plasmaforschung und Technologie). Many ship owners are also not comfortable with large quantities of hydrogen on a ship, adds Jens Wartmann, division director at the fuel cell research center ZBT in Duisburg (Zentrum für BrennstoffzellenTechnik). Ammonia, despite its toxicity, is easier and cheaper to handle.

Challenging for its use as fuel is its low flammability as well as slow burn rate. In an engine, this would lead to poor efficiency and high emissions. Only when mixed with other gases, for example hydrogen, can ammonia be used efficiently as a fuel. How is what the project Campfire is investigating, which is funded by, among others, the German ministry for research (BMBF) through its structural change program "Wir!" (see H2-international Sep. 2019).

Nearly 70 partners are now involved in Campfire, most of which are from northeastern Germany. They want, among other things, to develop ammonia- and hydrogen-powered engines for a sport yacht and a connection ferry. A fuel cell is to first be used on a yacht for onboard power supply. A concept study does not see ammonia engines driving cruise ships before 2030.

The research team is using commercial gas engines for this. Liebherr and Jenbacher are among the project partners. The researchers are adapting the injection and combustion technology for operation with ammonia. As a first demo project, a sport yacht with a 15 kW hydrogen engine burning a mixture of hydrogen and ammonia is to set sail at the end of 2023.

DYNAMIC SPLITTING OF AMMONIA To produce hydrogen, a special reactor is used to decompose the ammonia into hydrogen and nitrogen. In the Campfire project, the English term cracking has been adopted for it. The aim is to make hydrogen supply as close to on-demand and without interim storage as possible. "We don't want two tanks for different fuels on the same ship. This takes up too much space, causes high costs and makes the safety requirements very complex," says Kruth. This is the principle for all ship propulsion systems investigated in the project.

Scaling the cracker, reducing its cold start time, and enabling the most dynamic operation possible are the current research priorities. On the load side, an additional battery is to serve as a buffer so that the ship's engine can always react flexibly, even if the cracker reaches the limits of its dynamics.

The cracking technologies for Campfire are being developed at the ZBT in Duisburg. The two developers of the lab-stage cracking unit, Florian Nigbur and Michael Steffen, are already quite happy with its dynamics. "The power is able to be reduced by up to 30 percent," says Steffen. With scaling, however, it will be difficult to maintain this flexibility.

Another crucial aspect is the efficiency. The splitting of the ammonia needs about 10 to 20 percent of the energy contained in it. "In continuous operation, we are already at about 90 percent efficiency. In dynamic operation, it will probably be more like 80 percent to start with," says Nigbur. For a hydrogen engine, which would require that a large amount of ammonia be split, the cracking thus leads to significant losses. If an ammonia engine with hydrogen admixture is used instead, the losses are much less significant. "Then only a small stream of the ammonia of about ten percent has to be split at all," says Steffen.

SOFC FOR ONBOARD ELECTRICITY The 750 kW solid oxide FC on the yacht solely serves as an onboard power supply. "This is also potentially an effective use of the technology on cruise ships, since 50 percent of the fuel is needed for amenities. And continuously. Even during idle times," says Kruth.

Compared to an ammonia engine, the fuel cell has the advantages of higher efficiency and quiet operation.

When the ammonia yacht goes on the test trip in 2023, it will not be a luxury boat, but rather a floating laboratory. After evaluating the practical test, the Campfire partner wants to make the drive technology compact enough to integrate it in a new yacht model.

A 70 kW ammonia engine is to go into direct practical use in 2025 on the ferry F-Warnow, operated by Weiße Flotte, in Rostock, Germany. "There is a little more space on the ferry than on the yacht," says Kruth. Initially, only one of the three propulsion engines is to be replaced by an ammonia engine. The other two machines will remain as backup. The mixing ratio for the ferry is also different. For this especially, small amounts of hydrogen should be used with the ammonia. That saves not only energy for splitting, but also space, and the cracker can be smaller.

CO_2-FREE, BUT NOT WITHOUT EMISSIONS Ammonia engines do not emit any CO_2, since NH_3 contains no carbon. However, even with optimized combustion, certain amounts unburned ammonia, nitrogen oxides and nitrous oxide are still found in the exhaust gas. The ammonia released irritates the eyes and mucous membranes, even in small concentrations, while the generated laughing gas has a larger effect on the climate than CO_2 by a factor of 300. The climate- and environment-friendliness of an ammonia engine depends on not only the optimization of the engine, but also that of the connected exhaust gas scrubber.

"The processes for this are well known, but they have to be adapted for ammonia engines," says Steffen. An SCR (selective catalytic reduction) catalytic convertor breaks down the nitrogen oxides, and an oxidation catalyst turns the residual ammonia and nitrous oxide into nitrogen gas and water. Steffen confesses, however, "A propulsion system with engines and zero emissions will not be possible with ammonia any more than with other fuels." With SOFCs, on the other hand, truly zero-emission travel by ship is a possibility, according to Steffen.

HANDLING THE TOXIC GAS SAFELY In addition to environmental and climate issues, safety is a central aspect of the Campfire project, although major accidents with ammonia are rare. The most serious ammonia accident in Germany to date occurred in Erfurt in 1985. There, a truck carrying five tonnes of ammonia crashed and three people died. And in 2019, a technical defect at a public pool in Kulmbach caused an ammonia gas leak. Over 50 guests had to be treated at the hospital. Gunther Kolb of Fraunhofer IMM puts the incidents in perspective. "In Western Europe alone, 1.5 million tonnes of ammonia are transported by rail each year," he says. Accidents are most frequent in places where people have little experience with dangerous substances, for example when ammonia is used as a refrigerant.

It should also not be assumed that the crew and passengers on a yacht will have attended a hazardous chemicals training course. The ammonia is therefore to be brought on board the Campfire yacht in the form of easily replaceable gas canisters. "The system can be operated without special safety training and was already used in buses in Belgium in the 1940s," reports Kruth.

More sophisticated safety measures will be needed if a cruise ship with 2,000 tonnes of ammonia on board really is to be put in the water around 2030. This is the subject of a study within Campfire. "The staff will need safety training for this," says Kruth. In addition, the tank would have to be installed where guests would not have access. She sees the pungent smell rather as an advantage, since it could warn people in the event of a leak. Escaping ammonia can be well controlled by sealing the leak site and binding the gas with sprays of water.

Kolb of project ShipFC also considers possible ammonia leaks to be less harmful to the environment than, for example, oil leaks. He stresses that other fuels are not without danger either, and mostly in ways other than ammonia. Unlike methanol, ammonia is not, for example, mutagenic. And since ammonia is lighter than air, toxic fumes would dissipate very quickly, instead of forming toxic clouds like gasoline. "Gasoline will no longer be allowed as a fuel," he's convinced.

In the future, new storage technologies could also help to alleviate concerns about the caustic gas. Campfire is working, for example, on a salt storage medium to bind ammonia in solid form. It would only be freed with application of heat.

AMMONIA COULD ASSUME A KEY ROLE Overall, ammonia appears to be an easily manageable and CO_2-neutral fuel for

SPETRANS WANTS TO DO GREAT THINGS

The shipping company Spetrans Schiffahrts- und Spedions GmbH is one of the Campfire partners and has decades of experience in the handling of ammonia. In 1989/1990, the family business converted the TMS Odin into a gas tanker. Kerstin Malchow, who heads the third generation of the Uetersen-based company, told H2-international, "The TMS Odin was specially rebuilt to transport liquefied ammonia under pressure (8 to 12 bar on average) for flue gas treatment of the coal-fired power station Bergkamen Heil." However, the power plant will be taken off the grid at the end of 2022, which is why new uses for the ship are being sought. Malchow declared she would "gladly show the way with this example project" and "support green ammonia as an emission-free energy source for maritime mobility and stationary energy supply."

The company manager continued: "We don't want to start sometime in the future, but today. We can be part of a pilot project in the areas of transport, bunkering and storage of ammonia tomorrow. What we need is the support of companies, institutes and politicians who not only want an energy transition, but are also aware of the fact that this implies both financial investment and persuasion work. Even though as Spetrans with Odin we're a very small business, we hope to make a great difference. We are convinced that the launch of a small project would be the best way to demonstrate that the use of (green) ammonia is safe, is easier to transport than hydrogen, requires many times less storage volume and thus has a great cost advantage. With this, acceptance of NH_3 in industry and among the people would also rise." (sg)

Fig. 3: Ammonia tanker TMS Odin [Source: Spetrans]

Fig. 4: Warnow ferry [Source: Campfire]

the maritime sector, even with its special challenges. "Ammonia has a chance at a key role in the clean energy transition," Michael Steffen is therefore certain. However, there are still a number of hurdles to be cleared. The cruise company Carnival Maritime for example has declared LNG propulsion to be the benchmark in terms of cost and space requirements, as the Campfire website reveals. The direct comparison is to decide whether a cruise ship with ammonia propulsion will really be launched in about eight years.

An SOFC as being feasible for ship propulsion was difficult to imagine for a long time. Dynamics and power density are very low. In addition, it was considered difficult to scale, because of the temperature management but not least because of the expense. Jens Wartmann of the ZBT is seeing new advancements in materials for high-temperature electrolysis that could be exploited for SOFCs and could lead to price reductions. "New methods of manufacturing SOFCs will also open up the prospect of higher load dynamics and efficiency," he says.

How ammonia compares with other fuels, however, also depends on the climate targets for maritime transport. The UN agency IMO (International Maritime Organization) has set out a global roadmap. According to this, by 2050, emissions related to transport are to be reduced by 70 percent compared to 2008. And 40 percent by 2030. Container ships, through efficiency hikes, have already done more than their fair share, reports the German transport newspaper DVZ (Deutsche Verkehrszeitung), citing a study by the ship transport group Peter Döhle.

Political pressure for further action is growing, though, and in the long haul, shipping companies will have to deal with new types of propulsion systems. When stricter climate targets knock fossil fuels out of the running, the ammonia drive will have a better chance, thinks Kolb of ShipFC. He said, "Long-term forecasts predict lower costs for ammonia than for liquid hydrogen or synthetic diesel and methanol."

To support a successful changeover, Campfire also wants to answer some logistics questions. How can ships bunker ammonia? What could the infrastructure, logistics and value chain look like? How can they be built up step by step? And last but not least, how can green ammonia be produced as regionally and cost-effectively as possible?

In its ammonia study, the DNV GL sees the availability of green ammonia, or rather the green hydrogen needed for it, as the precise critical factor. To illustrate, according to the IEA, in 2018 around 32 million tonnes of hydrogen were poured into the production of 170 million tonnes of ammonia. If, as a mathematically extreme scenario, all current ships were to be changed over to ammonia engines, 120 million tonnes of green hydrogen would be needed. And that's in addition to the H_2 needed in current energy applications as well as new industrial applications, for example in steelmaking. A massive expansion of green electricity generation would be necessary. And perhaps more regionality in not only fuel production but also in the transport of goods would contribute to the solution. ||

ENGINE OR FUEL CELL? HIPOWAR COMBINES THE BEST OF BOTH TECHNOLOGIES

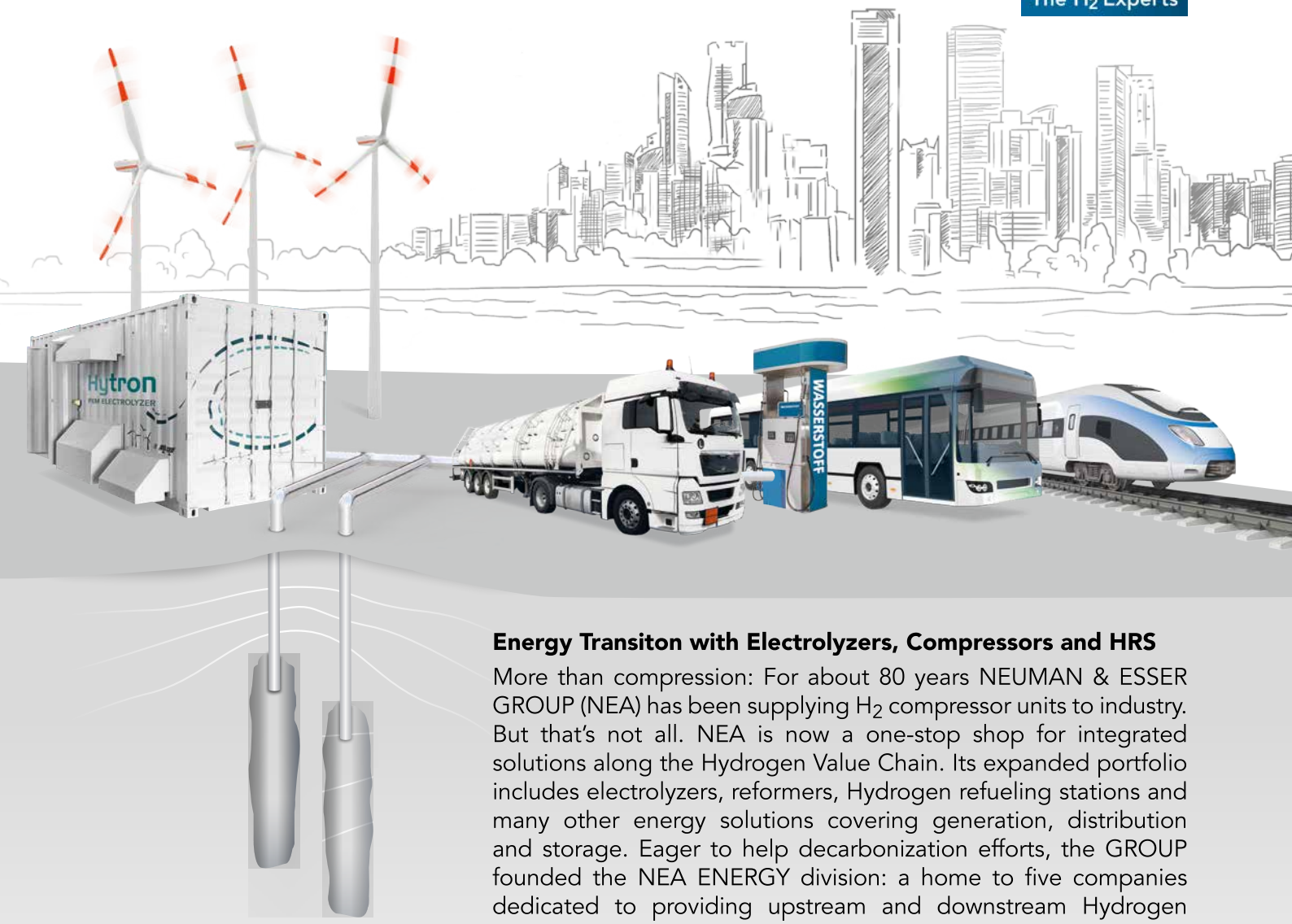
Out of Campfire arose the EU project HiPowAR (Highly Efficient Power Production by Green Ammonia Total Oxidation in Membrane Reactor). In this, a membrane reactor is to be developed in order to lower production costs and improve the efficiency of ammonia drives. To achieve this, the reactor joins elements of a fuel cell and a combustion engine. A pressure vessel is filled with ammonia and surrounded by a ceramic membrane, similar to with an SOFC. Oxygen in the air permeates this membrane.

In contrast to SOFCs, the membrane also allows electrons to pass to the outside, so that the charge remains balanced. Liquid ammonia and oxygen are converted into water vapor and nitrogen gas. The pressure inside the reactor rises sharply. Mechanical work is then obtained, like in a combustion engine, with the expansion of the gas. Whereas with the internal combustion engine, part of the work must always be spent on an initial compression step, all the energy can be used here. This enables very high efficiencies. At pressures of several hundred bar and temperatures around 1300 °C, 70 percent are theoretically possible. For the first demonstration system, however, the target is only about 30 percent.

So far, the technology is still in its infancy, but the plans are ambitious. On board are several research institutes as well as the turbine manufacturer PBS and the steam engine manufacturer Ranotor. "If everything goes well, we will be able to present a system for twenty to thirty kilowatts at the end of the project. In a follow-up project, we could then proceed with commercialization," says Ralf Kriegel.

INTEGRATED SOLUTIONS
ALONG THE H_2 VALUE CHAIN

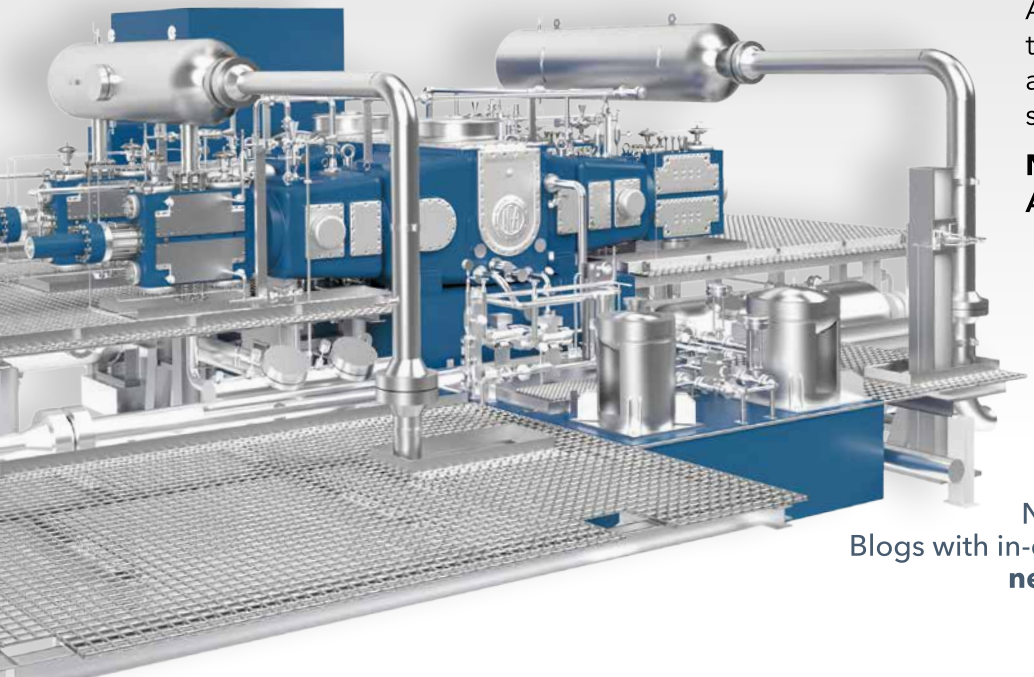
NEA
COMPRESSORS
The H_2 Experts



Energy Transiton with Electrolyzers, Compressors and HRS

More than compression: For about 80 years NEUMAN & ESSER GROUP (NEA) has been supplying H_2 compressor units to industry. But that's not all. NEA is now a one-stop shop for integrated solutions along the Hydrogen Value Chain. Its expanded portfolio includes electrolyzers, reformers, Hydrogen refueling stations and many other energy solutions covering generation, distribution and storage. Eager to help decarbonization efforts, the GROUP founded the NEA ENERGY division: a home to five companies dedicated to providing upstream and downstream Hydrogen solutions in everything from electrolyzer and fuel cell development to the production of e-fuels for use in rail, shipping and aviation. As a result, NEA is best placed to support its customers moving away from fossil fuels towards sustainable gases.

NEUMAN & ESSER
Agile. Solution. Experts.



Read the
NEUMAN & ESSER
Blogs with in-depth information
neuman-esser.com

Category: Energy storage | **Author:** Harald Weber

FULL-SCALE SECTOR COUPLING FOR POWER, HEAT AND TRANSPORT

Hydrogen Regions series: living lab – hydrogen storage power plant in Schwarze Pumpe

The production of green hydrogen is reliant upon electrolyzers being fed solar- and wind-generated electricity. Since these energy sources are fluctuating, and therefore not always available, a different approach and control mechanism is required compared with conventional power plants. At the RefLau model power plant in the area of Lusatia, work is underway as part of a grant project to analyze, initially on a small scale, how Germany's energy supply could be controlled in the future.

An extensive electricity supply network has been in existence since the 1920s. The first true power plant was the Niagara hydroelectric power plant in North America which was constructed in 1895 by Nikola Tesla and used to supply the city of Buffalo on Lake Erie. The venture was so successful that soon more electrical energy was needed. At the time, this increasing demand could only be satisfied by fossil fuels such as coal, which is why James Watt's piston steam engine and later the modern steam turbine came into use – then as thermal power plants. And not to mention the subsequent nuclear steam power plants that came about, working on the basis of Einstein's mass-energy equivalence. Nowadays, over 80 percent of electrical energy around the world is generated in thermal power plants, with the power requirement in Germany alone amounting to 600 terawatt-hours a year. Annual global electricity consumption is currently estimated to be around 20,000 terawatt-hours.

CASCADE CONTROL The electrical energy supply system is a controlled system that at any given time produces exactly the right amount of power to meet demand. This has led, starting from the Watt steam engine, to a cascaded control system in which the generated power has to be provided via various transformers and from a range of energy stores for different time periods:

1. Momentary reserve, immediate power provision, rotating masses (inertial reserve, inherent store, no active control necessary)
2. Primary control, frequency control, steam store (frequency containment reserves – FCR)
3. Secondary control, power/frequency control, coal store (automatic frequency restoration reserves – aFRR)
4. Tertiary control, relief for primary and secondary control, coal store (manual frequency restoration reserves – mFRR)

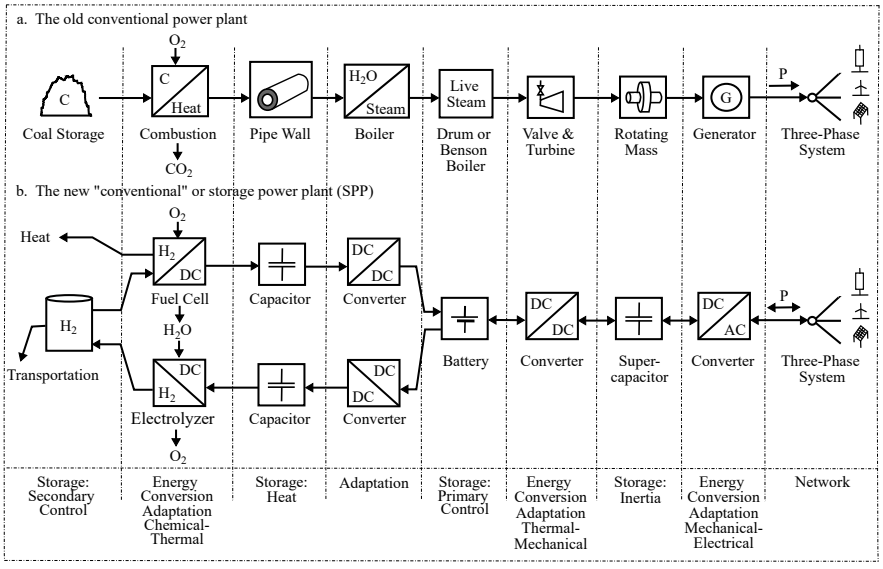


Fig. 1: Structural diagram comparing a hydrogen storage power plant with a conventional power plant

This cascade control is described in the ENTSO-E handbook as Policy 1: Load-Frequency Control and Performance. Due to these historical requirements, it is unimportant which of these generators is used supply electrical power provided that the above grid control obligations are met. If that fails to happen, then the system becomes unstable – a situation which can lead to a blackout.

Renewable energy sources such as solar arrays and wind turbines do not have a storage mechanism. What's more, they are connected to the electricity supply system by grid-supporting inverters in a way that means the amount of power they feed in at any time equates exactly to the power available from the sun and wind. Grid control is not an option here and instead this role needs to be left to the aforementioned conventional power plants.

STORAGE POWER PLANT IN SCHWARZE PUMPE INDUSTRIAL PARK Likewise electrolyzers are not primarily conceived with grid stabilization in mind; rather they are designed to produce hydrogen. As such, their power consumption is focused on the hydrogen demand and electricity price at the time. It's this gap that the RefLau model power plant in Lusatia, Brandenburg, is now seeking to close. The prototype plant will be constructed in the Schwarze Pumpe industrial park under the auspices of the park's ZV ISP association and will have a nominal output of -0.5 to +0.5 megawatts.

The idea behind it is simple and targeted: All the transformers and storage systems assumed by a conventional power plant up until now will be replaced by power electronics as well as electrical and electrochemical storage mechanisms, with a hydrogen tank deployed as the final, very large-scale storage system. At the same time, this should also serve as a link for coupling up various sectors, including heat and transport, provided that sufficient renewable energy is available.

In contrast to a conventional power plant, the hydrogen storage power plant is also capable of reversing its

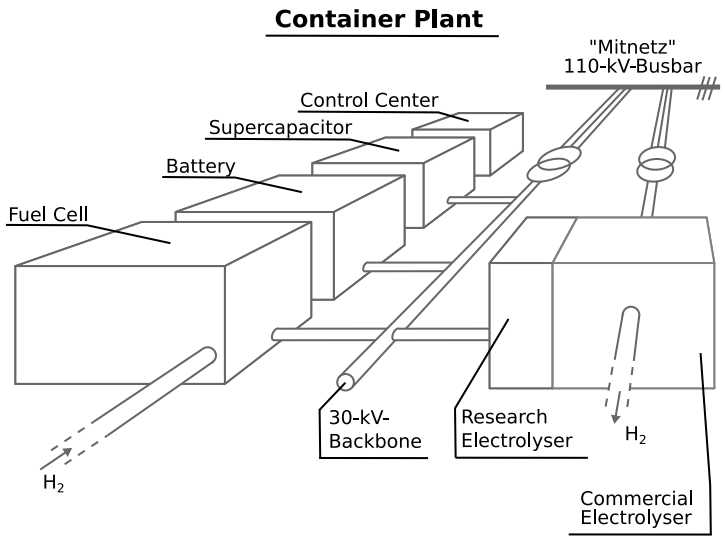


Fig. 2: System layout and connection

output via the electrolysis pathway, allowing it to cover an output range of -100 to +100 percent. The design of the fuel cell and electrolyzer energy converter is not predefined and will be focused on efficiency. For the RefLau project, no final decision has yet been made. It's entirely possible that, due to its stationary operation, there could be high-temperature fuel cell units, for example.

The plan is to build the prototype in shipping containers, with the electrolyzer forming part of a larger 10-megawatt system (see fig. 2). When needed, the electrolyzer can be activated and allocated to the power plant. If the system is operated in pure electrolyzer mode, it fully meets all the requirements of grid regulation when power is drawn, which is why this mode of operation is also known as "intelligent electrolyzer."

The individual containers are to be connected to each other via a 30-kilovolt backbone cable. The system will be connected to the grid via a 30/110-kilovolt transformer to a 110-kilovolt busbar from the company Mitnetz.

In future, the heating and transportation sectors will also be supplied from renewable sources. When it comes to scaling up, it's important to ensure that storage systems are sufficiently large in order to cover the dark and windless times that are to be expected and which need to be ridden through under the framework conditions of the annual utilization periods for PV and wind. Thus it's also necessary to be able to sustain coverage for two weeks at -20 °C in order to maintain stable operation of the power supply system even in these circumstances.

If there is excess power from sun and wind, on the other hand, then a policy of full grid management will be pursued which is why inefficient parallel operation of hydrogen gas turbines is superfluous. Otherwise the hydrogen storage power plant must be kept in electrolyzer mode so that the hydrogen requirement for sector coupling can be met at all times. This assumes the electrical consumers have a high degree of flexibility, allowing them to adapt as far as possible to the fluctuating supply of power from renewable sources. Prerequisites, here, are good forecasting and closely intertwined, secure IT systems.

PUTTING THE ENERGY TRANSITION TO THE TEST The RefLau power plant is one of the winners of the "energy transition living lab" ideas contest run by the German economy ministry. At the moment, this project remains at the coordination and approvals stage which is due to be completed by mid-2022. It is then anticipated that it will take another five years before operation begins.

The hydrogen storage power plant is being planned jointly by the University of Rostock and the Steinbeis Transfer Center Applied Research in Electrical Power Engineering in Rostock. Also involved in the initiative are the companies Energiequelle and Enertrag as well as the ZV ISP association, based in Spremberg. Once construction has finished and the prototype tests have been concluded, the plant will be used for university research and for training purposes within the ZV ISP.

The aim of the project is for the prototype to demonstrate that a hydrogen storage power plant can not only produce hydrogen – as is the case for a standard electrolyzer – but can also be operated in reverse by reconverting the hydrogen into electricity using fuel cells via sector coupling. This means that the power plant can continuously deliver all system services that are required for the electrical supply – assuming that a sufficiently large hydrogen store is available. This system behavior is necessary as conventional power plants will no longer be present to offer grid regulation in a future energy system based fully on renewable power supplied only by solar and wind plants. To achieve this project objective, a 0.5-megawatt prototype is to be built initially. This will later be capable of producing for the electricity market on a large industrial scale, covering all output levels from 0.5 megawatts to 500 megawatts.

The plant will consist of a supercapacitor, a battery, an electrolyzer and a fuel cell, which will be connected up via electronic switching elements. As it stands, only the capacities of the electrolyzer and the fuel cell are certain. The system type itself will be determined by the results of the pan-European tender.

The capacity of the overall system is set at 0.5 megawatts. According to the plans, the supercapacitor will provide a startup time constant of 10 seconds for the momentary reserve. The battery will supply 10 percent of the plant's nominal output as primary control power. The electrolyzer will fill the hydrogen store which will hold sufficient hydrogen to cover two days of reconversion into electricity. Consequently, the system will be capable of storing 12 megawatt-hours of chemical energy.

The facility is owned by the University of Rostock. A site directly adjacent to the hydrogen storage power plant, whose patent is held jointly by senior professor Harald Weber and the University of Rostock, will be used for the construction of a conventional 10-megawatt electrolyzer that will be operated by the above-mentioned consortium. ||

Author:

Prof. Harald Weber, Universität Rostock
→ harald.weber@uni-rostock.de

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

CAR AND OIL COMPANIES ADVERTISE FOR E-FUELS

Efficiency losses are accepted

Fig. 1: This chemical plant for the production of e-fuels is already on its way to Chile [Source: MAN Energy Solutions]

Industry fears that so-called e-fuels could be a similar flop to biofuels are high. There are too many parallels. Which is why some players are very unsettled. There are also numerous critics warning against extending the life of internal combustion engines. On the other hand, synthetic fuels offer a great opportunity, especially for the until now market-dominating corporations to maintain their influence. In addition, many billions of euros in revenue beckon. Hence this attempt to shed some light on the e-fuel debate.

Proponents of synthetic liquid fuels, also referred to as power-to-liquid (PtL) or e-fuels, advertise that motorists who have neither a garage nor a carport available to them and must park their car on the street depend on the more suitable non-electrical solutions. Synthetic fuels would allow further operation of vehicles or engines for which there is no electrical alternative, the belief is.

For example, despite its electromobility campaign, Volkswagen is also set on electrically generated synthetic fuels, as the Wolfsburg-based company assumes that the combustion engine will continue to be justified for many years to come. Especially sports car manufacturer Porsche, part of the VW corporation, wants to make the existing fleet cleaner with the help of synthetic fuels, in order to comply with the statutory CO_2 limits. Head of development Michael Steiner told the German press agency dpa months ago now, "Electromobility is an absolutely exciting and convincing technology. But on its own, it moves us toward sustainability less quickly than we want to progress. That is why we are also engaged in e-fuels."

E-FUEL FROM CHILE FOR PORSCHE A key aspect of this is that the Zuffenhausen-based company, unlike other manufacturers, do not intend to abandon the combustion engine in the foreseeable future. It is why Porsche is engaged together with Siemens Energy and the Chilean company HIF, with the support of the German ministry of economics, in the e-fuel plant Haru Oni in Chile. Shipment of a methanol synthesis unit from MAN Energy Solutions, a subsidiary of Volkswagen, for these pilot plants started at the end of February 2022. With the help of the abundant wind power, green methanol is to be produced there starting this fall. Subsequently, synthetic fuel is to be produced from it, which Porsche wants to use in motor sports as well as for research purposes.

However, in order for the high-performance engines to also tolerate the gasoline of the future, it is essential that Porsche have a say now in the specification of the new synthetic fuel. Steiner also remarked, "When E10 came onto the market, the blend also had disadvantages. This time must be different."

Therefore, the creation of a suitable gasoline and diesel substitute is a must for Porsche if the firm does not wish to alienate its customers. The sports cars are usually driven for a long time, but if in a few years' time there are no longer any suitable fuels to use, the high-horsepower cars will have to stay in the garage. Even the many oldtimers. This measure also does not contribute to compliance with the legal CO_2 limits, according to Steiner. He said, "For us, it would actually not be creditable for the vehicle fleet here and now."

ENDORSEMENT BY OIL AND VEHICLE INDUSTRIES Particularly attractive for the oil industry is that the existing infrastructure as well as facilities and tanks can continue to be used. John Cooper, chief manager of FuelsEurope, was pleased to see how many components of a conventional refinery are also suitable for the production of low-CO_2 fuels.

E-FUELS NOT FOR PASSENGER CARS

"The CO_2 limit values for fleets (CO_2-Flottengrenzwerte) have proven to be an effective means for more climate protection in the transportation sector. They cover the majority of vehicles on the road and have the potential to really advance climate protection. With the increase in the level of ambition, the EU Commission wants to strengthen this instrument. Actually, I would have liked to see even stricter CO_2 limits for before and for 2030... The use of e-fuels should not be counted towards the CO_2 fleet limits in the future either. In summary, the vast majority of vehicles on the road will switch to truly zero-emission powertrains. This brings a long debate in the federal government to an end. Because it's been clear for a long time that in road transport, electromobility is the most efficient, cost-effective alternative for more climate protection. Electricity-based fuels are to be used where there is no climate-friendly alternative, particularly in air and maritime transport."

German environmental minister Steffi Lemke

"The plans to promote synthetic fuels for passenger car transport in any way can only be understood by German manufacturers as a signal to further develop cars with combustion engines, while the rest of the world is already set on electric cars."

Nikolas von Wysiecki, the conservancy NABU

Fig. 2: CAC managing director Jörg Engelmann is filling the BMW Mini with synthetic fuel produced in the demonstration plant visible in the background [Source: Detlev Müller / TU Bergakademie Freiberg]

FuelsEurope sees itself as the "voice of the European oil refining industry" and acts as a representative of the refining and marketing industry in Brussels.

Ola Källenius, then still head of the managing board of Daimler, now of Mercedes Benz, had already declared in 2020 to the magazine Automobil Industrie, "Synthetic fuels can reduce vehicle fleet emissions. However, if you consider the production of the synthetic fuels, then an efficiency of just 10 percent remains in the end. In comparison, an e-vehicle comes to 70 percent. So this is not the best way to go economically, but we should let the different techniques compete against each other in free competition."

Stefan Pierer, head of the largest motorcycle manufacturer in Europe (KTM, Husqvarna and GASGAS), spoke more directly in an inside digital interview mid-February 2022. Electromobility is an "imposed idiocy pushed by scientifically illiterate politicians," according to the combustion engine fan. Pierer criticized, among other things, that when e-motorcycles are in a race, their batteries are recharged with diesel generators. His opinion is "the synthetic fuel is the solution, not the electric drive."

Especially Audi, another subsidiary of VW, has been researching e-gas, which has been conducted in Werlte for years. There, Audi Industriegas GmbH operates a power-to-gas test plant for the production of green hydrogen, which helped oil company BP start producing synthetic fuel in their refinery in Lingen, the Netherlands as early as 2018. Refinery manager Bernhard Niemeyer-Pilgrim had stated, "This makes us the first refinery in the world to actually use green hydrogen also for the production of fuels and thus show a possibility for a CO_2-poorer energy world."

Among the supporters of e-fuels is also the German national energy agency dena (Deutsche Energieagentur), which as early as 2018 founded Global Alliance Powerfuels. Members of this globally active initiative, including large companies like Bosch and Uniper, want to help e-fuels achieve a breakthrough. Also the German automotive association VDA (Verband der deutschen Automobilindustrie) has a strong interest in synthetic fuels and designated them a "fascinating progressive option."

The counterpart at the Germany level is the eFuel Alliance, an association of over 150 companies from the automotive, oil and supply industries. On the managing boards are high-ranking politicians as well as, among others, NOW chairman Kurt-Christoph von Knobelsdorff.

SEVERAL E-FUEL PROVIDERS NOW Several companies are currently positioning themselves as potential producers of synthetic fuels. One of the players is Ineratec. The startup created in 2014 as an offshoot of KIT, the institute of technology in Karlsruhe, has recently collected 20 million euros for a new large-scale plant in Höchst. Regarding this occasion, at the beginning of February 2022, co-founder Philipp Engelkamp said on the podcast Die Stunde Null, "We're doing it on the largest scale available anywhere in the world right now." To be specific, these cargo container-based plants can produce 350 tonnes of fuel per year.

"We know that the plants have to get even bigger, since I can't make the world sustainable with 350 tonnes," Engelkamp continued. Therefore, 3,500 tonnes, or 4.6 million liters, is to be produced annually at the site in Frankfurt starting 2023.

Another competitor in this field is the mobility company Q1, who starting this year wants to deal in synthetically generated diesel fuel and get into the heating oil business this way. The Osnabrück-based company is currently setting up a production facility at the former site of Hoechst AG in Frankfurt and has tested the e-fuel on a Mini Cooper. The synthetic fuel, designed by technical university TU Bergakademie Freiberg, is already being produced in a demonstration plant equipped with technology from Chemieanlagenbau Chemnitz (CAC).

Supporters of this initiative include the national association of independent fuel stations Bundesverband Freier Tankstellen (bft) as well as the national association for mid-size oil companies UNITI Bundesverband mittelständischer Mineralölunternehmen. UNITI advertises that "all cars, trucks, ships and aircraft can be powered by e-fuels – all

E-FUELS ARE NOT BIOFUELS

In principle, e-fuels are to be distinguished from first or second generation biofuels as well as from paraffinated fuels derived from organic waste or frying fat. In the past few years, fuel produced from biomass has been the subject of repeated discussion. The C.A.R.E. fuel for example is a diesel fuel by a Finnish company that has been tested by Bosch and was also considered by Deutsche Bahn for use in the German rail. This "eco-diesel," however, did not receive approval in Germany, because according to the federal environmental agency UBA (Umweltbundesamt), it did not meet the legal requirements. The main deciding factor was the energy basis for the production of gaseous and liquid fuels. On the one hand, it has to be biogenic raw materials and, on the other hand, electricity from renewable energy sources.

"Hydrogen produced in a climate-friendly way is a building block for achieving the German and European climate protection targets. In RED II (EU Renewable Energy Directive II) as well as in the draft of BImSchG/BImSchV (German emissions limitation laws), so-called renewable fuels of non-biological origin, so climate-friendly hydrogen from electrolysis or climate-friendly electricity-based fuels, are included as options to satisfy the requirements."

Nationaler Wasserstoffrat, the German national hydrogen council

around the world." International automobile and motorcycle manufacturers also certify that synthetic fuel is one hundred percent compatible with the existing vehicle fleet. This suitability was also confirmed last year in Close Carbon Cycle Mobility (C3-Mobility), the collaborative project of the technical development consultancy FEV.

C3-Mobility ran for over three years with 32 partners and funding from the German ministry of economics. They reported during the closing event at the end of 2021 that all substantial properties of an e-fuel, like material compatibility, CO_2 emissions and consumption, are equivalent to that of the fossil fuel. The oxidation stability and the particle emissions are even more advantageous, so they concluded.

Prof. Martin Gräbner, director of the institute for energy technology development and chemical engineering (Institut für Energieverfahrenstechnik und Chemieingenieurwesen, IEC) at TU Bergakademie Freiberg, stated, "The establishment of this fuel synthesis process is an important step towards closing carbon cycles with the aid of electrical energy. In this way, regeneratively generated electricity can be stored in a long-stable, CO_2-neutral fuel that can also be made available in times and regions with little sun or wind." ||

Literature:
[1] dena, LBST – im Auftrag des VDA, Das Potenzial strombasierter Kraftstoffe für einen klimaneutralen Verkehr in der EU, November 2017

STUDIES

According to a study by the energy think tank Agora Verkehrswende from 2017, to go 100 kilometers an automobile with an electric drive requires 15 kilowatt-hours of electrical power, a hydrogen-powered car 31 kilowatt-hours and a car running on PtL fuel 103 kilowatt-hours.

Regarding another study in 2017, conducted by energy agency dena and consultancy LBST, one of the authors, Patrick Schmidt, told HZwei, "The term 'e-fuels' is a categorical term. In the study by the VDA (German automobile association) and in the scientific community, 'e-fuels' are understood as all electricity-based energy carriers, including and especially PtH_2. The shortening of 'electricity-based synthetic fuels' to 'e-fuels' is unfortunate, in my opinion... because the fact that direct use of hydrogen is much more efficient than PtL and that it has zero-emission capability so easily falls through the cracks."

"All means of transport should be electrified or partially electrified wherever ecologically and technically feasible. E-fuels will be crucial for transport applications for which, as it stands, no electric power trains are easily available." [1]

Category: Electric transportation | **Author:** Johanna Büchler

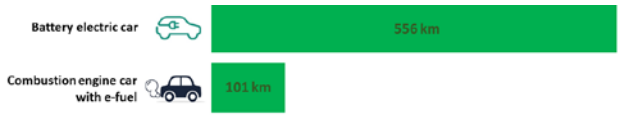
DISPELLING THE E-FUELS MYTH

Commentary – against e-fuels

If there were to be a widespread switchover to e-fuels for transportation we would be shooting ourselves in the foot in environmental terms. The more we rely on e-fuels, the more impossible it will be for us to turn around the world's energy system before it's too late. The internal combustion engine isn't getting any greener and a fundamental rethink of mobility is absolutely essential.

In no other sector does Germany's own climate objectives lag so far behind than in transportation: After 30 years with zero drop in carbon dioxide emissions, we now need to almost halve them within eight years. To keep to the 1.5 °C limit, things really do need to happen much more rapidly.

If you listen to the lobby groups of the oil and automotive industries, the answer you'll hear touted is electrofuel, otherwise known as e-fuel – synthetic fuel that can be used across the board in conventional internal combustion engines or ICEs. E-fuels make transportation green without the necessity for uncomfortable structural changes, at least that's the promise.



[Source: DUH, Azat Valeev/stock.adobe.com]

It's a dangerous illusion. Environmental Action Germany has compiled the most common myths about e-fuels [1]: E-fuels are always discussed within the context of climate protection, and yet they can in no way be considered automatically sustainable and indeed their very use can lead to increased emissions. The production of e-fuels is extremely energy intensive and their effect on the climate is highly dependent [1] on the provenance of the energy used for the manufacturing process. E-fuels can only help mitigate climate change if 100 percent of the additional electricity generated for these purposes is renewable in origin. Hydrogen and e-fuels from fossil gas, which some proponents would like to call "low carbon," are associated with enormous greenhouse gas emissions [2] and would only fan the flames of the climate crisis rather than extinguish them.

Nevertheless, green electricity is a precious and scarce resource and will remain so in the longer term. It needs to be used in a targeted way that reaps maximum environmental benefit. Every kilowatt-hour of renewable power that is channeled into direct electrical applications (in the power sector, for electric vehicles or heat pumps) brings about by far the greatest saving in emissions. And that's the case the world over. Even in windswept Chile, almost 80 percent of the country's primary energy requirement is met by fossil energy sources. To then use valuable wind power to produce e-fuels for Porsche rather than to focus it on decarbonizing Chile's domestic energy sector puts an additional burden on the climate rather than unburdening it.

If the electrical power generated by 10 wind turbines is used to produce e-fuel for an ICE vehicle, the energy from more than eight of those turbines will be wasted due to conversion losses [3]. The more we rely on e-fuels, the more impossible it will be for us to transform the world's energy ecosystem in time. In order to significantly reduce emissions within the small window of opportunity that, according to the Intergovernmental Panel on Climate Change, still remains for us to halt the escalating climate, we must massively lower our energy consumption, not push it up further with energy-hungry technologies.

When it comes to the resources needed for e-fuels, things don't just stop at green power: Large amounts of treated water, carbon dioxide extracted from the atmosphere, rare metals for electrolyzers [5] and enormous tracts of land for all the processing plants are also required. Even assuming the best-case scenario for the scaling of e-fuel manufacturing, e-fuels will only be produced in exceedingly small quantities in the runup to 2030 [6] and even after this point will continue to be an expensive commodity that is in extremely short supply. In the current decade – a period which will be decisive for climate action – e-fuels will not help us make any forward progress.

There are sectors such as long-haul aviation in which e-fuels can contribute to emissions reduction in the medium term – that is after all avoidance and displacement strategies have first been exhausted. Road transportation is not one of those sectors, however, especially as e-fuels do nothing to solve the problem of poisonous nitrogen oxide emissions [4]. Efficient battery-electric powertrains are far superior in ecological and economic terms.

Industry is using e-fuels as a Trojan horse in order to delay the phaseout of the internal combustion engine and stall attempts to truly transform the transportation system. But a "keep calm and use another fuel" approach only serves to perpetuate environmentally damaging and socially unjust transportation policy, cementing our lasting dependency on fossil-based forms of energy and preventing the necessary restructuring of the mobility sector. A green fuel for 48 million German ICE cars does not exist. Instead of e-fuel fairy tales we need specific measures that will bring down car numbers and car transportation significantly and make the switch to walking, cycling and public transport easier and more attractive. ||

Literature:

[1] Kasten, P.; Heinemann, C.; Not to be taken for granted: climate protection and sustainability through PtX, Oeko-Institut, 2019

[2] Oni, A. O.; Anaya, K.; Comparative assessment of blue hydrogen from steam methane reforming, autothermal reforming, and natural gas decomposition technologies for natural gas-producing regions, ScienceDirect, 2022

[3] German Advisory Council on the Environment (SRU), The role of hydrogen in climate protection: quality rather than quantity, 2021

[4] Transport & Environment, Magic green fuels: Why synthetic fuels in cars will not solve Europe's pollution problems, 2021

Author:

Dr. Johanna Büchler
Environmental Action Germany, Berlin
→ buechler@duh.de

Category: Electric transportation | **Author:** Andreas Luczak

NEED FOR E-FUELS A LONG WAY OFF

Commentary – against e-fuels

It will come as no surprise that the case for e-fuels is preached particularly by those branches of industry whose products and infrastructure are designed to a large extent around fossil fuels. The hope that carbon-neutral natural gas, gasoline, diesel, fuel oil and kerosene would allow our lives to continue undisturbed by the energy transition is being thankfully absorbed by both society and the political establishment. The fact that vested economic interests primarily lie behind this e-fuel propaganda is being intentionally ignored.

If you take a sober look at e-fuels, alas a disillusioned picture emerges: Fundamentally, e-fuels only reduce emissions if they are made using surplus renewable electricity. Otherwise the power-hungry production of e-fuels leads to higher utilization of the fossil-based power plants that will still be needed for several decades to come. This would then result in more emissions than could be recouped by the use of e-fuels elsewhere. As it stands, however, only a small percentage of renewable power is curtailed, meaning that the potential for producing e-fuels is extremely low.

In addition, these curtailments, i.e., when power generation is scaled back during periods of insufficient demand, only occur for a small number of hours each year. Consequently, the expensive infrastructure required for manufacturing e-fuels would be utilized extremely poorly. As is similar to the situation for hydrogen use, the ensuing costs for saving a ton of carbon dioxide will be higher than alternative carbon reduction measures until at least 2035, even if the expansion of wind and solar capacity is rapidly accelerated.

WHY THERE SHOULD BE NO STATE FUNDING FOR E-FUELS

Also in the long term, the use of e-fuels will only be cheaper than alternative technologies for a very limited number of no-regret applications that seemingly cannot be decarbonized by other means. And even then it would only be for a proportion of aviation, shipping and heavy-duty vehicle transportation. The decarbonization of these applications is so costly that it only becomes worthwhile if all cheaper courses of action have first been used to raise the renewable portion of primary energy consumption to around 80 percent. If you consider that it was only possible to increase the share of renewables from 1 percent to 17 percent between the years 1990 and 2020, in spite of considerable efforts, then you can begin to fathom how far we are from a sensible use of e-fuels.

Attempts are often made to invalidate this problem by citing the argument that it would be possible to import large quantities of inexpensive e-fuels in the foreseeable future as the green power needed for their production can be generated much more cheaply in many regions of the world than is the case in Germany. Nevertheless, the calculated starting point when this could begin to make a significant contribution is unrealistically early. In addition, for potential exporter countries, the basic principle applies that it only makes sense to produce e-fuels shortly before net zero is reached.

Even if it were possible to arrive at this tipping point within a few decades, it would be much more expedient to deploy the e-fuels within the producer country itself rather than to export them. Furthermore, it is not necessarily the case that the importation of e-fuels is associated with lower costs; while it is true to say that green electricity costs are extremely low in some areas of the world, this advantage is offset by higher transport costs.

The costs of the energy transition will be increased unnecessarily by the generous state funding of technologies right now that won't be needed until the energy transition enters its final phase. In order to avoid this, we should instead strengthen cross-sector emissions trading as a key instrument in climate policy. This market-based approach, which is both efficient and technologically unbiased, consistently ensures emissions reduction by the cheapest means possible. ||

Literature:

Luczak, A. (2022), "Zukünftige Erzeugung und Nutzung von grünem Wasserstoff in Schleswig-Holstein: Abschätzung der CO_2-Vermeidungskosten," Landeskompetenzzentrum für Wasserstoffforschung Schleswig-Holstein.

Author:

Prof. Andreas Luczak,
Kiel University of Applied Sciences
→ andreas.luczak@fh-kiel.de

GREEN HYDROGEN AND E-FUELS ARE INDISPENSABLE!

Guest opinion – pro e-fuels

Our society is facing great challenges. The climate targets for 2030 (Klimaziele 2030) must be achieved without negatively impacting our mobility and Germany as an economic center. To reduce greenhouse gas emissions, in addition to new battery electric and fuel cell vehicles, existing vehicles must also be considered. For these, renewable synthetic fuels, so-called e-fuels, must be the only option. Only through their use can a ban on the driving of conventional vehicles, which the federal government is considering in light of Klimaziele 2030 and which would mainly affect lower-income citizens, be prevented.

However, the EU Commission intends to make such optimistic and idealistic demands on the production of renewable fuels that the necessary ramp-up of renewable synthetic fuel production is massively hampered. Implementation of the European Commission's current draft of RED II (Renewable Energy Directive II) would delay the success of a game-changing technology and thus make the German climate targets in the transport sector unattainable. The federal government must therefore become active in this regard at the EU level. In addition, Germany should make full use of the extent of its policy-shaping power. After all, the Federal Republic has set much more ambitious targets for its future percentage of renewable fuels, more than 25%, than the EU, only 14%. The federal government has this responsibility to its voters and to the environment.

The previous federal government had adopted a mandatory greenhouse gas reduction quota of 25 percent. At the same time, green hydrogen was granted a special role, deviating from the EU directive. Its energy content is counted double towards greenhouse gas reduction. With this, the theoretical conditions for achieving the targets with green hydrogen and e-fuels in a cost-neutral manner were created. What is still missing is a regulation that guarantees investment security for companies during implementation.

The new federal government is now called upon to issue a regulation for renewable synthetic fuels based on green hydrogen. To become the lead market for hydrogen technologies, Germany needs to balance climate protection, societal fairness and the promises set out by the new government, including personal freedom, fairness and sustainability. Ideological and too stringent conditions on electrical supply from renewable energy sources would be a threat to budget-neutral short-term ramp-up of a green H_2 economy.

There is no doubt that we want to and must achieve the climate targets in transportation. In doing so, however, the government must ensure that, on the one hand, the costs for citizens, transport of goods and agriculture do not increase to an unbearable extent and, on the other hand, that energy supply continues to be secure. This applies all the more against the backdrop of the currently high inflation and the current events in Ukraine. With appropriate tax incentives for fuels, a minimum percentage of these for renewable synthetic fuels, the new government has the ability to shape a socially tolerable transformation process towards climate-neutral mobility. The new federal government will decide whether Germany seizes the chance to become the lead market in the economically promising green hydrogen industry. And also whether the 2030 climate targets can be achieved realistically and in a socially fair manner. ||

Author:

Werner Diwald
Deutscher Wasserstoff- und Brennstoffzellen-Verband e. V., Berlin
→ diwald@dwv-info.de

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

FUEL CELLS FOR LONG HAUL, BATTERIES FOR CITIES

VDI/VDE study on sustainable commercial vehicles

According to European Union guidelines, carbon dioxide emissions from heavy-duty vehicles will need to be cut by 30 percent by the year 2030 in order to ensure emissions reductions are on track to meet the EU's 2050 net-zero target. This would mean that around 200,000 emission-free trucks would have to be operating on Europe's roads by 2030. That's the finding of a recent study carried out by the association of German engineers VDI and the testing and certification institute VDE entitled "Sustainable commercial vehicles – a comparison of different technology pathways for carbon-neutral and carbon-free propulsion." It found marked advantages for the use of fuel cell power systems for long-distance transportation using large commercial vehicles while battery-electric powertrains were seen as clearly beneficial for small commercial vehicles.

Fig. 1: Twenty-five transportation and logistics companies have been relying on the Hyundai XCIENT since October 2020 [Source: Hyundai]

In their study, the authors investigated five different options for sustainable commercial vehicles and drew comparisons between them: battery-electric vehicles (BEV), catenary trucks (CAT), fuel cell electric vehicles (FCEV), hybrid vehicles (a combination of BEV and FCEV) and vehicles powered by liquefied synthetic fuels (SYN).

Their research revealed that buyers of commercial vehicles have fundamentally different criteria which they consider relevant with regard to costs compared with users of private cars. It also found that, due to the long distances traveled each year, freight forwarders would accept higher purchase prices if the variable costs, e.g., fuel, are lower. According to the analysis, the existence of widespread infrastructure is an important factor alongside the total costs of ownership (TCO).

As it currently stands, alternative propulsion methods are not yet competitive with conventional diesel-powered vehicles. Nevertheless, the study's authors recognize that a good foundation exists to enable this to change in the future. They calculate that the production costs of fuel cells (FCs) and batteries will fall and their performance will increase. In addition, it is anticipated that the costs of green hydrogen will decrease significantly. The regulatory situation, too, looks positive. For instance, the operation of diesel vehicles will become more expensive via increasing carbon taxes and will therefore become less economical. Plus, legislation is placing ever more restrictions on the operation of diesel-powered vehicles.

SWEEPING STATEMENTS IMPOSSIBLE The conclusion of the VDI/VDE study is unambiguous: In order to meet EU targets, the focus needs to be on fuel cell power systems for heavy-duty vehicles on long journeys and on battery-electric propulsion for small commercial vehicles in urban areas. Indeed, BEVs are fundamentally more efficient; fuel cell vehicles, on the other hand, offer advantages in terms of vehicle range and fuel tank duration.

"Sweeping statements along the lines of 'batteries are better than fuel cells' should be avoided," recommended Remzi Can Samsun. According to the head of the reactors and systems group at the FZ Jülich research center, it is far more important to take a detailed look at each application in terms of journey distances and journey profiles. "Years ago, people still thought that neither batteries nor fuel cells would have a place in a 40-ton truck. Since then they've seen that it can work with both technologies. That's a significant step forward," Samsun said.

With regard to the assumptions made on the efficiency of the various technologies (see table), Thomas Grube from the Institute of Energy and Climate Research at FZ Jülich admitted that: "Efficiency calculations are difficult." For example, the assessments are highly dependent on whether the hydrogen used in the process needs to be liquefied again, which would bring down the level of efficiency. On this subject he stressed that: "When it comes to fuel cells, our calculations put the value at around 35 percent."

BATTERIES: A WEIGHTY PROBLEM While it may be said that batteries have an advantage in terms of efficiency, Martin Pokojski is keen to remind us that the longer the range required, the bigger the battery will need to be. The chairman of the VDE/VDI technical committee on hydrogen and

Table: Efficiency assumptions when comparing technologies

Form of propulsion	Efficiency
Catenary system	57% to 70%
BEV	57% to 63%
FCEV	24% to 29%
Synthetic fuels	17% to 20%

Source: VDI/VDE

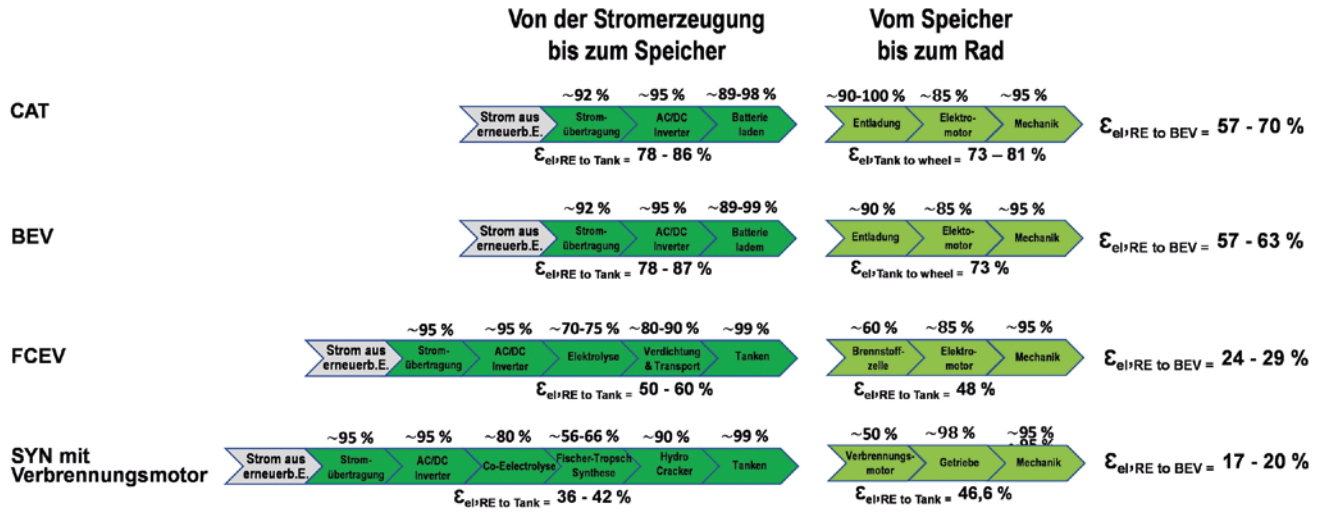


Fig. 2: Efficiencies and process chains of sustainable propulsion systems [Sources: FZ Jülich, dena, own calculations, VDE/VDI study]

fuel cells stresses that the weight of the battery restricts the payload and therefore, in his opinion, the best way to utilize a battery's efficiency is on short transport routes. "Commercial vehicles, however, now travel up to 1,600 km (1,000 miles) on one tank. Something similar is also expected of electric vehicles," explained Pokojski.

"The distances required to be traveled over a vehicle's lifetime are very high and far exceed a million kilometers (620,000 miles). This is clearly more than a car has to travel," expanded Grube. He also highlighted the range requirements. If it is assumed that a distance of 620 miles (1,000 kilometers) is traveled on a regular basis, this would work out at a battery weight of between 5 metric tons and 7 metric tons. In the expert's view, "That's a considerable limitation not only in terms of mass but also volume." Indeed, there is currently the special arrangement for large battery- or fuel cell-powered commercial vehicles that allows the gross vehicle weight to be extended to 42 metric tons, which, in Grube's opinion, is helping to mitigate the situation now, but things won't remain this way in the long term.

And what's the outlook for the other two forms of propulsion investigated? The committee chairman pointed out that the idea of catenary trucks raises the question of how far society is prepared to go in terms of accepting additional infrastructure. He added that the installation of overhead cabling along freeways entails enormous investment. According to Pokojski, synthetic fuels represent, on the one hand, an elegant way to decarbonize existing vehicles. On the other hand, there is a problem with efficiency, given that the efficiency level is around 50 percent lower than for fuel cells. In Pokojski's view, the situation is clear: "If we are interested in higher efficiencies, then this makes the argument against this energy carrier at least in the longer term." He believes that synfuels are a feasible option as a temporary fix but are unlikely to be a lasting solution (see also pp. 32 to 37).

FCEV SUPPLIERS' MARKET ON THE MOVE According to Thomas Grube, the trend in the suppliers' market is also another important aspect. Here he sees very encouraging signs for FCEVs. "There is sufficient industrial activity to prove that this demand actually exists or at least that it can be expected," he observed. The researcher has noticed, for example, that Nikola is increasing its activities, while Hyundai is also making progress in this area via its project in Switzerland. Added to that is the array of new projects being carried out by Toyota – not just in Europe but in the US.

Remzi Can Samsun is likewise convinced of a positive trend in this area. He states that around 50 Hyundai XCIENT trucks are currently deployed as part of the South Korean company's large-scale rollout in Switzerland, demonstrating that the company already has a business case in which the use of FCEV trucks is made viable thanks to tax exemptions. Across its other projects in Asia and Europe the vehicle manufacturer has indicated higher figures totaling around 600 fuel cell trucks, reported Samsun.

It is understood that the project is enabling Hyundai to assimilate a great deal of experience and is also benefiting from the technology transfer with fuel cell car models. A similar strategy is being pursued by Toyota. "There's a lot going on," concluded Samsun. And China should also not be forgotten here. In the past year, approximately 800 heavy-duty fuel cell trucks made by various manufacturers have been brought onto the Chinese market, he said, explaining that the country is also increasingly using systems developed by Chinese companies alongside technology from Ballard.

On this point, Pokojski described a stumbling block that was encountered when compiling the study – a degree of reticence in companies' communications. While many companies will, in fact, be working on both technologies, the publicity will only be limited, he said.

RELATIVELY LOW INFRASTRUCTURE COSTS Another important consideration scrutinized by the study was the charging and refueling infrastructure for commercial vehicles. In this regard, Grube referred to a study on cars that the VDI and VDE associations published in 2019 which outlined an affordable "fuel" for both technology options: BEV and FCEV. Grube substantiated this, saying: "The variable mobility costs relating to the fuel were virtually identical following the transitional period." Here, the transitional period means the switchover in the hydrogen sector from gray hydrogen to the initially more expensive green variety.

The second lesson learned was that the proportion of infrastructure costs in relation to total mobility costs "is very small." In the study, calculations for the automobile sector in Germany in the runup to 2050 indicated more than 1,000 hydrogen filling stations and several 100,000 charging points, amounting to EUR 50 to 60 billion in infrastructure costs. "That's relatively low when you compare it with other infrastructure costs," underlined Grube.

The key element when considering costs, however, is the degree of utilization. For trucks, infrastructure can be high-

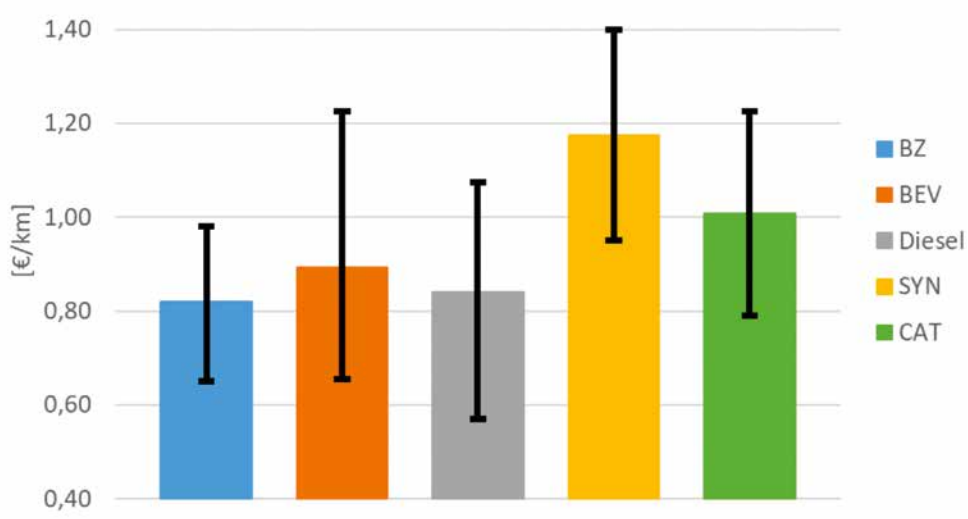


Fig. 3: TCO for 40-metric-ton long-range vehicles based on various studies [Source: VDE/VDI study]

ly concentrated along major long-distance routes. According to Grube, it involves around 500 locations. Here the market analyst sees distinct advantages: On the one hand, this hydrogen infrastructure will establish itself "very quickly" and on the other hand it will be cost-effective to operate due to the expected high level of utilization. To Grube's mind, the situation in the automobile sector in terms of hydrogen refueling stations is much more challenging.

TRUCK-FRIENDLY INFRASTRUCTURE NEEDED Yet if this is to be realized, policy needs to work in partnership with these pursuits. "The latest plan to stop subsidizing the construction and operation of hydrogen filling stations could have fatal consequences. As a result, policy is hampering EU objectives to reduce carbon dioxide emissions for heavy trucks," complained Pokojski. In his opinion, now is the right time to further expand existing hydrogen filling stations and to build new ones.

An additional hindrance is the present lack of consideration given to hydrogen station design when it comes to meeting the requirements of heavy-duty vehicles. The current 90 available 700-bar filling stations are only partially suitable for trucks in terms of the necessary volumes and speed of refueling. That is why the study's authors are calling for 70 truck-friendly hydrogen refueling stations to be built and evenly spaced along Germany's autobahns by the year 2030.

Fig. 4: Martin Pokojski, chairman of the VDE/VDI technical committee on hydrogen and fuel cells

The situation for charging infrastructure is similarly critical. A survey of the roughly 16,000 charging points that are currently available indicated that, at present, only 25 points are suitable for trucks. In order to meet the needs of just 5 percent of existing vehicles, however, this would require 1,200 charging points with a power output of 720 kilowatts.

The authors of the study agree that, in the medium to long term, sustainable commercial vehicles have a role to play in lowering economic costs in the transportation sector. Nevertheless, achieving this would need a suitable level of R&D funding in these areas in order to develop innovative technologies in commercial vehicle production.

In addition, committee chairman Pokojski believes that a multitrack approach is the appropriate strategy. "We are not yet at the stage where we are able to discern the correct path," he underlined, adding that it is extremely risky for both a company and a society to commit to just one technology at such an early phase of development. "Differentiation is the right route to take here, even if it does initially cost more money," Pokojski concluded. ||

AVAILABLE HYBRID COMMERCIAL VEHICLES

- Nikola Two (240 kW FC power output, 125 – 250 kWh battery): 465 to 745 mile (750 to 1,200 km) range
- Toyota Project PORTAL 2.0 (228 kW FC power output, 12 kWh battery, gross vehicle weight 36.3 t): > 300 mile (480 km) range
- ESORO: FC truck with trailer / COOP (100 kW FC power output, 120 kWh battery, 350 bar, 31 kg H_2): 230 to 250 mile (375 to 400 km) range
- Hyundai XCIENT Fuel Cell (190 kW FC power output, 73.2 kWh battery, 350 bar, 32 kg H_2, gross vehicle weight with trailer 36 t): approx. 250 mile (400 km) range
- Dongfeng Special Vehicle with Ballard stack (30 kW FC power output, 3.2 t carrying capacity): 205 mile (330 km) range
- Kenworth Class 8 Drayage Truck (85 kW FC power output, 25 kg H_2): 150 mile (240 km) range

Source: VDI/VDE study

"Commercial vehicles, however, now travel up to 1,600 km (1,000 miles) on one tank. Electric vehicles are also expected to do something similar."

Martin Pokojski, VDE/VDI

Fig. 1: At IAA Mobility 2021, EKPO Fuel Cell Technologies presented various next-generation fuel cell stack platforms with improved design and higher performance [Source: EKPO]

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

MOMENTUM CAN BE FELT EVERYWHERE

EKPO sets the pace in automated stack production

The joint venture between ElringKlinger and Plastic Omnium has built up a production capacity of 10,000 stack units per year at the Dettingen site. According to chief finance officer Dr. Gernot Stellberger, the fuel cell manufacturer from Baden-Württemberg has a lead of about two years over the competition in the area of industrial stack design. The company is aiming for a sales revenue of up to one billion euros by the end of the decade. In addition to the commercial vehicle sector, there is great interest from the maritime and rail industry. In the joint venture Aerostack with Airbus, EKPO Fuel Cell Technologies GmbH is developing a stack for use in aviation.

According to Dr. Gernot Stellberger's analysis, the first step in the commercialization of fuel cells in the mobile sector will not be taken with passenger cars. "We are currently registering very strong interest in the light and heavy freight transport sector, in trains and in maritime solutions," said the EKPO chief finance manager. The joint venture between the German and French automotive suppliers was established in October 2020 and commenced operations at the beginning of March 2021. Due to the majority shareholding structure, where ElringKlinger holds 60 percent and Plastic Omnium 40 percent, the company is consolidated within the ElringKlinger Group.

According to Stellberger, who previously led the Global Strategy, M&A and Innovations division at ElringKlinger, the dynamics in the market have increased strongly. "We receive an average of ten to twelve new requests per month. We almost can't keep up processing them with the same high quality." These are mainly pilot- or prototype-driven projects, reports the CFO. Many companies are now approaching the topic of hydrogen. This confirms the expectations of the company headquartered in Dettingen an der Erms that hydrogen will be a major topic in mobility in the future.

As Gernot Stellberger reports, the momentum of FC technology is being felt everywhere, both on the customer and supplier sides. He describes the current situation so: "The companies take stock of their situation and try out adequate solutions for the respective needs. And this is done in test fleets of maybe ten vehicles here, twenty there." This way, they've been able to speak with nearly all the significant commercial vehicle manufacturers and can say that these have pursued a hydrogen agenda.

THE H_2 PILLAR IN THE BUSINESS Stellberger calls EKPO Fuel Cell Technologies "the hydrogen pillar" in the transformation strategy of ElringKlinger AG. With Plastic Omnium, they've found a partner who "itself believes in hydrogen and also has its own hydrogen agenda." The French company also uses the EKPO stacks in its own systems, a pleasing aspect for the CFO, who exclaimed, "What could be better than having

The French automotive supplier had a consolidated revenue of over 7.7 billion euros for 2020. The revenue of ElringKlinger AG lay at 1.48 billion euros. EKPO has a target sales revenue of 700 million to 1 billion euros for the year 2030.

Fig. 2: EKPO has set up a highly automated stack production facility with a production capacity of 10,000 units per year in the Swabian city of Dettingen an der Erms [Source: EKPO]

an investor who represents a guaranteed volume of demand and at the same time also contributes operationally?"

The strategy behind founding EKPO as an independent unit was "to have a player who can fully concentrate on the FC business." The joint venture offers FC stacks and components in various size classes for a wide range of applications. A particular benefit is the expertise of ElringKlinger, as the company has been active in FC technology for over 20 years.

Stellberger assumes that it has a lead of about two years over its competitors with regard to the readiness of the stacks for mass production. "We are able to manufacture up to 10,000 units per year on an industrial scale in our lead factory in Dettingen an der Erms at marketable prices," he said. The automated stacking line set up there is already the second generation. The first line was realized four years ago as part of a grant project.

HIGHLY AUTOMATED PRODUCTION TECHNOLOGY According to Stellberger, the degree of maturity is expressed in the type and manner of highly automated production technology based on automotive standards, on the one hand, and also in the maturity of the products themselves. He uses the stack NM5-EVO, which is to be used primarily in passenger cars and light commercial vehicles, as an example. The current PEM stack module, which went into series production in 2021 and has an output of 76 kW_{el} at 2.5 bar operation, is the third stack generation, after NM5 and NM5B. "This was a continuous development. Especially the shift from a good design to a good industry-scalable design," expressed the CFO.

With the larger NM12 stack, which was also presented to a larger audience at the latest IAA Mobility (see H2-international Jan. 2022), the increased active surface area ensures an increased power output. With a power density of 6.2 kW per liter, it represents, according to Stellberger, a benchmark in the technology. With the PEM stack module NM12 TWIN, the 598 cells (2 x 299 cells) on metallic bipolar plates comes to an electrical output of up to 205 kW. The plug-in module is thus primarily aimed at heavy commercial applications such as trucks, trains and ships.

FLEETS AS A LOGICAL FIELD OF APPLICATION Stellberger has observed a lot of development activity particularly in the area of commercial vehicles. "Three years ago, hardly any vehicle programs were being launched in mid-size and small commercial vehicles. The situation today is that already over 50 hydrogen-based models in the less than six-tonne category have been announced for availability by the year 2030 worldwide," he said. According to the CFO, two arguments clearly speak in favor of FCs in the commercial vehicle sector: "Where the business model requires continuous operation, where operating time is money, battery technology alone makes little sense as a production or value-creating medium due to the long charging times and thus downtimes of the vehicle. Therefore, wherever fleets are in operation, from the last mile delivery to the taxi fleets, is a logical field of application for hydrogen and FCs."

Mid-last year, EKPO got its first large series order, in the tens of millions of euros range, from the Aachen-based mobility company AE Driven Solutions GmbH (AEDS). The company that reached a high degree of notability for developing the battery-operated delivery van StreetScooter, used by DHL, is now also focusing on fuel cell-powered vehicles in connection with new mobility concepts in urban regions. They will be employing the NM5-EVO stack, which, according to Stellberger, scored high with its comparatively low weight and power range of up to 76 kW at operating pressure. "If successful, we're talking about thousands or tens of thousands of units per year," the CFO reports.

TALKS WITH SHIP AND TRAIN MANUFACTURERS In the maritime market, higher power classes in the range of several hundred kW up to the MW range are often requested. Here, Gernot Stellberger observed, especially manufacturers and operators of ferries and yachts are currently showing major interest (see p. 43. "These are increasingly coming under pressure due to the increasing legal demands on harbors with regard to emissions," states the EKPO CFO. Here too the battery reaches its technical limits. "Who wants to have to leave their yacht in the harbor for 15 hours?" Stellberger wonders. In addition, yachts have enormously high energy demands for air conditioning and other infrastructure, so fuel cells can also demonstrate their strengths here.

Trains are also a very interesting area for FC use. "We are in very good and intense discussions with various train manufacturers," reports Stellberger. The subject is often emissions-free operation of cable-free rail vehicles. Since retrofitting is quite cost-intensive, hydrogen-powered trains are an attractive alternative. EKPO currently addresses this market with the NM12 TWIN solution, which is primarily aimed at commercial applications in the higher power range (> 100 kW).

Fig. 3: Gernot Stellberger [Source: EKPO]

AVIATION JOINT VENTURE AEROSTACK Somewhat more concrete are the activities already underway in air transport. In October 2020, the company entered the joint venture Aerostack GmbH with Airbus. At EKPO head-

quarters in Dettingen, work is being done to produce a stack for use in aviation. Stellberger knows, "In air travel, volume and weight are the most important criteria." Especially important is therefore the power density. Here too the NM12 stack platform, with a power density of 6.2 kW per liter, is the basis for the work.

In aviation, higher temperature levels or different humidity levels are also at play. And the development cycles are also different from those in the automotive sector for example. In a press release, Airbus shared that it wants to have produced an FC aircraft by 2035. "In the same 14-year period, as comparison, we have already managed three or four automobile cycles," underscores Stellberger.

At the beginning of February, Aerostack received a follow-up order. In the coming two years, EKPO will fulfill its development role and supply FC stacks optimized for air applications. They will also be contributing expansion of the knowhow for the central components, like the bipolar plates and insulation technology, EKPO shared.

COOPERATION WITH RESEARCHERS For the further development of FC stacks, EKPO has also established cooperations with scientists and researchers. At the state of Baden-Württemberg's "research factory" for hydrogen and fuel cells HyFaB (Forschungsfabrik für Wasserstoff und Brennstoffzellen) in Ulm, the company is working with experts from ZSW, Baden-Württemberg's center for solar and hydrogen power research (Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg), which is next door, to develop the necessary requirements and procedures for large-scale production of such stacks. The current project aims at a generic FC stack as a pre-competitive and vendor-independent development platform. According to information provided by ZSW, the platform will be "a type of universal tool for further technical development of fuel cells." The stack of around 500 individual cells is conceived for a maximum output of up to 150 kW. ||

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

FUEL CELL POWERTRAINS NOW AN OPTION FOR LARGE SHIPS

Ammonia, methanol and hydrogen as marine fuels

Currently they run on heavy fuel oil – a substance that is more reminiscent of tar than vehicle fuel. It's the residue that remains after various crude oil distillation processes have been carried out. While the more volatile fractions such as kerosene, gasoline, diesel and household fuel oil are separated off for other uses, the large, robust two-stroke engines of ocean-going giants make do with the leftover black sludge which is so viscous it needs to be heated up before it can be combusted. The changeover to fuels like liquefied natural gas, LNG, has already begun but this in itself won't be enough. That's why an increasing number of industry players are looking to hydrogen and are now making initial attempts to embed this fueling option in seagoing vessels.

Fig. 1: The ONE 50 will be capable of sustainable sea travel [Source: Meyer Werft]

Although hydrogen is still an unrealistic prospect for container ships, it is starting to be given some serious consideration when it comes to vessels of a similar size – cruise liners. Previously, any thoughts of using hydrogen in this part of the industry, however, have been limited to onboard energy supply solutions. Before now, replacing the enormous long-stroke engines with hydrogen power units has just not been possible. Yet in summer 2021, shipping company MSC announced its intention to conduct a study to see if cruise ships could manage without with fossil energy sources.

To do so, MSC joined forces with the large shipbuilder Fincantieri and gas supplier Snam, both from Italy. Together, these three heavyweights want to test out whether cruise liners can operate on hydrogen. The initial plan is to carry out a feasibility study which will analyze the design and construction of the vessel as well as the build-out of the associated refueling infrastructure.

The shipping company's aim is to reach carbon neutrality by 2050. The International Maritime Organization, IMO, foresees only a 50-percent reduction in greenhouse gas emissions by that date compared with levels in 2008.

STACK MANUFACTURERS DISCOVER SHIPPING German company Pro-

Fig. 2: The HyShip 72 system from Proton Motor [Source: Proton Motor]

ton Motor Fuel Cell is also working with Trieste-based Fincantieri and in late January 2022 revealed it was supplying a new fuel cell system named HyShip 72. This is a 142-kilowatt system that has been specially adapted to the Zero Emission Ultimate Ship model, known as ZEUS, developed by the Italian shipbuilder. The compact unit is composed of two hydrogen-driven PEM stack modules of the type PM 400-120, a battery system and a metal-hydride hydrogen tank.

Parallel to this, the fuel cell manufacturer is also collaborating with Torqeedo, headquartered in Gilching, Germany, on a construction kit for hybrid powertrains in marine applications. Working under the banner of Ma-Hy-Hy, which stands for Marine Hydrogen Hybrid, the two Bavarian companies are endeavoring to fit out the Torqeedo's existing Deep Blue Hybrid system with fuel cell technology – namely the PM 400 Stack.

Torqeedo is an e-mobility business that specializes in seafaring applications and has been part of the Deutz Group since 2017. Its product portfolio includes powertrain systems from 0.5 kilowatts to 100 kilowatts for the commercial and leisure sectors. The goal of Ma-Hy-Hy is to develop hybrid powertrain solutions with power outputs between 50 kilowatts and 200 kilowatts using fuel cells (30 to 120 kW) and batteries (40 to 160 kWh). The project, which is being supported by the Bavarian state government, will be ongoing until 2024.

Its competitor PowerCell Sweden is also making inroads in this area. The company presented its own fuel cell module, PowerCellution Marine System 200, in May 2021 – a system that comprises several PowerCell S3 stacks. Every module produces a power output of 200 kilowatts, a figure that can be scaled up to the megawatt range by connecting individual units up in parallel. Richard Berkling, CEO of PowerCell Sweden, explained: "With PowerCellution Marine System 200 we can offer the marine segment a scalable and fully industrialized solution meeting the segment's need for an increased electrification."

These large-scale systems could be deployed, for example, at Havyard, which back in 2019 announced its plans to build sizable ships with fuel cell power systems (see H2-international Mar. 2020). Havyard Group is a Norwegian shipping company which founded its own subsidiary – Havyard Hydrogen – in November 2020 with the express intention to expand its business activities in this area. Its vice president, Kristian Osnes, said: "We can now offer a system with 3.2 MW fuel cells. This will make it possible for large vessels to sail with zero emissions over longer distances. At the same time, the system is scalable and can be used by both large and small vessels."

Meanwhile Canadian corporation Ballard Power is also at pains to make its fuel cell modules seaworthy. To this end, in-house engineers, working in partnership with colleagues in Hobro, Denmark, have created the FCwaveTM module with a power output of 200 kilowatts, which is based on the liquid-cooled FCgen® LCS stack from the heavy-duty sector. The unit is expected to be used in the C-H2 Ship, a hydrogen-powered vessel that the Vancouver-based fuel cell manufacturer is planning jointly with the Australian company Global Energy Ventures. It is understood that the C-H2 Ship will have a propulsion power of approximately 26 megawatts and will be designed to carry 2,000 tons of compressed green hydrogen. Over the past 30 years, Ballard has channeled around USD 1.5 billion of investment into the development of its PEM technology.

TOP-TIER SEGMENT OFFERS ROUTE TO ENTRY Also toying with similar powertrains, only bigger, is Meyer Werft. In fall 2021, the German shipbuilder presented the concept for a megayacht at the Monaco Yacht Show. The family company, located in Papenburg, describes the making of megayachts as a "new market segment" and has created its own brand: Meyer Yachts. The ONE 50 will be "the start of our ideas and plans," company director Thomas Weigend explained.

This first model is expected to be 150 meters long and 20 meters wide and have a power output of 25 megawatts, not to mention a top speed of 23 knots. The design features six decks that will offer up to 44 guests a range of facilities, from a spa suite, a cinema, a billiards room, an entertainments area with stage, an art gallery and a huge pool. "For megayachts we see a great deal of potential for new sustainable technologies which we are harnessing directly in ONE 50, for example the fuel cell for zero-emission ship operation," said Malte Poelmann from the Meyer Werft management team.

Another yacht builder has meanwhile partnered up with German company SFC Energy. Nordic Yachting revealed in July 2021 that its Winner Yachts-branded pleasure boats can in future be fitted with EFOY fuel cells sourced from SFC – both for the purposes of supplying electricity on board as well as charging the battery that powers the engine. The move sees the Brunnthal-based manufacturer of hydrogen and methanol fuel cells taking a further step into marine applications following its announcement in fall 2020 that it would be entering a collaboration with ePropulsion, a supplier of electric outboard motors.

On a somewhat smaller scale is Hyrex 28 – an e-boat that was unveiled in November 2021 in Norway. The electric craft is equipped with a 20-kilowatt-hour battery storage unit and a 30-kilowatt fuel cell supplied by Cummins as a range extender. The 17 kilograms of hydrogen stored in two tanks makes it possible to sail for 20 to 25 hours at a speed of 10 knots, it is claimed. The development of this e-boat was undertaken by Hyrex, a company that was established in February 2020 in Nøtterøy on the western bank of Oslo Fjord.

Henrik Torgersen, one of the founders, told engineering magazine Teknisk Ukeblad that the company could, in his opinion, initially build five such boats a year. The vessel could be supplied by hydrogen refueling stations operated by Hynion, which was known by its original name "Hydrogenic" (no "s" on the end) prior to its renaming in September 2019.

Fig. 3: Freudenberg's methanol-powered maritime fuel cell system (500 kW) [Source: Freudenberg]

NORWAY: HOTBED OF MARINE ACTIVITY Fast-forward to today and Norway is still witnessing a great deal of activity in this sector. For instance Hexagon Purus has set up its own company, Hexagon Purus Maritime, that is specifically devoted to hydrogen-propelled shipping – primarily in Norway but also elsewhere. Morten Holum, CEO of Hexagon Purus, stated: "Our efforts to bring zero-emission solutions to Norwegian waterways are a great opportunity for us to initiate something, and can serve as a showcase to the rest of the world. […] We're seeing a strong dynamic for green energy and clean transport across the entire world, including in Norway – and we believe that progress can't wait."

Hexagon has already taken part in numerous demonstration projects, for example the Hellesylt Hydrogen Hub and H2CarbonCat as well as Sea Change, a hydrogen-powered catamaran that conveys passengers across San Francisco Bay (see H2-international, January 2019). Furthermore, the Norwegian company, along with Ballard and a number of European enterprises, are joining forces as part of an EU subsidy program to build a hydrogen ferry named Europa Seaways which will have space for 1,800 passengers and 380 cars or 120 trucks. The Danish shipping line DFDS has plans to start operating this 23-megawatt vessel between Copenhagen and Oslo from 2027.

But it's not only hydrogen which is playing a role. Both ammonia (see p. 25) and methanol solutions are being investigated. For instance, Freudenberg is co-developing a power unit for yachts with builder Lürssen. Freudenberg, which is actually first and foremost an automotive supplier, is increasingly broadening its range of activities and is now not only entering the bus and stationary fuel cell sectors but also penetrating the maritime industry.

Adopting a similar strategy to the companies previously mentioned above, Freudenberg has set its sights initially on the high-value market of superyachts. According to a company statement, the fuel cell system serves the purpose of enabling the yacht to "anchor for 15 days with neutral emissions or cruise for 1,000 miles." Here, Freudenberg is not just tying itself to methanol but also has LNG at its disposal thanks to reformer technology which is integrated into the marine fuel cell systems in the hydrogen supply module. Consequently, the downstream fuel cell stacks can process hydrogen that has been reformed from both methanol and LNG and turn it into power and heat, or alternatively the stacks can run on pure hydrogen.

Manfred Stefener, vice president of fuel cell systems at Freudenberg Sealing Technologies, said: "We will cover the entire energy requirement of ships including the main power unit thanks to the integration of fuel cell battery solutions. This hybridizing strategy makes it possible to perform the necessary installations in the two-figure megawatt range for each ship in a sustainable and cost-effective way."

At the same time, the two companies, Freudenberg and Lürssen, are continuing to work with other partners in the Pa-X-ell 2 funding project on the development and testing of a hybrid energy system for yachts and seagoing passenger vessels. Commenting on this, Claus Möhlenkamp, CEO of Freudenberg Sealing Technologies, stated: "Following on from our cooperation with Meyer Werft on cruise liners, we are now collaborating with Lürssen to demonstrate the general transferability of our technology to all maritime subsegments."

TOYOTA SUPPORTS ENERGY OBSERVER The Japanese Toyota Group has meanwhile expanded its horizons toward the maritime industry. For many years, the automaker has been a supporter of the Energy Observer (see H2-international Nov. 2017), which is undertaking zero-carbon voyages around the world. On board the catamaran, Toyota is trialing a modular hydrogen powertrain solution that is based on the fuel cell modules found on the Mirai hydrogen car. This REXH2 module is now also used in the 12-meter yacht Hynova 40. As hinted at by the name, this system is a range extender.

Another offshoot from this collaboration is a 290-kilowatt stationary fuel cell generator that can provide clean electricity to off-grid locations. The GEH2 is sourced from the French research company Energy Observer Developments, also known as EODev; the fuel cell technology is supplied by Toyota. ||

E4PORTS

NOW began researching marine hydrogen applications back in 2009 for the flagship project e4ships. In September 2021 this was supplemented by another initiative. e4ports – as the name suggests – is focused more on ports than the vessels themselves. The kickoff event, held in Berlin and online, brought together port organizations, terminal operators, logistics companies, shipping lines, energy producers and suppliers, network operators and the authorities in order to discuss the issue of how to make maritime transport emission free.

NOW managing director Kurt-Christoph von Knobelsdorff explained: "Ports are the nerve centers of an economy. Nothing happens without them – and that includes meeting climate targets. Because ports are hubs for goods transportation and commercial trade, they are characterized by complex energy flows. To switch these to renewable energy is a challenge which the various parties involved in e4ports are together addressing."

Category: Development | **Author:** Klaus Steiner

ADJUSTING THE REGULATORY FRAMEWORK FOR HYDROGEN

News on the H_2 regulations by the DVGW

The tasks of grid operators include, on the one hand, the safety-oriented design of the gas infrastructure and, on the other hand, guaranteeing the proper functioning and operational reliability of the gas networks over their lifetime of use. Network operators ensure this by adhering to the requirements in the technical regulations of the DVGW, the German association for gas and water standards (Deutscher Verein des Gas- und Wasserfaches e.V.), for all gases in accordance with reference sheet (Arbeitsblatt) G 260. Which now also includes hydrogen. With the publishing of the new Energiewirtschaftsgesetz (German energy industry law, EnWG) in August 2021, the DVGW also became responsible for establishing the technical rules and requirements for the supply of hydrogen by pipeline to the general public. On the one hand, this is a leap of trust in the expertise of the gas industry and, on the other, an impetus to further develop the regulatory framework especially for hydrogen.

Fig. 1: Connection for a mobile pig trap of the H_2 pipeline in Falkenhagen [Source: Dr. Klaus Steiner]

The requirements for the quality of fuel gases of the public gas supply are specified in Arbeitsblatt G 260 "Gasbeschaffenheit" ("G 260 Technical Rule 'Gas quality'"). Since the version from May 2021, it also includes a gas family for hydrogen. This so-called 5th gas family includes two different purity levels. Group A requires an H_2 content in the gas of at least 98 percent and group D of more than 99.97 percent.

With the publishing of G 260, Arbeitsblatt G 262 "Nutzung von Gasen aus regenerativen Quellen in der öffentlichen Gasversorgung" (use of gases from regenerative sources in public gas supply), which had specified the quality of renewable gases fed into the grid, was withdrawn. Users, however, still need to comply with the ordinance for entry into the German gas network (Gasnetzzugangsverordnung, GasNZV). It requires that biogas, which legally includes hydrogen from regenerative sources, comply at the feed-in point and during feed-in with the conditions laid out in the 2007 version of DVGW reference sheets G 260 und G 262. As a result, the regenerative gases fed into the network, to date, must still adhere to the standards set out in these earlier reference sheets.

The new G 260 reference sheet does not set a concentration limit for the hydrogen content of methane-rich gases of the 2nd gas family. However, this content is indirectly limited by the ranges of permissible combustion characteristics that must be adhered to. Furthermore, the gas infrastructure and applications concerned must be demonstrably suitable for the given H_2 content. In the evaluation of the combustion characteristics, it should be taken into account that the composition of the methane-rich gas strongly influences the combustion characteristics of a methane-hydrogen mixture.

POWER-TO-GAS PLANTS DVGW Arbeitsblatt G 220 stipulates the safety and technical requirements for power-to-gas (PtG) plants. According to the DVGW regulatory framework, the pressure and process connection to the gas network is crucial. It is obvious that the standards can also be applied to power-to-gas plants that are not connected to the gas grid. But this application is not the primary focus of the Arbeitsblatt.

According to the Arbeitsblatt, a power-to-gas plant is an operational, functional, safe and controllable technical facility for the conversion of electrical into chemical energy in the form of hydrogen or methanized hydrogen, i.e. synthetic natural gas (SNG). According to ordinance EnWG, the feed-in of renewable gases into the gas grid is to occur via feed-in stations in accordance with Arbeitsblatt G 265-1 for SNG or in accordance with G 265-3 for hydrogen. Reference sheets G 220, G 265-1 and G 265-3 provide the safety, operating and functional requirements.

Arbeitsblatt G 220 goes beyond the use paths for hydrogen. It also specifies requirements in the use paths for oxygen from electrolysis and waste heat from catalytic methanation. For the gas industry, plant operation for processes such as electrolysis or catalytic and biological methanation are new. The reference sheet therefore takes care to address these proce-

dures and technologies from the point of view of the network operator. Examples are the vessel design for pressure vessels that undergo heating, the monitoring of gas quality, especially during storage, start-up and shut-down procedures, and the commissioning of experts and qualified professionals.

Power-to-gas plants are means of operation (Betriebsmittel) under German work safety laws. The reference sheet therefore gives suggestions for the determination of risks and hazards in view of the information published by the German statutory accident insurance association (Deutsche Gesetzliche Unfallversicherung e. V., DGUV) in DGUV Information 203-092 "Arbeitssicherheit beim Betrieb von Gasanlagen" (work safety in the operation of gas plants).

The August 2021 G 220 Arbeitsblatt has been published in English as well as in German. The intention of the DVGW was to make knowledge from experience with PtG plants in Germany available to all of Europe.

FEED-IN STATIONS FOR HYDROGEN Arbeitsblatt G 265-3 for hydrogen feed-in stations is still in the deliberation phase. The final draft is expected to appear within the first half of 2022. It will replace the G 265-3 reference sheet from May 2014. The new sheet will also take into account the requirements of the federal networks agency (Bundesnetzagentur, BNetzA) on gas quality in the feed-in of hydrogen in gas lines that are operated with methane-rich gases of the 2nd gas family.

It discusses how the mixing of the hydrogen with the base gas can be achieved. Since this depends on the velocity and quality of the gas as well as the geometry and dimensions of the feed-in point, the sheet uses simulation results to illustrate solutions for adequate and fastest possible mixing. This is important, because unclear mixing ratios at withdrawal points downstream of the feed-in point would lead to uncalculable combustion values. This is, according to the conditions in the German measurement and calibration laws (Mess- und Eichgesetz, Eichordnung), not allowed.

APPLICABILITY OF THE TECHNICAL RULES The DVGW currently has several hundred applicable technical regulations for the various piping, installations, objects and devices of gas networks in its repertoire. In order to properly comply with the requirements of the EnWG, these regulations and standards are regularly revised to reflect current operational practices. Updating all of these documents for the new 5th gas family, meaning hydrogen, and for hydrogen-containing methane-rich gases of the 2nd gas family for which the hydrogen content exceeds the limits set by the operator, is expected to take several years of work.

To make the DVGW regulatory framework on gas networks, in accordance with the EnWG, already valid and safe today, however, the DVGW has created reference sheet G 221.This guideline for application of the DVGW regulatory framework to the supply of hydrogen and hydrogen-containing gases by pipe to the general public covers the planning, preparation, erecting, testing, start-up and operation of the gas infrastructure between the H_2 production stations and the sites for transfer to customers for all gases in accordance with DVGW Arbeitsblatt G 260, including hydrogen. Wherever the reference sheet does not have a technical standard specifically for hydrogen, the requirements in G 221 can be applied.

NEW OR ALTERED RISKS AND HAZARDS The determination of the suitability of a network section by the operator for the use of hydrogen and hydrogen-containing gases above limits set by the operator and thus permissible basically always involves the same topics:

Identification of
1. altered risks
2. new risks
3. new or altered risks and their associated potential hazards

Reference sheet G 221 therefore sets out hydrogen-specific requirements for the conversion of methane-rich gases of the 2nd gas family to hydrogen of the 5th gas family and the increase in the hydrogen content of methane-rich gases of the 2nd gas family beyond the limits set by the operator. The sheet also addresses additional hydrogen-specific requirements for the construction of new gas infrastructures and the expansion of existing ones. It also sets out a procedure for determining the suitability of the gas infrastructure or a section of the gas network for operation with hydrogen or hydrogen-containing gases. DVGW reference sheet G 221 was published in December 2021.

CONVERSION OF GAS NETWORKS The changeover from the 2nd to the 5th gas family, namely to hydrogen, breaks the status quo. The resulting substantial change requires testing by experts, qualified persons and/or persons qualified to carry out inspections. The tests required are specified in the respective DVGW reference sheets for the gas. If the network section falls within the applicability of the German ordinance for high-pressure gas lines (Gashochdruckleitungsverordnung, GasHDrLtgV), tests and inspection tasks are to be performed by an expert or qualified person who, similar to

Fig. 2: Safety shut-off valve in accordance with DVGW Arbeitsblatt G 491 to prevent unallowable increases in pressure level in the PtG plant in Falkenhagen [Source: Dr. Klaus Steiner]

the case with new building projects, will write a summary of the performed checks (gutachterliche Äußerung), which ought to be sent (Anzeigepflicht) to the responsible local authority for complete approval.

The new EnWG law states that the responsible authority ought to be notified if a gas network is being converted for hydrogen. The operator needs to send with this the written summary from the inspector approving the suitability of the network section. To what extent the written summary required by the EnWG is identical with that required by the GasHDrLtgV after the substantial change in its application range must be clarified for the specific case with the authority.

A roadmap with flowchart for the conversion of gas network sections to hydrogen has recently been published [1]. The flow is based on the requirements in DVGW reference sheet G 221 and indicates the necessary steps.

GAS APPLIANCES AND GAS APPLICATIONS Reference sheet G 655 from December 2020 expands on G 221 to include pressure ranges < 1 bar. It sets requirements for the planning, erecting and operation of gas applications and filling facilities such as refueling stations for hydrogen-containing methane-rich gases of the 2nd gas family with up to 20 percent hydrogen content. It expands the technical and safety requirements to include hydrogen-specific conditions for points of transfer to end customers as well as for industrial and business end applications and refueling stations. It furthermore describes the requirements for persons, companies, construction components, materials, laying, gas appliances, setup, combustion air supply, exhaust gas routing and adjustment or conversion of household gas appliances.

HIGH-PRESSURE LINES FOR HYDROGEN The planning and erecting of steel high-pressure gas lines in accordance with DVGW Arbeitsblatt G 260 proceeds according to DVGW Arbeitsblatt G 463. New in the version from October 2021 are the fracture evaluation methods for high-pressure gas lines for the transport of hydrogen or hydrogen-containing gases. With it, the potentially greater crack growth compared with methane and that with regular changes in operating pressure can be evaluated.

Reference sheet G 409 from September 2021 builds on this methodology to evaluate and specify the suitability of gas lines made of steel pipes with welded joints for the transport of hydrogen. Taken into consideration are in addition to cyclic strains, also the gas quality, suitability of the materials, required wall thicknesses and status information from maintenance, among others. The reference sheet can also be used, where appropriate, for operating pressures under 16 bar and for determination of the suitability of a line for operation with hydrogen-containing gases with hydrogen content over the limit set by the operator.

GAS PRESSURE REGULATING STATIONS AND PRESSURE VESSELS The application range of reference sheets G and G 498 were expanded in the April 2020 and March 2021 versions to include hydrogen-containing gases of the 2nd gas family and hydrogen of the 5th gas family. These specify, among other things, air tightness tests, settings and response setpoints for safety shut-off devices, requirements for explosion safety, and hazard assessment for facilities for operation with hydrogen-containing gases or hydrogen.

Experts and qualified persons inspecting these facilities to be put into operation are to primarily test whether during operation the safety measures to fulfill the safety criteria of the applicable technical rules and norms are suitable and sufficient. The inspector has to certify the effectiveness and the testing of the protective measures. Detailed descriptions of the tasks can be found in reference [2].

With the revisions and first publishings of the essential reference sheets, the DVGW has expanded the regulatory framework to include the use of gas networks for the transport and distribution of hydrogen-containing gases and hydrogen. The regulatory framework can more effectively guide future projects in the gas sector involving the transport and distribution of regenerative gases and thus support Germany's climate protection goals. ||

Literature:

[1] Steiner, K.; Drews, D.; Schrader, A.: Umstellung von Netzabschnitten auf Wasserstoff nach dem DVGW-Merkblatt G 221: ein Vorschlag für ein Programmablaufdiagramm;
Teil 1: energie | wasser praxis 1 (2022), S. 16-23
Teil 2: energie | wasser praxis 2 (2022), S. 14-19

[2] Steiner, K.; Bode, A. und Schrader, A.: Wasserstoffspezifische Abnahmen von Gasdruckregelanlagen durch Sachverständige – die Umsetzung des DVGW-Arbeitsblattes G 491, Anhang O; energie | wasser praxis 4 (2020), S. 22–29

Author:
Dr. Klaus Steiner, Erdgas & Verwandtes, Bochum
→ Klaus-christoph.steiner@t-online.de

Category: Development | **Author:** Eva Augsten

NEW MOLECULE STORES ENERGY FROM LIGHT

Photochemical hydrogen generation

Fig.: In this photoreactor, the research team succeeded in storing light energy in their newly developed molecule [Source: Heiko Grandel]

Instead of by electrolysis, hydrogen can also be produced photochemically. A research team at Universität Ulm has developed a molecule that stores energy from light by holding onto electrons released by another molecule. The hydrogen can then be produced with this stored energy at a later time as needed.

The new molecule is a type of covalent photosensitizer–polyoxometalate (PS-POM) dyad. Dyad means that the compound fulfills two functions: one part of the molecule is responsible for the transfer of electrons and another part stores the energy. The exact name of the molecule does not appear in the publication. "The name would be about four lines long," explained Dr. Sven Rau of the Institut für Anorganische Chemie der Universität Ulm (institute for inorganic chemistry at the university Universität Ulm).

The substance is liquid at ambient conditions, which makes storage easier. If you bring it together with a substance that emits electrons when exposed to light, each storage molecule takes up two electrons. If the substance is stored in the dark and in the absence of air, the molecules retain the electrons and don't release them until positive hydrogen ions (H^+) are added. This can be done for example with an acid. In the experiment, the researchers used sulfuric acid.

The hydrogen ions react with the stored electrons to form hydrogen. The reaction of the storage molecule is reversible. This means that it can be charged and discharged with electrons again and again. The research team was not only the first to show how the hydrogen can be produced with the help of light, they could also control the timing of this reaction in such a way that it can be used for energy storage.

The next steps entail some optimization work. For example, the efficiency so far is still very low. "We have shown that it works. Now we, and all other scientists, can increase the efficiency," said Rau. "In addition, a number of the loaded molecules react prematurely, and according to a yet completely unknown mechanism," he said. In the first experiments, one sixth of the stored electrons were lost within 150 minutes. However, Rau thinks storage for days or weeks is possible, "in principle also longer."

The to-do list also includes the search for a suitable reactor design as well as for sustainable and cost-effective reagents. For example, instead of the nitrogen compound now used, an alcohol could be used as an electron donor. Or in the far future, even water, which could directly supply the H^+ ions.

Although this temporary energy storage technique is unique, researchers from Ulm are not the only ones looking for a photoelectric route to hydrogen. The Helmholtz-Zentrum Geesthacht, for example, is working on an artificial leaf. What all methods have in common, however, is that they are still in the laboratory stage. ||

Category: Development | **Authors:** Julia Barisic, Christian Geml

SUSTAINABLE USE OF UNUSED HYDROGEN

Hydrogen recycling at DHBW Mannheim

While hydrogen's deployment as an energy carrier is only in its infancy, this element already forms the backbone of many different industrial processes around the globe. In order to ensure hydrogen feedstock is handled as efficiently as possible, the ELCH electrochemical research cluster at DHBW Mannheim university is carrying out a pioneering joint project which is looking into hydrogen recycling by means of electrochemical compression. The focus of the EH2C project is on recycling hydrogen that accrues during the production of solar cells and other semiconductors.

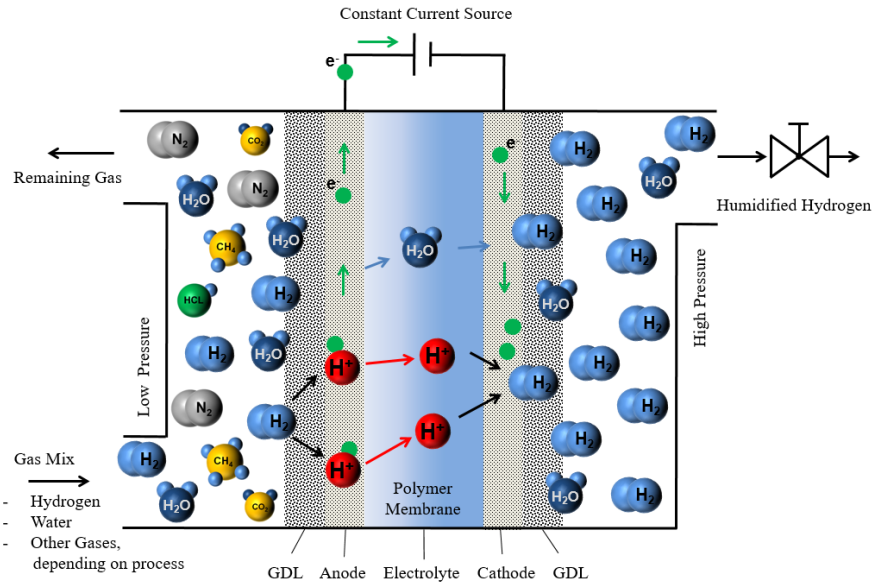


Fig. 1: Schematic layout and operating principle of an EHC [Source: DHBW Mannheim]

Unusually for a German scientific institution, DHBW Mannheim has its own hydrogen and fuel cell laboratory, situated at its Eppelheim campus, with an electrochemical hydrogen compressor or EHC, making it an ideal base for the research project. The EH2C initiative is, in fact, a follow-up to the Horizon 2020 project known as MEMPHYS which succeeded in developing a system to purify and compress hydrogen.

EH2C now takes this method four levels higher in terms of technology readiness, meaning that the process could be adopted by industry very soon. The research team, led by Sven Schmitz, is concentrating on one specific use case: the hydrogen that arises during the manufacturing of solar cells and other semiconductors.

Up until now, this gas has been either diluted with air or released into the atmosphere through combustion – without being utilized. In Europe alone, this equates to several thousand tons of hydrogen a year. In addition to a detailed viability analysis, EH2C plans to optimize the electrochemical compressor to make it possible to filter hydrogen out of the waste gases from semiconductor production and compress it in order to facilitate its reuse.

BONUS FOR PHOTOVOLTAIC AND SEMICONDUCTOR MANUFACTURING

Hydrogen is often used as a carrier gas, particularly in photovoltaic and semiconductor production. Its role is to convey various precursors and byproducts through the processing plant. Achieving a high-quality end product requires a high level of hydrogen purity which has an impact on operating costs. Being a carrier gas means that the hydrogen itself is involved only to a small degree, if at all, in the chemical reactions occurring within the processing plant and is therefore still present in large quantities in the waste gas emitted. Given the huge production volumes in these sectors, which are continuing to experience strong growth, gas recycling offers enormous economic and ecological potential.

FLEXIBLE, SCALABLE AND RELIABLE

The technical challenge when recycling hydrogen in the semiconductor industry is the number of small- and medium-sized production plants involved. Traditional reprocessing methods, however, are only designed with large-scale recycling in mind, making it relatively uneconomical to scale down. The compact and modular form of the EHC recycling system purifies both small and large waste gas flows and is therefore suitable for a broad spectrum of manufacturing facilities. What's more, the composition of the waste gas and thus its hydrogen content can vary widely depending on the fabrication method and the particular process step. Here, too, this particular recycling system is the right answer since it adapts well to the changing circumstances and guarantees a consistently high purity level.

HOW THE EHC WORKS The EHC has a similar design to a fuel cell with a polymer electrolyte membrane. In the compressor, hydrogen is split catalytically on the anode side into electrons and protons. The released H+ protons are carried through the membrane while the electrons flow via the electrically conductive components and the external electrical circuit to the cathode where the protons are further reduced and recombine into molecular hydrogen. This process works highly selectively for hydrogen and needs only a comparatively small amount of energy. Other constituents of the anode gas are not affected by the transport mechanisms and are removed from the system. Consequently, the purification and pressurization of hydrogen is able to take place in one step. Operation can be easily controlled and can be optimally adjusted to suit the continuously changing composition of the waste gas from processes in the semiconductor industry.

EHC technology provides a flexible and efficient method for recycling hydrogen and presents a way to achieve more profitable and, above all, sustainable industrial production through a careful use of resources. As such, the technology offers considerable advantages on several levels – not just in eco-

Strong team from academia and industry

The process is set to enter the demonstration phase within the two-year period of funding from the German economy ministry and will enable the partnering companies to gain an immediate benefit with recycling rates of at least 75 percent. At the same time, the project will supply key knowledge about the application of the recycling process in this and other areas – a process that would be ready to deploy as soon as hydrogen establishes itself as an energy carrier.

A team of experts from a variety of sectors has assembled to support this cutting-edge scheme. The initiator of EH2C was centrotherm clean solutions – a company with global operations that focuses on treating waste gases for processes in the semiconductor and photovoltaic sectors as well as related coating processes. Meanwhile, the university brings to the table not just infrastructure but also scientists from the ELCH electrochemical research cluster: Sven Schmitz along with academic colleagues Christian Geml and Kai Tornow have extensive practical expertise in electrochemical hydrogen purification, having clocked up several thousand hours of operating time on the electrochemical compressor between them. Another member of the project team is associate partner HyET Hydrogen – the highly experienced manufacturer that makes the EHC. Further project partners in the shape of Fraunhofer Institute for Solar Energy Systems ISE, plant manufacturer FCT Systeme and AZUR SPACE Solar Power also bring to the project many years of combined know-how in production processes in the coatings and semiconductor industries.

Fig. 2: The EH2C team: Kai Tornow, Sven Schmitz and Christian Geml (from left to right) in the hydrogen and fuel cell lab at DHBW Mannheim

logical terms – compared with previous alternatives. Besides the application of hydrogen recovery in industrial plants, the EHC's operating principle can also be used in other domains, thereby accelerating developmental progress, for instance in transportation and building technology as well as the storage and distribution of hydrogen.

FROM FEASIBILITY STUDY... The basic feasibility of recycling hydrogen from industrial waste gases has already been proven through several precursory projects with an EHC on a laboratory scale. EH2C will now investigate the setting up and commissioning of a pilot plant on an industrial scale. The facility will be used to purify and compress hydrogen specifically from different industrial waste gases before reutilizing it in the same process. This will allow recycling rates of at least 75 percent to be reached, enabling the quantity of new hydrogen purchased to be significantly reduced.

The system is being integrated into representative manufacturing facilities for the semiconductor sector in order to test its functionality under real conditions as well as to explore the effects on the production plant and the products themselves. As a result, it is expected that this proof of concept will demonstrate the feasibility of the technology in the field – something that is vital for its acceptance among potential industrial users. In addition to the technical evaluation, the financial assessment is also extremely important. This will determine how widespread the technology will later become in the branches of industry under investigation and more generally. The biggest influencing factor is the price trend for renewably manufactured "green" hydrogen.

"The subject of recycling normally only comes to the fore at a later point in time. We're looking to the future right now. We're optimistic that our process could be deployed in the first few companies within two years. At the same time, we're delivering a solution that can be used immediately when hydrogen as an energy carrier becomes market ready."

Sven Schmitz, project leader at DHBW Mannheim

... TO OPERATIONAL TESTING While measuring work will be carried out at DHBW Mannheim, the recycling system pilot plant will be commissioned and operated at the testing room at centrotherm clean solutions. Here, the objective is to cooperate with project partners to further optimize the functionality and interaction of all components and prepare them for the conditions that will be encountered at semiconductor manufacturing facilities. In the next step, the pilot plant will be integrated successively into various processing plants at Fraunhofer ISE and at FCT Systeme so as to evaluate the effects of hydrogen recycling – both on the day-to-day running of the plant itself and the manufacturing results – using wide-ranging methods of analysis.

Besides monitoring the quality of the product, the project will also examine the long-term stability of the recycling process. In this case, DHBW Mannheim will be responsible for on-site measurements, particularly those concerning the EHC subsystem, with the aim of producing the best possible technical and financial results. Project partner centrotherm clean solutions will also help DHBW to assess the measuring data which will be used to create resource and energy audits and the viability analysis as well as possibly to improve the operational strategy. It is hoped that the insights gained and the pilot plant itself will form the foundation for subsequent product development. ||

Authors:

Julia Barisic, DHBW Mannheim, Mannheim → julia.barisic@dhbw-mannheim.de
Christian Geml, DHBW Mannheim, Mannheim → christian.geml@dhbw-mannheim.de

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

THE HYDROGEN TRAIN IS RAPIDLY PICKING UP SPEED

Stock analysis by Sven Jösting

At the stock exchange, you may get the feeling that all companies dealing in fuel cells and hydrogen technologically and as a business model are one group moving in parallel, as expressed in the trend of their stock prices. However, this is far too undifferentiating, because the companies rely on completely different business strategies. One builds filling stations for hydrogen and produces electrolyzers (e.g. Nel, ITM, Plug Power, Bloom), while another produces fuel cell stacks and modules (e.g. Ballard Power, PowerCell, Cummins, Weichai Power).

Some providers focus on specific applications, others offer multiple solutions so as to be a one-stop shopping partner like, for example, an OEM that sells complete FC powertrains for various fields of use. Then, there are the providers of solutions designed to produce electricity and heat via fuel cells or to produce hydrogen on site (e.g. Bloom Energy, Enapter, FuelCell Energy). Or to trade hydrogen as a commodity (e.g. Plug Power, Bloom Energy).

Then, there are the large industrial groups that are either active in the large-scale production of hydrogen across the color spectrum (e.g. Linde, Air Liquide, Air Products) or see themselves as plant manufacturers. A business model might involve total solutions for the manufacture and distribution of clean energy, from the (electrolysis) stations for producing hydrogen to the FC power plants to generate electricity and heat, where the networking of regenerative energy sources with hydrogen takes place (also via CHP) and is conducted by a single provider (e.g. Siemens Energy).

In addition, there are new business models based on development of unique, perhaps proprietary technology, software or hardware to capitalize on hydrogen as a consumable, similar to ink in toner cartridges for printers (e.g. Bloom Energy, Plug Power, Nikola Motors).

Of course, service and maintenance contracts are also associated with high profit margins, and can run over the entire lifetime of the hardware (e.g. Nikola Motors, Hyzon Motors, Hyundai). In addition, there are a large number of supplier companies that, for example, produce H_2 tanks or contribute other important units such as compressors, valves, pumps or sensors. There are numerous players here for various tasks, including blending in gas grids and transport of green ammonia or green methanol. These are all specialists in different areas, from electrolysis to the production of fuel cell stacks (e.g. Bloom Energy, Dräger, Burckhardt Compression).

The different turnover potentials with correspondingly varying profit margins are what distinguish all these companies from one another. A lot of money can be earned selling "hardware" such as FC trucks, but in the end much more if a running supply of energy, H_2, can be delivered in parallel. And this could be offered as a full package – possibly following a pay-per-use model based on the hardware as well as the self-produced or purchased hydrogen.

It is clear that all these companies will benefit from the ramp-up of the megatrend hydrogen and fuel cells. However, the profit margins do vary considerably, especially as the competition and opportunities dramatically increase – all around the world. Some business models end or change when, for example, the fuel cell is already permanently installed in the hardware (forklift) and no longer needs to be or can be retrofitted (Plug Power and Ballard Power as stack providers).

Ultimately, the provider has the say and can make the best possible offer to the customer/buyer, which can be expressed in terms of the price per kilogram of hydrogen or, for an FC product, in the total cost of ownership (TCO) (e.g. Bloom Energy, Plug Power, Linde, Air Liquide, Air Products, Shell, BP). Similarly, most suppliers can be expected to benefit from the sheer size of these new markets around fuel cells and hydrogen. Consequently, there are already many mergers, joint ventures, cooperations and even strategic acquisitions – normal for a new market that is being newly defined and is at the beginning of its ramp-up.

To respond to climate change technologically and to ensure the energy supply, strong efforts – worldwide – are crucial. Only on the stock exchange could (will) there be some differences in the valuation of the individual listed compa-

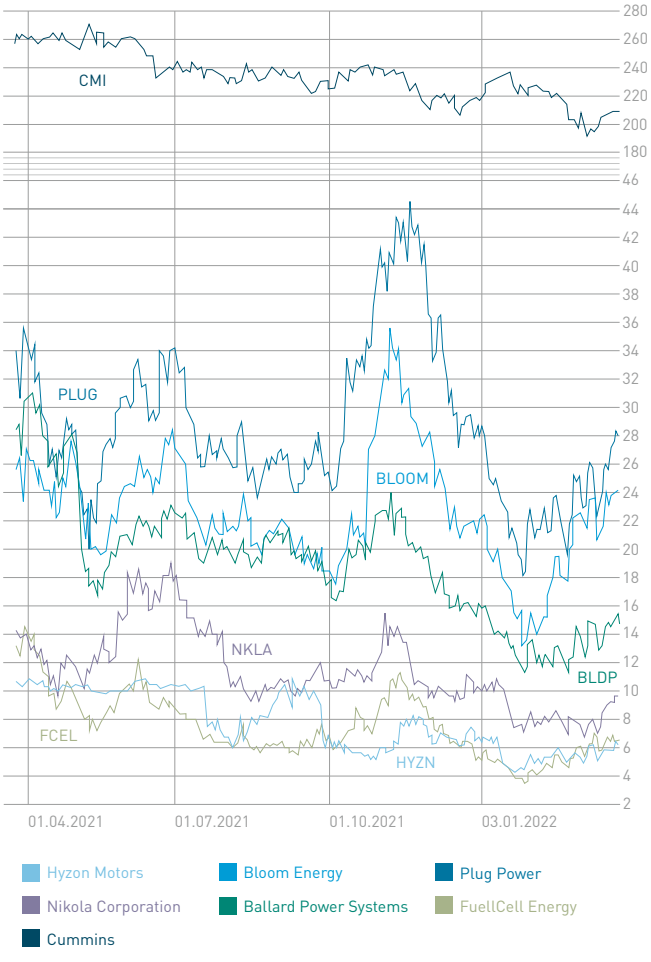


Fig. 1: Share price development of the companies discussed [Source: www.wallstreet-online.de] Stock prices on March 25, 2022

nies – depending on the respective growth and profit expectation based on the respective margins.

The parallelism in the price developments of the shares concerned here will start to become less pronounced this year, so expect large divergences in price development. Those who win over the most (have the most profit, new orders, new technologies, etc.) will also be the most rewarded by the stock market – through higher share prices.

H_2 PROFITS FROM THE CRISIS

Unfortunately, it must be stated so: the global increase in the price of oil and gas or LNG, which is also fueled by Russia's bellicose actions here in Europe, is beneficial for the ramp-up of the hydrogen economy, since at the end of the day, aside from climate and economic policy issues and price, it's about the ensured availability and delivery of energy. So there is a winner in this crisis: hydrogen – green hydrogen.

Because hydrogen is set to become a new commodity, a tradeable good, in more and more regions of the world. And in large quantities, for better and better negotiation conditions. It is therefore growing into a serious competitor of the battery, since the raw materials for such are becoming scarcer and more expensive, as is the price for electricity. Its assumed advantages, lower costs for travel, are increasingly losing meaning.

The current crisis situation is letting investments in hydrogen – production, warehousing, transport, markets – rise dramatically, where much still needs to be done before a sufficient guarantee of availability is reached. In a sense, the markets around hydrogen and fuel cells have been dealt a favorable hand, which in turn benefits the shares of the listed companies in this industry.

ENERGY PRICES SKYROCKET On the stock market, the first few months of the year have produced only very weak share prices for the listed companies discussed here. Nevertheless, there have recently been noticeable upward trends again, even if the solid prices from the beginning of 2021 – still – seem very far away. Some short sellers have also made their contribution to this and additionally depressed weak prices. This is now coming to an end and the direction is finally changing, as the companies are very well positioned and publish thoroughly satisfying news with respect to their growth prospects, new products, partnerships and JVs, and above all, strongly increasing influx of orders for their production sites (e.g. stacks, electrolyzers).

While the shares of oil companies in particular rose sharply because of the skyrocketing energy prices, this group has the potential to be replaced by those of the hydrogen economy in the long run. However, it should be added that at the same time very large corporations from the fossil industry (gas and oil) have recognized hydrogen's potential and have massively invested in this area, since hydrogen will replace oil and natural gas, even though this could still take many decades. The journey is the destination.

MARKET MOMENTUM PICKS UP – WORLDWIDE Daily, reports come in about new major projects and initiatives in countries all over the world involving the production of hydrogen, especially the green kind. In addition, countries such as India have now also announced very ambitious hydrogen programs. This year, 26 nations are to publicly share their country-specific H_2 strategy or news about their implementation. In 2021, it was already 21.

Major Indian corporations or the largest business conglomerates there, like Reliance, Adani and Tata, plan huge investments in hydrogen topics in amounts of tens of billions of dollars. Joint ventures (for now MOUs) like that between Adani and Ballard Power will surely be followed by others. It feels like a race in which everyone will participate and benefit equally. After all, we are talking about a new megatrend that also counteracts climate change – using market-based instruments to offset existing uncertainties in oil and gas production. Hopefully a win-win-win situation. India predicts that in a few years, it will be able to produce hydrogen at an export value of 500 billion USD per year (5 million tonnes per year) – at prices of 1 to 2 USD per kg.

Perfect conditions like strong sun or wind intensity paired with expansive areas of usable land as well as connections to water – sea water that can be desalinated – are the perfect mix for producing very large quantities of hydrogen. For the transport, new types of ships are emerging that will take hydrogen in the form of ammonia or green methanol across the world, if putting hydrogen (blends) into an existing gas grid is not an option.

There are also completely new transport media, for example a zeppelin, the H2 Clipper, developed in California, which not only runs on but transports hydrogen. Hydrogen critics, who like to use the stereotype of the Hindenburg as an argument against this technology, will have to think about this anew and may even be appalled. But new technologies also allow for completely new approaches.

All these hydrogen projects to be announced by their countries are extremely exciting. No one wants to be on the sidelines anymore. They want to belong to the group of frontrunners. For some, it's about new revenue streams. For others, it is a means to the goal of decarbonization as well as for the creation of new industries, products and markets. In my opinion, on the stock exchange, the train of companies discussed here and their shares are now really picking up speed and will emerge from this period of weakness even stronger. In detail:

BALLARD POWER – THINK OUTSIDE THE BOX!

Fig. 2: Gautam Adani [Source: Adani]

The company is about to enter a phase of exponential, long-term growth, is my interpretation of the earnings call on March 14, 2022 regarding the 2021 annual figures and the fourth quarter. Year 2023 should really start off with Ballard reaping the fruits of years of intensive research and development, various pilot projects and building up production capacities. The Canadian company is working on scaling production capacity in the target markets bus, truck, rail and ship. But that doesn't happen overnight.

On the 2020 investor day, Ballard estimated the volume of this global market to be worth 130 billion USD until the year 2030. Now the talk is of 250 billion USD, as conditions for fuel cells and hydrogen have drastically improved.

BUSES, TRUCKS, ETC. The Canadian company is now expecting individual orders for bus stacks to number 100 or even several times that. There are now cooperations with Wrightbus, Van Hool and Solaris in Europe, New Flyer, among others, in the US, Tata in India and Global Ventures in New Zealand. Somewhat of a paradigm shift can be discerned, since instead of battery-electric buses, hydrogen-powered buses are now increasingly chosen. For example, TC Transit in the USA had initially decided on 70 percent battery-electric and 30 percent fuel cells, but now wants the reverse. A large Californian bus fleet operator is even set on 100 percent hydrogen. This trend might spill over into trucks, as a result of emissions legislation, or ships and rail as well.

Following the first three regions, the provinces Shanghai, Peking and Guangdong, China has now announced special funding programs for hydrogen and fuel cells in four more. Ballard is represented in these new regions through the JV with Weichai. It is now able to equip 20,000 buses per year with FC stacks – the world's largest stack and bipolar plate production in the world. Each of these regions is planning to put 5,000 to 10,000 H_2 vehicles, primarily buses and trucks, on the road. One million in total are to be moving about China by 2030.

MOU WITH THE ADANI GROUP OF INDIA Ballard has signed a memorandum of understanding with Adani, one of the largest business conglomerates in India, which opens the door for establishment of a joint stack production in the country, but also makes many further business relationships possible. Will the group with market cap of over 150 billion USD directly join forces with Ballard, like Weichai has, in a joint venture? CEO Randy MacEwen has already directly and personally met with CEO and company founder Gautam Adani – nothing more to it.

In addition to energy production (see Bloom), Adani is active in maritime transport as well as rail transport and operates ports, airfields, bus and truck fleets, and transmission networks. The corporation specially founded the subsidiary Adani New Industries for the intersect with hydrogen. Maybe something concrete has already been started by the time you read this report here. Adani is planning investments around 70 billion USD in regenerative energies within the next 10 to 15 years, especially in hydrogen, with a goal of being able to produce 1 kg_{H2} for 1 USD.

Ballard is also working with the Indian company Tata Motors on, for example, FC stacks for buses and some pilot projects. Ballard has also reported various technological breakthroughs, whether with Chart Industries in liquid hydrogen or with ABB in FC systems for ships (multiple successful series of tests and certification).

FIGURES AND OUTLOOK The fourth quarter of 2021 saw a 28.3 percent increase in turnover to 36.7 million USD, with a higher than expected loss of 0.15 USD per share, which was due to high investments in R&D. The annual turnover reached 104.5 million USD and was thus at the previous year's level. A loss per share remained of -0.39 USD. For the current year, substantially higher investments of 10 to 60 million USD are expected to be applied, to production capacities, test centers and acquisitions, among others. At the same time, operating costs will increase by between 140 and 160 million USD, which is linked to the planned expansion of the company. With a good 1.1 billion USD in the bank, Ballard can very well finance all this itself.

I'm betting on extraordinary developments, e.g. JVs, shareholdings (Adani?) and large orders. Time is needed for these key investments in fuel cells. The proper ramp-up is predicted to occur in 2023. With share values around 10 USD (from 3 USD two years ago and over 40 USD at the beginning of 2021), these are of great interest for mid- and long-term investment.

BLOOM ENERGY – GROWTH RATE ACCELERATES

What an outstanding view K. R. Sridhar, CEO of Bloom Energy, describes: Bloom is on track to achieve annual growth of up to 35 percent instead of the previous 25 to 30 percent, as the company is optimally positioned – technologically and in terms of business model – in H_2 energy markets around the world.

The stock market also sees it this way. This quarter, the share price went from under 14 USD to over 22 USD, so it can be said that the value will reach 24 USD within the beginning of this year, although it was already at 44 USD at the beginning of 2021. What is clear now, however, is that we are dealing with a price turnaround, which will be based off new forecasts and pushed by the very high (crisis-related) prices for natural gas and oil. Short sellers will have a harder time of it, as they were certainly involved in driving the price down so much in the first place. In the beginning of March 2022, over 18 million shares were sold short. At the end of 2021, it was under 14 million.

ON TRACK WITH COMPANY FIGURES The figures for the fourth quarter of 2021 came out better than expected: 342.5 million USD turnover, an increase of 37.3 percent from the fourth quarter of 2020. The bottom line, (non-GAAP) a net loss of 0.05 USD/share in the last quarter of the year – minus 0.19 USD/share (GAAP). Note that the last figure takes stock-based compensation into account, so shares that were bonuses for employees are included in the mathematical result.

Turnover reached 970 million USD and is expected to rise to 1.1 to 1.2 billion USD this year. Current orders total 8.5 billion USD. In the bank lies around 615 million USD, 250 million of which I think will flow into the second tranche of Bloom's work with SK ecoplant in the course of the year. Word is that they are well on the way to generating a positive cash flow from now on until the end of the year – the fourth quarter of 2021 already indicated this. The transition to profitability is therefore only a matter of time and could see its start in 2022.

FROM 4 TO 20 BILLION USD TURNOVER IN 10 YEARS Bloom Energy has the target turnover of a good 4 to 5 billion USD in 5 five years, and 15 to 20 in 10 years, according to the CEO and company founder K. R. Sridhar. Those are the ranges of turnover size, minimum and maximum, Bloom predicts. In its view, the company is – in a way – in a leadership role, whether through the technology or the business model. They have reached a very positive "exciting inflection point" and are preparing for very high long-term growth.

Fig. 3: Bloom Boxes at the SK Group [Source: Bloom]

This will involve high investments in proprietary technologies, expansion of production capacities, cost control and margin widening. In addition, top talent was recruited for the management. One of the major customers that knows how to support this vision is T-Mobile, which will equip several locations (data centers) with Bloom's technology. In South Korea, the planned 450 MW of clean energy from FC power plants could also be considerably expanded.

SUCCESS WITH PARTNERS In addition, the FC manufacturer is working on sophisticated carbon capture technologies that enable CO_2 emission to be stored or processed, in case natural gas is to be employed until hydrogen can take over. Capacities now need to be adjusted to the high order intake, which means (forecasted) that growth is likely to remain subdued (40% share) in the first half of 2022, but then gain momentum in the second half of the year (60% share), and that the final result for the year as a whole will end up being very positive.

Capacity now stands at 2 GW of new energy output per year. Other exciting markets include ship transport, where Bloom has developed fuel cell systems for LNG tankers, which should number 1,000 by 2030. Here, high growth through the conversion of existing ships (retrofit option) can also be envisioned. The first steps in cruise ships (see p. 43 and H2-international blog) have been made with MSC Cruises.

Bloom itself states that it is a leader in electrolysis, as its own SOFC devices are "45 percent more efficient than PEM and alkaline electrolyzers" of the competition. This is expressed in a lower electricity requirement, which eases the production of high H_2 volumes. It is important to note that for all types of electrolyzers, the price at which one kilogram of hydrogen can be produced is a crucial factor. The purchase costs for the electrolyzer as well as the required amount of electricity and its price play an important role here.

Bloom is also relying here on Heliogen, a company that has developed a technology that focuses strong solar rays like a laser and then produces the hydrogen using SOFC fuel cells in so-called energy towers. Together, the two companies are planning to set up the first production facility in La Paz County in Arizona. Specifically the Brenda Solar Energy Zone, which is located on a major gas pipeline.

20% MARKET SHARE IN ELECTROLYSIS In addition, Bloom is active in the Phoenix Metropolitan Area and the Port of Los Angeles, from where it wants to transport hydrogen by ship. The target is an annual production of 20,000 tonnes of green hydrogen. There will certainly be more to follow.

Bloom expects to be able to get 20 percent of the global electrolyzer market in the long run, which is a huge amount if you consider the IEA's figures indicating that electrolysis capacities will increase to 40 GW by 2030. There are predictions (Linde) that the global electrolyzer capacity market will rise to a value of 150 billion to 1 trillion USD by 2050, far more than prior forecasts. Bloom plans to develop 2.4 GW of electrolysis capacity of its own by as soon as 2023. Bloom expects a price of 1.50 USD per kg green hydrogen by 2030. Impressive numbers!

SOCALGAS PLANS 10 TO 20 GW BY 2030 Bloom is also already in business with SouthernCaliforniaGas. Theirs is about blending hydrogen in natural gas lines. The company plans to cover 25 percent of its gas production with hydrogen in the future. The talk is of 10 H_2 projects involving 10 to 20 GW of electrolysis capacity in total. Three million gallons of diesel per day are to be replaced by hydrogen. This would be

> "Yes, I said 15 Billion US-$ or greater. In many ways as the industry transforms, we are in a category of our own with growing revenue, margin expansion, strong backlog, and the best most innovative solutions to customers who want a low carbon and resillient power today and zero emissions energy tommorrow."
>
> *K. R. Sridhar, CEO Bloom Energy*

the largest green hydrogen infrastructure project in the US and would be designated "Angeles Link," as it relates to the Greater Los Angeles Area.

Meanwhile, in India, a comprehensive funding program for ramp-up of the H_2 economy there is in the planning phase. NHPC, the government-owned and largest utility provider, plans to get 10 GW of new regenerative energy in the works – hydrogen is considered an important component. Bloom is engaged there as well – on the first hydrogen-based micro-grid. A solar farm will be used as regenerative energy for production of the hydrogen, to make energy available 24/7. The Indian energy ministry is also involved.

Billion-dollar Indian companies, or their conglomerates, like Adani, Tata or Reliance, have announced project volumes for renewable energies and hydrogen that each are in the high tens of billions range (see Adani, who recently signed an MOU with Ballard). The Adani Group, which is also involved in gas pipelines as well as the world's largest solar park, alone wants to invest 70 billion USD in the next 10 years. According to my own assessment of the situation, and that only, there's a good possibility that a cooperation with Bloom will come about. Bloom's CEO, Shridar, is Indian by birth.

Last but not least, together with the MSC Group, Bloom has equipped the ship MSC World Europe with an SOFC fuel cell system that will first run on LNG, but later on hydrogen. Initially, 60 percent of CO_2 emissions and 100 percent of other emissions and particulates will be reduced. MSC is now the third-largest cruise company and number 1 for transport/container ships, followed by Maersk. One hundred cruise ships are to be built worldwide by 2027 – a big opportunity for Bloom. But also for Ballard, who, with its recently certified PEM FC system, is working with ABB in this space.

Summary: Bloom is developing into a leading company in the H_2 and FC industry, which is already demonstrated by the 2021 turnover of nearly 1 billion USD. With high probability, Bloom will be the first company in this environment to break even and also have above-average growth potential in various markets – worldwide. In addition, the stock possibilities if Bloom uses its own technologies for the production of hydrogen, and thus becomes a producer of raw materials and energy itself, is something to think about. With the commodity hydrogen, it can generate very high profit margins.

INVESTOR DAY IN MAY 2022

In May, an important investor day is taking place. Until then, many investment banks are likely to raise the category to Kauf (buy) or even Strong Buy. After all, the prospects could hardly be better. At least that is my personal assessment.

Bloom has been represented at a variety of industry-specific conferences of well-known investment banks. Current price targets are 27 to 44 USD – so for now a 50% plus upside potential on average. Prices of 100 USD plus in two to three years doesn't sound so unrealistic considering the large global market for clean energy and hydrogen, to address climate change, as well as the situation in the energy markets and the company's own forecasts.

If I were CEO of a company like Siemens Energy or GE, I would stake an interest in Bloom or enter into a strategic partnership to create company-specific uses for their technologies or to scale the current business in this area. Currently, Bloom Energy is valued at scarcely four times its turnover, which is very low for the industry. But the stock market will certainly compensate for this.

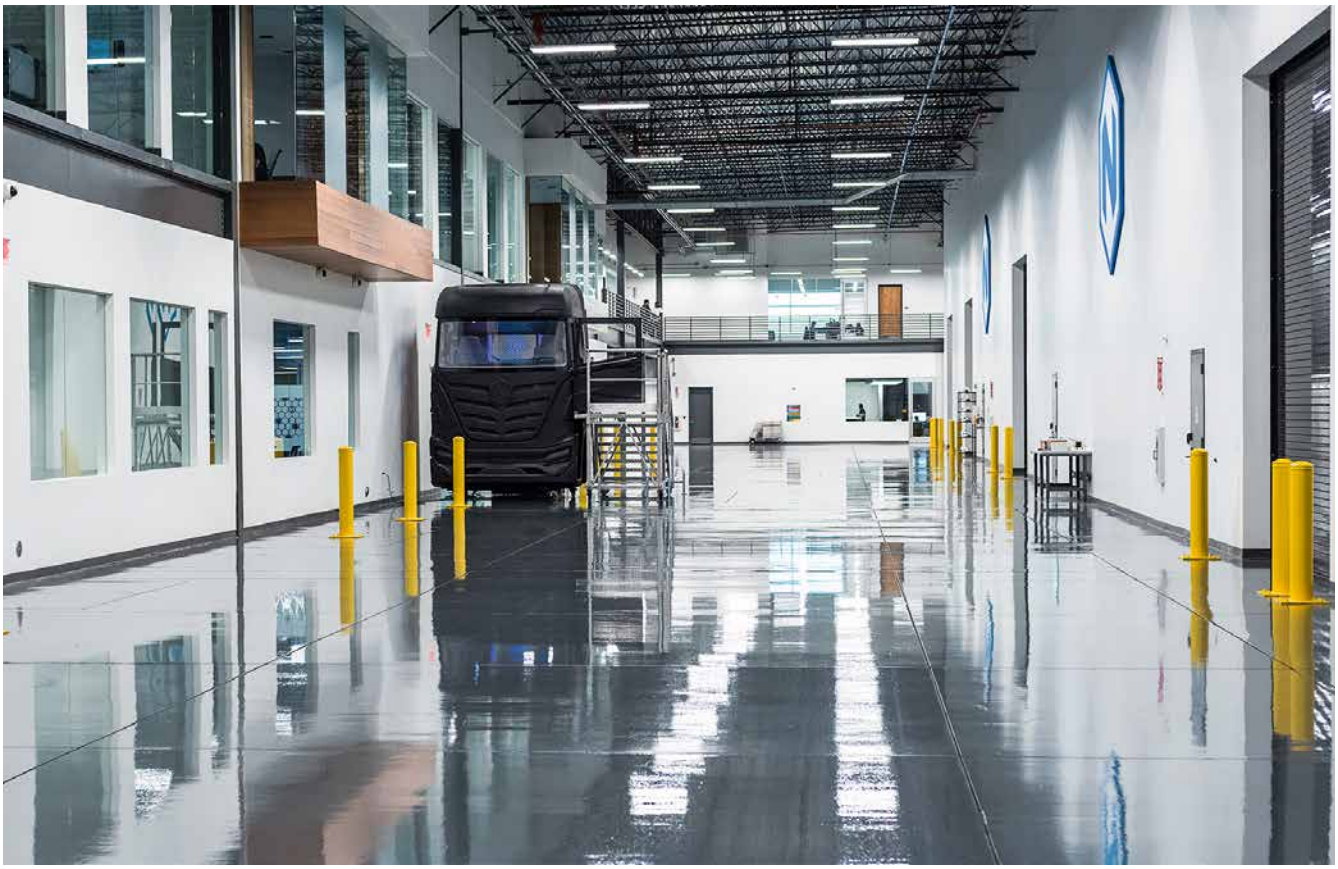


Fig. 4: At Nikola headquarters [Source: Nikola]

NIKOLA MOTORS – THE OUTLOOK KEEPS LOOKING BETTER

Nikola Motors needs to be understood/categorized as a start-up in the process of implementing its business plan. The construction of its factory in Coolidge, Arizona is underway, and the first battery-electric trucks (BEV trucks) are already with customers. This year should see 300 to 500 of these, along with sufficient capacity for 2,400, which should reach 20,000 by 2023. In Ulm, Baden-Württemberg, the number of units produced by partner Iveco is to increase from 2,000 to 10,000.

Turnover for the first operating year (2022) will be 90 to 150 million USD. In 2023, the hydrogen-powered trucks (FCEV trucks), designed for long hauls, will be launched. Nikola is working to provide the necessary amounts of hydrogen for them by building electrolysis capacity and H_2 filling stations. The commercial vehicle manufacturer sees itself well on its way and wants to see hydrogen established as an energy source in its own right, as it would become a long-term revenue source.

During the Super Bowl, two Nikola FCEV truck prototypes drove up to the stadium to deliver beer in an environmentally friendly and also marketing-effective way. So far, Anheuser Busch, via an LOI for 800 FC trucks, is Nikola's biggest customer. Nikola considers a minimum of 500 miles (805 km) long-haul, which its FCEV truck covers. BEVs, on the other hand, Anheuser has been buying from Chinese company BYD. Test series of Nikola's BEVs affirmed that Nikola has achieved the furthest range out of all suppliers in this segment.

Altogether, the North American company now has 1,385 trucks, via LOIs or MOUs, in its books – 375 battery-electric and 1,010 hydrogen-powered. There have been various announcements such as 100 Tre BEVs for Heniff Transportation, to be maintained by Thompson Truck Centers. There are certainly many more to come. In parallel, Nikola is working on mobile charging stations, called mobile charging trailers. Six have already been sold, and orders are in hand for a further six.

Interesting are the subsidy programs of individual US states. In California, there is an incentive of 120,000 USD per battery-electric truck, which could be up to 150,000 USD for special types. A similar program is on the way to New York. Here, there is even talk of an incentive in the amount of 185,000 USD per truck. Before Nikola lies the task of communicating these subsidy opportunities to customers, but also speaking to authorities of different states about how such government subsidies will look, how they will be implemented and what can be expected for hydrogen-powered options.

LEGAL DISPUTE WITH COMPANY FOUNDER MILTON Following the agreement with the Securities and Exchange Commission (SEC) to pay 125 million USD within two years – the first installment has already been paid – Nikola has meanwhile sued founder Trevor Milton for damages. The trial is ongoing, and Milton would have the money to pay compensation to the company if he loses. Yes, he divested over 300 million dollars' worth of shares. But that's a sideshow that does not affect Nikola's operations. It is of course good for liquidity in the event of success.

FIGURES The loss for the year 2021 is a minus of 690.4 million USD. However, if taking into account stock-based compensation to employees, then the minus was only 302.7 million USD. All in line with the expectations and liquidity. As to the latter, 436 million USD is available (after share issue to Tumin/3i). For the end of 2022, a liquidity cushion in the amount of 225 to 250 million USD is predicted. So enough for implementation of the business plans up to the gradual ramp up of production in 2023.

Summary: Nikola is well on track. But short sellers still dominate the action. They've sold 65 million shares short and could think about stocking up if share prices gradually rise with implementation of the business plan. Even the thought of larger orders, such as the potential ones from Anheuser Busch, becoming a basis for the next fiscal year is exciting to investors. Only supply chain problems for parts and batteries could be the cause of delays. Maybe companies like Amazon could give them some large orders that could encompass 1,000 or even 10,000 vehicles.

In my opinion, however, the share price takes into account all the negative aspects, but hardly any positive ones. The pressure on, or requirement of, logistics companies in many regions of the world to switch over to CO_2-free trucks should give weight to Nikola. That means a market of 3 million commercial vehicles in the USA and just as many in Europe. But time needs to be given along with the investment.

HYZON MOTORS – TRUCK ORDERS COMING FROM SAUDI ARABIA?

Things are happening on the analyst and investor front: BlackRock has raised its position in Hyzon Motors. Over 100 institutional investors are already involved. The largest of these is the Saudi Arabian state fund PIF, which holds over 8 million shares. Billionaire Izzy Englander named Hyzon as one of his top three picks and acquired 1.36 million shares.

The average price the analysts at Hyzon expect lies at 13 USD. Goldman Sachs has broken from this with a more recent assessment and for now only assumes 7 USD. The reason for this reluctance is the still missing H_2 infrastructure. However, the hydrogen problem will be solved little by little, as the cooperations with TC Energy (for H_2 production, pipelines) signify. Through these ties, Hyzon's fate is similar to Nikola Motors, but the problem of hydrogen production is addressed.

The first large order, so 1,000+ FC trucks, will be very exciting. Maybe it will come from Saudi Arabia. The country's project NEOM (500 billion USD investment) relies heavily on regenerative energies and hydrogen. One goal is to produce 10,000 hydrogen-powered trucks locally. Among others, Hyzon has been mentioned – but no confirmation as of yet.

Hyzon is also active in the global market for H_2 trucks. Specifically in China, since there is where the biggest growth in the commercial vehicle sector of the H_2/FC industry is envisioned. In Australia, Hyzon has now selected Melbourne as its head office and has already concluded cooperation agreements there. For those who are interested in a closer view of the company's development, there is a shareholder/fan group

Fig. 5: Expected (e) wind power additions per year worldwide until 2030 [Source: Wood Mackenzie, Global Wind Power Market Update: Q4 2021]

on Facebook that provides very detailed reports on all of the company's activities.

Meanwhile, the first major order has come from Holland via LOI. The waste removal corporation Geesinknorba (7,500 trucks throughout the Netherlands, France, Spain and 30 other countries) plans to order 300 FCEV trucks from Hyzon over three years. In the US, a second production facility in Chicago is planned, designed for an annual production of 12,000 trucks. In the UK, the company was able to sign an MOU with John G Russell – one of the five largest logistics companies in the country. First to be worked on is a 44-tonner with specifications specially tailored for the country. Planned is a cooperation with Hyzon in service, repair, distribution and financing (leasing).

Whoever wants to take a chance on the fuel cell in commercial vehicles (trucks) will do right with Hyzon, but should also recognize the opportunity in Nikola. With these two stocks, the market of battery-electric as well as hydrogen-powered trucks is very well covered. However, both companies should be seen as start-ups, so the risk level of the investment and the price fluctuations (volatility) ought to be classified as high – not for conservative investors.

CUMMINS ENGINE HEAVILY SET ON THE FUEL CELL

Cummins Engine is highly committed to the H_2 industry – also in the commercial vehicle sector, starting with trucks and going all the way to ships. The company is also expanding its own electrolysis technologies. A project with Sinopec consists of an electrolysis capacity of 1 GW – 1,000 H_2 fueling stations for the Greater Peking Area. Cummins Engine is vehemently driving its transformation from a diesel engine producer to a fuel cell company and in doing so majorly implementing and scaling the special knowhow of the purchased/integrated Canadian company Hydrogenics (see also Cummins update on p. 7).

The Chinese parallel is Weichai Power, which maintains a joint venture with Canadian Ballard Power and holds a 15 percent stake in it. Both first-tier diesel engine manufacturers are maturing into top fuel cell companies and treat hydrogen as the fuel of the future – especially for commercial vehicles.

WIKIFOLIO BZVISION – BACK TO THE START BEGINNING 2022

Since the beginning of this year, the wikifolio BZVision has fully recovered its loss. Stocks like those of Bloom, Ballard and Nikola came under a lot of pressure (short sellers?). However, there was a noticeable upward movement from mid-February onwards. The crisis around gas and oil as well as their price development naturally plays into the hands of hydrogen.

The three stocks together represent the best mix of companies in the industry for me in terms of business models, markets and products. I sold a put on Tesla – unfortunately a few days too soon, as the shares of over 1,100 USD fell to under 800 USD and the put options had a strike price of 1,000 USD and had nearly doubled in price.

But this chapter is now closed and BZVision is again 100 percent H_2/FC. All the same, the annual return of this fund still comes out to over 35 percent. I expect that there will now be a noticeable upward trend in the portfolio, as the backdrop (see my commentary on each company) could not be better and we may see prices again in the coming years that match or exceed those from early 2021. But this is only one, my, personal assessment, and only that.

SIEMENS ENERGY – STILL IN THE VALLEY OF TEARS

Siemens subsidiary Gamesa still doesn't seem to be out of the woods, looking at the strong loss (minus 627 million EUR) that this company contributed to its parent (total minus of 560 million EUR). Onshore wind is considered a problem area – combined with miscalculations and supply chain issues. For this reason, there is speculation that this subsidiary will be fully integrated or restructured via a share swap, which could be implemented in, among other things, a realignment or even a split-off. A partial merger with a competitor may also be possible.

On the other hand, Siemens Energy can generate great potential in all areas. New gas power stations that are H_2-ready (see p. 10) are becoming increasingly important, just considering Germany's goals alone of shutting down coal-fired power plants as well as nuclear energy. The global demand for electrolyzers should also keep the order books of Siemens Energy full, so the current share price performance ought to be classified under "buy on bad news."

FUELCELL ENERGY – LEGAL DISPUTE WITH POSCO MUTUALLY ENDED

Finally: FuelCell Energy has agreed and settled with South Korean company Posco. FuelCell is now independent from Posco again and can pursue other opportunities in Asia. The company figures of FuelCell Energy are not yet very convincing, given the last quarterly results: a measly 14 million USD turnover. Although there are pending orders of 1.29 billion USD in the books, so far seemingly few new orders are coming in. The cooperation with ExxonMobil was extended once again, but with no new conditions to report.

The balance sheet, however, is in good alignment. FuelCell used the run from about 0.50 USD to over 25 USD in 2021 perfectly and, by reissuing at 8.50 USD per share, was able to take in 360 million USD. So the company is in a very good financial position today: 460 million USD on hand.

Likewise for competitor Bloom, the two programs of the Biden administration amounting to 1.7 to 2 trillion USD present an interesting opportunity. If that comes, then even larger sums will massively secure the supply of energy grids as well as stimulate ramp-up of the hydrogen economy in the US.

NUMBERS RAISE QUESTIONS The first quarter of fiscal year 2022 saw an increase in turnover to 31.8 million USD (previous year: 14.9 million USD). However, included in this is an order as a result of the legal settlement with Posco: six modules were delivered for 18 million USD, and another eight will follow in the course of the first quarter, ending April 30th. At the same time, 24 million had to be borne for legal fees arising from the dispute. The stated loss for the year of 46.1 million USD is considerable, even taking into account the aforementioned (legal) costs.

The company makes use of electricity that it generates itself from FC power plants. So far, this involves 41.4 MW of power, which is sold, recurrently, via PPA (power purchasing agreement). In Canada, FuelCell has started a project with Clean Resources Innovation Network (CRIN) on carbon capture technology. With Exxon, the company has reached a new stage: Exxon is paying 5 million USD but FuelCell Energy is investing the same amount in the project in Rotterdam. About 405 million USD in cash (freely available and restricted) still lies in the bank.

What's missing, in my opinion, is a clear company vision. Perhaps new inspiration will come from Asia. The amount of shares traded daily shows that day traders and also neobroker platforms are very active there. The share therefore is still only for investors interested in an investment with short-term, high fluctuations. If that's the case, prices of over 10 USD will be quickly reachable. Nevertheless, the valuation of FuelCell Energy, 2.5 billion USD, relative to Bloom Energy at 4 billion USD, is very low, which makes purchase in the latter seem much more reasonable.

PLUG POWER – IN THE PROFIT ZONE WITH H_2 PRODUCTION

The plans are huge: three sites are to start production already this year. The first target for the current fiscal year is 70 tonnes of hydrogen per day. This should enable a profit margin of 30 percent. Of this, 40 to 50 tonnes per day are needed for existing activities and 20 to 30 t/day will be brought to market as a tradable commodity, is my expectation.

Here too the subsidies of the American government for green hydrogen (3 USD tax credit per kg_{H2}) might play a role. The production target is 500 tonnes per day for fiscal year 2025 and 1,000 t/day for 2028. Also Plug's cooperation (50/50 JV) with the Australian company Fortescue, founded by Australian billionaire Dr. Andrew Forrest, to achieve an electrolysis output of 1 GW sounds huge and may have a very positive effect on Plug's development, especially since the conditions in Australia, plenty of sun and wind, are perfect. With Forrest, a partner has been gained who gives the topic of hydrogen the highest priority, shows very strong commitment here and meets many superlatives. He wants to become the world's largest producer of hydrogen (see p. 11).

Plug Power is positioning itself to cover the entire hydrogen and fuel cell value chain through strategic acquisitions. For this, the company is developing a number of applications and markets. In addition, Plug plans to make various calls for tender for use of the company's own electrolysis capacity (from subsidiary Giner EXL) worldwide and thus generate revenue from this as well. Furthermore, the North Americans are working on optimizing and scaling the technology and the entire business model.

In the material handling area, for example forklifts, Plug is probably getting several more major US and European customers. In 2030, this segment alone is expected to generate a turnover of 4 billion USD. Smaller customers that need less than 50 kg_{H2}/day are also desirable, for which a trailer/containerized solution might make more sense as the H_2 fueling station. Initially, Plug sees the international portion of the business as 25 percent, but 30 to 40 percent in the long run, which can be seen in various projects not only in Australia, but also in Spain, Egypt, South Korea (JV with SK Group), France, Holland and Germany.

Fig. 6: Project manager Robert Zalinski presented Plugs products at the new Duisburg site

HYVIA – JOINT VENTURE WITH RENAULT In 2022, 250 vans are to be delivered to around 20 customers. The number is to be 250,000 in 2030. Among the buyers was named Amazon, but also taxi fleets. Plug's acquiring of the companies Frames Group, Applied Cryo Technologies (liquefaction of hydrogen) and Joule Processing is certainly expedient, but the time of their integration will tell their true contribution to the business development and corporation.

Summary: With nearly 2.5 billion USD in the bank (plus 1.2 billion USD of available-for-sale securities), Plug can still bear the weight of its ambitious plans itself. However, the extensive investments in production facilities and acquisitions will cause the capital base to melt away before profits are made, so the transition to the profit zone is likely to take a few more years. One billion USD is considered the investment (liquid asset outflow per year), so it cannot be ruled out that more capital will have to be raised by issuing shares, which, in view of the massive increase in the number of outstanding shares to over 570 million in the last two years, might even be seen as critical.

In addition, major orders from customers such as Amazon and Walmart need follow-up. I previously reported on the stock warrants that brought both companies very high profits (billions?). The service contracts of Plug are also triggering questions among analysts (what's the profit margin like?).

The turnover forecasted for this year of over 900 million USD (following the 501.7 million in 2021) sounds huge, but it should be considered in context of the profit margin. With over 14 billion USD stock market valuation, the future already looks positive. High self-initiated losses (investment in production) will still be reported before transition to the profit zone occurs. There could be some disappointment in the period until then. But: Plug is considered a leader in the industry, which is why analysts at major investment banks are expecting share prices of 40 to over 70 USD. Plug is also well-positioned with small investors, as seen on the trading platforms Reddit and Robinhood. This means that the share has good upside potential. If the Biden administration's second infrastructure program comes through, Plug – as well as, of course, the whole H_2/FC industry in the US – will massively profit from it and in turn, of course, also the share price. ||

WARNING
Each investor must always be aware of their own risk when investing in shares and should consider a sensible risk diversification. The FC companies and shares mentioned here are small and mid cap, i.e. they are not standard stocks and their volatility is also much higher. This report is not meant to be viewed as purchase recommendations, and the author holds no liability for your actions. All information is based on publicly available sources and, as far as assessment is concerned, represents exclusively the personal opinion of the author, who focuses on medium- and long-term valuation and not on short-term profit. The author may be in possession of the shares presented here.

HIGH-PRESSURE VALVES FOR H_2 STATIONS

In February 2022, GSR Ventiltechnik GmbH & Co. KG introduced a new servo-controlled solenoid valve for high-pressure applications. As the company from Vlotho-Exter announced, this valve can be used with pressures up to 1,000 bar and was specifically developed for H_2 refueling systems.

According to information from the company, the components of hydrogen filling stations are subjected to high stresses and strains, which "challenge function, air-tightness, durability and safety to the highest degree." Solenoid valves are "subject to very frequent switching operations," so GSR Ventiltechnik has used its decades of experience to include a new 2-way valve in its repertoire. It is designed for pressures from 5 to 1,000 bar. And the geometry and use of high-quality materials allows for a long service life of over 100,000 switching operations, keeping operating and maintenance costs for the system low.

The 3/071-1W high-pressure valve is available in different connection sizes. It requires only an electrical connection, no instrument air, so neither complex piping nor a compressor has to be dealt with. It can be used in the temperature range -40 °C to +60 °C and has ATEX certification. It will be presented for the first time May 9th to 11th, 2022 at the World Hydrogen Expo in Rotterdam. ||

VALVE TECHNOLOGY FOR THE ELECTROLYSIS SECTOR

Hydrogen is as safe to handle as other energy carriers or gases. The thing is, suitable safety measures need to be taken or components designed for this purpose must be used. Proper safety valves are indispensable, especially where the hydrogen is to be produced: in electrolyzers.

WITT-Gasetechnik GmbH & Co. KG has products for protection against overpressure available. The AV 619 and AV 919 valves, for example, are especially geared for the pressure and temperature ranges of PEM and solid oxide electrolyzers. According to information from the company, "the opening pressure can be precisely set between 5 and 500 mbar, the operating temperature can be up to 250 °C."

For alkaline electrolysis systems, the Witten-based component manufacturer has conceived the model SV 805, where the opening pressure can be set from 0.5 to 45 bar, with up to 150 °C operating temperature. As it says, these pressure relief valves open "highly precisely and reliably when the set opening pressure is reached and reliably protect the sensitive equipment from even minimal overpressures." All of the valves have a comparatively small body size, yet allow for relatively high flow volumes. They are oil- and grease-free, can be positioned any which way, and are available with various inlet and outlet connections and in different materials – with corresponding TÜV certificate if desired.

Marketing manager Alexander Kampschulte told H2-international that WITT has recently perceived an increase of interest in the electrolysis sector. He said, "We have received feedback from customers that the valves of the AV series in particular, with their low opening pressure and high temperature range, are perfectly suited to this application and that there are few comparable products of this quality on the market." ||

Source: Witt

Category: International | **Author:** Aleksandra Fedorska

HYDROGEN IMPORTS FROM THE EAST

H_2 pipeline from Ukraine to Germany

The German-American talks regarding a possible activation of Nord Stream 2 also specifically addressed Germany's involvement in Ukraine. Ukraine, which fears economic disadvantages as a result of Nord Stream 2, is to receive support from the Federal Republic of Germany in the further development of its energy supply system. Or that was the plan, before Putin's attack of the country. Due to the current war, it is completely open what the future will look like in Eastern Europe, including what the energy supply situation will be. In order to show what opportunities could arise after the, hopefully near, end of this invasion, we describe here the initial situation, as it still looked at the end of 2021.

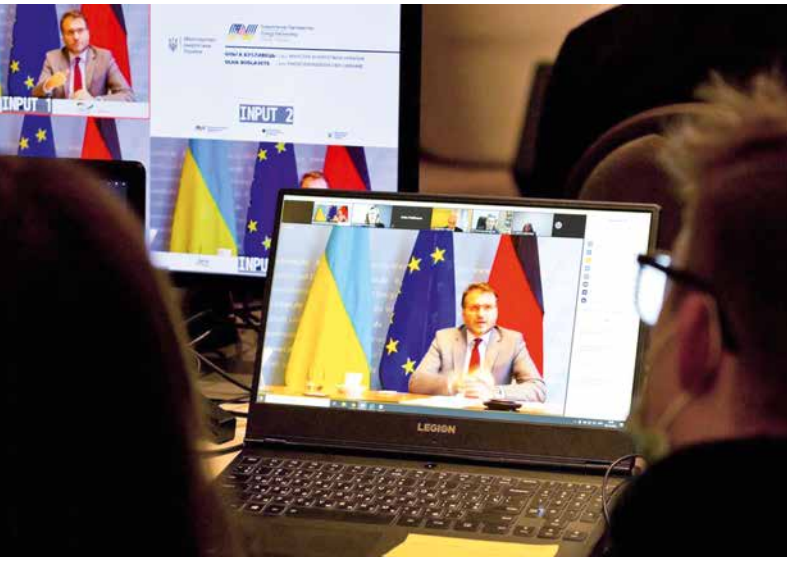


Photo: First German-Ukrainian Energy Day [Source: AHK]

The German energy consultancy dena (deutsche Energieagentur) is already cooperating with the Ukrainian energy industry within the framework of the German-Ukrainian Energy Partnership. A corresponding letter of intent was signed at the first German-Ukrainian Energy Day event, on August 28th, 2020. The current objectives of this energy partnership are to increase energy efficiency, modernize the electricity sector, expand renewable energies and reduce CO_2 emissions. In the future, the focus will also be on the transformation of coal regions, the integration of renewable energies, the production of green hydrogen and the modernization of district heating systems. Dena sees great opportunities and potentials in the energy sector, but there are still many open questions.

DEVELOPMENT OF RENEWABLES In order for them to export green hydrogen to Germany in significant quantities in the future, there will need to be a corresponding amount of energy from renewable sources in the energy systems of the countries in Eastern Europe. This is currently not the case at all, as the percentage of renewables in primary energy consumption is only in the upper single digits in the case of Ukraine, for example. In Kazakhstan, it is just about three percent.

The installed capacity has increased from 2,300 megawatts at the end of 2018 to around 7,700 megawatts currently. Since 2015, over 5 billion euros has been invested in expansion of renewable energies to reach a capacity of over 6.7 gigawatts (dena). Whether and in what form the future expansion of renewable energies in Ukraine can be realized at all is currently unknown, as the uncertain political situation in the country makes it almost impossible for investors to find potential interested parties and investors for new projects in the renewables sector.

The draft horses driving the expansion are typically foreign investors. In Kazakhstan, for example, the Swedish-German Svevind Group is venturing a huge hydrogen project in cooperation with a Kazakh partner. Svevind wants to build 45 GW of wind and solar farms in Kazakhstan. With this, the Kazakh partner could produce up to three million tonnes of green hydrogen per year with its 30 GW of electrolysis capacity.

SO FAR THE LINE INFRASTRUCTURE IS MISSING For the supply, countries such as Ukraine, Kazakhstan and Belarus have a network of pipelines for the transfer of natural gas. Whether these lines could be technically modified to such an extent that they could also channel hydrogen is not clear at the present time. Oleksandr Riepkin, president of the Ukrainian Hydrogen Council, has therefore brought another option into play. He proposed the use of ships that could bring hydrogen to Central Europe via the Danube.

Already in fall 2021, the Slovakian gas network operator EUSTREAM, along with GTSOU (Ukraine), NET4GAS (Czech Republic) and the German transmission system operator OGE announced that they wanted to establish a corridor for hydrogen transport. With the initiative Central European Hydrogen Corridor, a pipeline network starting in the Ukraine, running through Slovakia and the Czech Republic and bringing up to 43.8 TWh of hydrogen per year to Germany is to be built. This is by no means a unique idea. Others also have a similar pipeline in mind.

The pipeline H2EU+Store is, for example, strongly influenced by Austrian conceptions. This is a line to Baumgarten an der March, a major gas hub near the eastern border of Lower Austria. From Baumgarten, the hydrogen could flow to many other European countries, including Germany of course. While the Central European Hydrogen Corridor project has not yet specified where and how the hydrogen can be produced in Ukraine, H2EU+Store announced its cooperation with the Ukrainian company Eco-Optima LLC. Eco-Optima is a Western Ukrainian solar energy producer with an installed capacity of 154 MW. The owner of this company is Maksym Kozytsky, governor of the region Lviv Oblast and member of the political party of President Volodymyr Zelensky. ||

References:

dena, Deutsch-Ukrainische Energiepartnerschaft

This report was drafted before the political situation between Russia and Ukraine intensified and has now been adjusted accordingly.

BUSINESS DIRECTORY

AUTOMATION

XENON Automatisierungstechnik GmbH, assembly and test automation for fuel cells and electrolysers, Pforzheimer Str. 16, 01189 Dresden, Germany, Phone +49-351-40209-100, *www.xenon-automation.com*

BIPOLAR PLATES

SITEC Industrietechnologie GmbH, prototypes, series production, production systems for your bipolar plates, stack assemblies and balance of plant, *info@sitec-technology.de, www.sitec-technology.com*

COATING

Aalberts Surface Technologies GmbH, Seelandstr. 7, 23569 Lübeck, Germany, Phone +49-451-39006-0, *www.aalberts.com*

Coatema Coating Machinery GmbH, Roseller Str. 4, 41539 Dormagen, Germany, Phone +49-21339784-121, Fax -170, *www.coatema.de*

Holzapfel Metallveredelung GmbH, Unterm Ruhestein 1, 35764 Sinn, Germany, Phone +49-2772-5008-0, Fax -55, *www.holzapfel-group.com*

COMMUNICATION & MARKETING

Mission Hydrogen GmbH, Lise-Meitner-Str. 20, 71364 Winnenden, Germany, Phone +49-7195-904390-0, +49-162-2109822, *www.mission-hydrogen.de*

mummert – creating relations, Uta Mummert, German-French Communication Services – Media, Events, Marketing, 85 Chemin du Vignal, 07230 Lablachère, France, Phone +33-652980552, *info@mummert.fr, www.mummert.fr*

COMPRESSORS

Mehrer Compression GmbH, Rosenfelder Str. 35, 72336 Balingen, Germany, Phone +49-(0)7433-2605-0, Fax -7541, *www.mehrer.de*

Neuman & Esser Group, Werkstraße o.Nr., 52531 Übach-Palenberg, Germany, Phone +49-2451-481-01, Fax -100, *www.neuman-esser.de*

J.P. Sauer & Sohn Maschinenbau GmbH, Brauner Berg 15, 24159 Kiel, Germany, Phone +49-(0)431-3940-0, *sales@sauercompressors.de, www.sauercompressors.com*

CONSULTING

Griesemann Gruppe, Studies, Basic & Detail-Engineering, Implementation, Industriestr. 73, 50389 Wesseling, Germany, Phone +49-2232-7080, *kontakt@griesemann.com, www.griesemann.com, https://griesemann.com/en/*

Haas Engineering GmbH & Co. KG, Reinhold-Schneider-Str. 18a, 79194 Gundelfingen, Germany, Phone +49-(0)761-503649-0, Fax -69, *info@haasengineering.de, www.haasengineering.de*

DISTRIBUTION

Hydrogenious LOHC Technologies GmbH, Weidenweg 13, 91058 Erlangen, Germany, Phone +49-(0)9131-12640-220, Fax -29, *www.hydrogenious.net*

Kälte- und Systemtechnik GmbH, Refrigeration systems for cooling hydrogen according SAE, Heavy duty refueling, Strassfeld 5, 3441 Freundorf, Austria, Phone +43-2274-44109, *office@kustec.at, www.kustec.at*

Wystrach GmbH, Industriestr. 60, 47652 Weeze, Germany, Phone +49-(0)2837-9135-0, Fax -30, *www.wystrach-gmbh.de*

ELECTROLYZERS

Asahi Kasei Europe GmbH, Fringsstr. 17, 40221 Düsseldorf, Germany, Phone +49-211-3399-2000, *info@asahi-kasei.eu, www.asahi-kasei.eu*

Cummins Inc., Am Wiesenbusch 2 – Halle 5, 45966 Gladbeck, Germany, Phone +49-2043-944-133, Fax -146, *powersales@hydrogenics.com, www.cummins.com*

Elogen GmbH, Eupener Strasse 165, 50933 Köln, Germany, Phone +49-221- 2919073-0, Fax -9, *www.elogenh2.com*

Enapter srl, AEM eletrolyzers for all applications, Pisa, Berlin, Chiang Mai, Via di lavoria 56G, 56040 Crespina Lorenzana (PI), Italy, Phone +39-50644281, +49-30-921008130, *www.enapter.com*

a company of FEST group, Phone +49-05321-687-0, *kontakt@fest-group.de, www.green-h2-systems.com*

Giner ELX, Inc., 89 Rumford Avenue, Newton, Massachusetts 02466, USA, Phone +1-(0)781-529-0500, *information@ginerelx.com, www.ginerelx.com*

GreenHydrogen.dk ApS, Platinvej 29B, 6000 Kolding, Denmark, Phone +45-(0)7550-3500, *www.greenhydrogen.dk*

H-Tec Systems GmbH, PEM electrolyzers for industry application, Am Mittleren Moos 46, 86167 Augsburg, Germany, Phone +49-821-507697-0, Fax +49-451-399-41799, *info@h-tec-systems.com, www.h-tec.com*

Hytron Energy & Gas Ltda., Eritrina, 181, Condomínio Industrial Veccon Zeta, Sumaré – SP – Brasil, CEP.: 13.178-543, Phone +55-19-30322522, *www.hytron.com.br*

iGas energy GmbH, Cockerillstr. 100, 52222 Stolberg, Germany, Phone +49-(0)2402-9791600, *info@igas-energy.de, www.iGas-energy.de*

IPS-FEST GmbH, Power Supplier, Eisenbahnstr. 22-23, 53489 Sinzig, Germany, Phone +49-02642-9020-20, *sales@ips-fest.de, www.ips-fest.de*

thyssenkrupp Uhde Chlorine Engineers GmbH, Vosskuhle 38, 44141 Dortmund, Germany, Phone +49-231-547-0, Fax -2334, *info-uce@thyssenkrupp.com, www.thyssenkrupp-uhde-chlorine-engineers.com*

ELECTRONICS

plating electronic GmbH, DC Power Supplies, Rheinstr. 4, 79350 Sexau, Germany, Phone: +49-7641-93500-0, *info@plating.de, www.plating.de*

Prüfrex Innovative Power Products GmbH, Egersdorfer Str. 36, 90556 Cadolzburg, Germany, Phone +49-(0)9103-7953-0, Fax -55, *www.pruefrex.com*

ENGINEERING

H2 Core Systems GmbH, Construction, Service, Electrolyser, Fuel Cell, Compressor, Storage, Berliner Str. 82–88, 25746 Heide, Germany, Phone +49-15777438466, *info@h2coresystems.com, www.h2coresystems.com*

MACEAS GmbH, Königstr. 2, 26676 Barßel-Harkebrügge, Germany, Phone +49-4497-9269-90, Fax -18, *www.maceas.com*

FITTINGS, REGULATORS, VALVES

Bürkert Werke GmbH & Co. KG, Solenoid Valves, Mass Flow Controller, Fluid Power System Solutions, Christian-Bürkert-Str. 13-17, 74653 Ingelfingen, Germany, Phone +49-7940-10-0, Fax -91204, *www.buerkert.com*

Eugen Seitz AG, Leading H_2-solenoid valve technology from 10 to 1,000 bar, Spitalstr. 204, 8623 Wetzikon, Switzerland, Phone +41-44-9318190, *h2info@seitz.ch, www.seitz.ch*

GSR Ventiltechnik GmbH & Co. KG, Im Meisenfeld 1, 32602 Vlotho, Germany, Phone +49-5228-779-0, *info@ventiltechnik.de, www.ventiltechnik.de*

Magnet-Schultz GmbH & Co. KG, High-pressure-cut-off-, safety–shut-off-, flow-control valves for H_2, Allgäuer Str. 30, 87700 Memmingen, Germany, Phone +49-8331-104-0, Fax -333, *www.magnet-schultz.com*

Nova Werke AG, H_2 High Pressure Solenoid Valves, Vogelsangstr. 24, 8307 Effretikon, Switzerland, Phone +41-52-3541616, *www.novaswiss.com*

OMB Saleri SpA, Via Rose di Sotto 38/c - 25126 Brescia, Italy, *hydrogen@omb-saleri.it, www.omb-saleri.it*

PTEC – Pressure Technology GmbH, pipelines, screw connections, filters, valves, regulators, TPRD, Linde 11, 51399 Burscheid, Germany, Phone +49-2174-748-722, *mail@ptec.eu, www.ptec.eu*

FUEL CELLS

SFC Energy AG, EFOY Fuel Cells, Eugen-Sänger-Ring 7, 85649 Brunnthal, Germany, Phone +49-89-673592–555, *info@sfc.com, www.sfc.com, www.efoy-pro.com*

Siqens GmbH, Landsberger Str. 318d, 80687 München, Germany, Phone +49-89-4524463-0, *info@siqens.de, www.siqens.de*

FUEL RECIRCULATION AND AIR SUPPLY

Busch Clean Air S.A., Chemin des Grandes-Vies 54, 2900 Porrentruy, Switzerland, Phone +41-(0)32-46589-60, Fax -79, *info@buschcleanair.com, www.buschcleanair.com*

Celeroton AG, highly compact turbo compressors for fuel cell air supply, Industriestr. 22, 8604 Volketswil, Switzerland, Phone +41-44-25052-20, *info@celeroton.com, www.celeroton.com*

Haskel International, LLC, 100 E Graham Place, 91502 Burbank, CA, USA, Phone +1-818-84-34000, Fax -14291, *www.haskel.com*

sera ComPress GmbH, sera-Str. 1, 34369 Immenhausen, Germany, Phone +49-5673-999-04, Fax-05, *info-compress@sera-web.com, www.sera-web.com*

GAS DIFFUSION LAYERS (GDL)

MeliCon GmbH, Metallic Lightweight Construction, Porschestr. 6, 41836 Hückelhoven, Germany, Phone +49-(0)2433-44674-0, Fax -22, *www.melicon.de*

SGL Carbon GmbH, Werner-von-Siemens-Str. 18, 86405 Meitingen, Germany, Phone +48-(0)8271-83-3360, Fax -103360, *fuelcellcomponents@sglgroup.com, www.sglgroup.com*

HYDROGEN GENERATION

RIX Industries, 4900 Industrial Way, Benicia, CA 94510, USA, Phone +1-707-747-5900, *learnmore@rixindustries.com, www.rixindustries.com*

Rouge H_2 Engineering GmbH, Reininghausstr. 13, 8020 Graz, Austria, Phone +43-316-375-007 Germany: Rouge H_2 Engineering Deutschland GmbH, Maurener Str. 11/1, 71155 Altdorf, Phone +49-2175-6688-575, *www.rgh2.com*

INTEGRATION

Deutsche Zentrum für Luft- und Raumfahrt (DLR) / German Aerospace Center, Institute of Engineering Thermodynamics, Energy System Integration, Pfaffenwaldring 38–40, 70569 Stuttgart, Germany, Phone +49-(0)711-6862-672, Fax -747, *www.dlr.de/tt*

Framatome GmbH, Paul-Gossen-Str. 100, 91052 Erlangen, Germany, Contact: Mrs. Gemmer-Berkbilek, Phone +49-(0)9131-90095221, *www.framatome.com*

MEASUREMENT AND CONTROL TECHNOLOGY

ADZ NAGANO GmbH, H_2-pressure sensors with EC79 approval, Bergener Ring 43, 01458 Ottendorf-Okrilla, Germany, Phone +49-035205-596930, *sales@adz.de, www.adz.de*

Henze-Hauck Prozessmesstechnik / Analytik GmbH, Wasserstoffanalysatoren, ATEX zertifiziert, Sicherheitstechnik, Dünnhauptstr. 14, 06847 Dessau, Tel. 0340 5169363, *info@henze-hauck.de, www.processanalytik.de*

MEASUREMENT DATA MANAGEMENT AND MONITORING

DiLiCo engineering GmbH, Lorenzweg 43, 39124 Magdeburg, Germany, Phone +49-(0)391-505859-86, *info@dilico.de, www.dilico.de*

MEMBRANES AND SEPARATORS

AGC Chemicals Europe, Ltd., FORBLUE™ Membrane Technology, Commercial Centre, World Trade Center, Zuidplein 80, 1077 XV Amsterdam, Netherlands, Phone +31-20-880-4170, *forblue.info@agc.com, www.agcce.com*

Chemours International Operations SARL, Chemin du Pavillon 2, 1218 Le Grand Saconnex, Switzerland, Patrick Redon, Phone +33 680 28 21 40, *www.chemours.com, www.nafion.com*

FUMATECH BWT GmbH, Carl-Benz-Str. 4, 74321 Bietigheim-Bissingen, Germany, Phone +49-(0)7142-3737-900, Fax -999, *www.fumatech.com*

ORGANIZATIONS

German Hydrogen and Fuel Cell Association, Deutscher Wasserstoff- und Brennstoffzellen-Verband e.V. (DWV), Moltkestr. 42, 12203 Berlin, Germany, Phone +49-(0)30-398209946-0, Fax -9, *www.dwv-info.de*

hySOLUTIONS GmbH, Steinstrasse 25, 20095 Hamburg, Germany, Phone +49-(0)40-3288353-2, Fax -8, *www.hysolutions-hamburg.de*

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

ORGANIZERS (EVENTS)

European Fuel Cell Forum, Obgardihalde 2, 6043 Luzern-Adligenswil, Switzerland, Phone +41-(0)4-45865644, Fax 35080622, *forum@efcf.com, www.efcf.com*

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*

Tobias Renz FAIR, Berlin, Tobias Renz, *tobias@h2fc-fair.com,* Phone +49-30-60984556, *www.h2fc-fair.com*

REFORMERS

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

RESEARCH & DEVELOPMENT

DBI Gas- und Umwelttechnik GmbH, Karl-Heine-Str. 109/111, 04229 Leipzig, Germany, Phone +49-341-2457-113, *www.dbi-gut.de*

Fraunhofer Institute for Microengineering and Microsystems IMM, Reformer and Heat Exchanger, Carl-Zeiss-Str. 18-20, 55129 Mainz, Germany, Phone +49-(0)6131-9900, *info@imm.fraunhofer.de, www.imm.fraunhofer.de*

Fraunhofer ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany, Phone +49-(0)761- 4588-5208, Fax -9202, *www.h2-ise.de*

Fraunhofer-Institut für Windenergiesysteme IWES, Postkamp 12, 30159 Hannover, Germany, Phone +49-471-14290-456, *www.iwes.fraunhofer.de*

HyCentA Research GmbH, Inffeldgasse 15, 8010 Graz, Austria, Phone +43 (0)316-873-9501, *office@hycenta.at, www.hycenta.at*

IAV GmbH Ingenieurgesellschaft Auto und Verkehr, Carnotstr. 1, 10587 Berlin, Germany, Phone +49-30-39978-0, Fax -9926, *www.iav.com*

Wenger Engineering GmbH, Research and Development Center for Thermodynamics, CFD Simulation & H_2-Technology, Einsteinstr. 55, 89077 Ulm, Germany, Phone +49-(0)731-790605-0, Fax -99, *mail@wenger-engineering.com, www.wenger-engineering.com*

STORAGE

GKN Powder Metallurgy Holding GmbH, Pennefeldsweg 11-15, 53177 Bonn, Germany, *www.gknhydrogen.com*

Hexagon Purus GmbH, Otto-Hahn-Str. 5, 34123 Kassel, Germany, Phone +49-561-58549-0, Fax -29, *www.hexagonpurus.com*

HPS Home Power Solutions GmbH, Carl-Scheele-Str. 16, 12489 Berlin, Germany, Phone +49-(0)30-5169-5810, *mail@homepowersolutions.de, www.homepowersolutions.de*

Hydrogenious Technologies GmbH, Weidenweg 13, 91058 Erlangen, Germany, Phone +49-(0)9131-12640-220, Fax -29, *www.hydrogenious.net*

Kessels Prüfwerk Gmbh & Co. KG, Lehmkuhlenweg 13, 41065 Mönchengladbach, Germany, Phone +49-(0)2161-65907-0, Fax -68, *www.kessels-pruefwerke.de*

Reuther STC GmbH, Fabrikstr. 8, 15517 Fuerstenwalde, Germany, Phone +49-(0)3361-694-0, Fax -852, *www.reuther-stc.com*

SUPPLIERS

Anleg GmbH, Advanced Technology, Am Schornacker 59, 46485 Wesel, Germany, Phone +49-(0)281-206526-0, Fax -29, *www.anleg-gmbh.de*

Borit NV, Bipolar Plates and Interconnects, Lammerdries 18e, 2440 Geel, Belgium, Phone +32-(0)14-25090-0, *contact@borit.be, www.borit.be*

HIAT gGmbH, Schwerin, Germany, CCMs / MEAs / GDEs for PEFC, DMFC & PEM-Electrolysis, *www.hiat.de*

Kerafol Keramische Folien GmbH & Co. KG, Ceramic Electrolytes, Solid Oxide Cells, Glass Tapes, Koppe-Platz 1, 92676 Eschenbach, Germany, Phone +49-(0)9645-884-30, Fax -90, *www.kerafol.com/sofc*

Pajarito Powder, LLC, 3600 Osuna Road NE, Suite 309, Albuquerque, NM 87109-4427, USA, Phone +1-505-2-935367, Fax -448040, *www.pajaritopowder.com*

Sandvik High Precision Tube, ZN der SMT D GmbH, 33824 Werther, Germany, Phone +49-5203-91090, *info.hpt@sandvik.com,* H_2 Stainless Steel Tube Applications / Coil Container Service – On Site Tubing Solution

Siemens, contributes to successful process implementations in H_2 production, conversion, storage, transport and usage as reliable partner with a comprehensive automation and digitalization portfolio. *www.siemens.com/h2*

Spir Star AG, Auf der Rut 7, 64668 Rimbach-Mitlechtern, Germany, Phone +49-6253-9889-0, *info@spirstar.de, www.spirstar.de*

WEKA AG, Schuerlistr. 8, 8344 Baeretswil, Switzerland, Phone +41-(0)43-833434-3, Fax -9, *info@weka-ag.ch, www.weka-ag.ch*

TESTING

JA-Gastechnology GmbH, Albrecht-Thaer-Ring 9, 30938 Burgwedel, Germany, Phone +49-(0)5139-9855-011, Fax -33, *www.ja-gastechnology.com*

Maximator GmbH, High Pressure Hydrogen Technology, Testing Equipment, Customer Testing Services, Lange Strasse 6, 99734 Nordhausen, Germany, Phone +49-3631-9533-5040, *info@maximator.de, www.maximator.de*

Resato International B.V., H_2-Pressure Testing, H_2 gas booster for refueling stations, high pressure technology, Duitslandlaan 1, 9400 AZ Assen, Netherlands, Phone +31-(0)501-6877, *h2sales@resato.com, www.resato.com*

Sonplas GmbH, H_2 test stand, Testing of hydrogen-carrying components with real fuel, Sachsenring 57, 94315 Straubing, Germany, Phone +49-9431-9275-0, *info@sonplas.de, www.sonplas.com*

TesTneT Engineering GmbH, Eschenallee 11, 85445 Oberding Phone +49-(0)89-237109-39, *info@h2-test.net, www.h2-test.net*

Zeltwanger, Leak and Functional Testing, Automated Lines for Laser Applications and Assembly Tasks, Maltschachstr. 32, 72144 Dußlingen, Germany, Phone +49-7071-3663-106, *a.nobel@zeltwanger.de, www.zeltwanger.de*

TEST STANDS

DAM Group, 200 Rue Léon Blum, 69100 Villeurbanne, France, Phone +33-478-269583, *www.damgroup.fr*

EVENTS

You can also find upcoming online and live events as well as possible changes to these at www.h2-international.com/events.

MAI

World Hydrogen 2022 Summit & Exhibition
May 9-11 2022, in Rotterdam
www.world-hydrogen-summit.com/

HyVolution 2022
May 11-12 2022, at the Porte de la Villette Paris, France
www.hyvolution-event.com/en/event

ees Europe
Fair Ground 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)
May 18-20 2022, in Madrid, Spain
www.ehec.info

f-cell Canada
May 25-26, 2022, Edmonton, Alberta, Canada
www.hyfcell.com

JUNE

International Electric Vehicle Symposium & Exhibition – EVS35
June 11-15 2022, Norway Convention Center,
Lillestrøm, Norway, *https://evs35oslo.org/*

EMEA2022
Workshop on Ion Exchange Membranes for Energy Applications
June 20-22 2022, Bad Zwischenahn, Germany
www.emea2022.welcome-manager.de

HiPEM-TECH2022
Workshop on High Temperature Polymer Electrolyte Membrane Fuel Cell Technology
June 22-24 2022, Bad Zwischenahn, Germany
www.hipem-tech2022.welcome-manager.de

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

Hydrogen Technology Conference & Expo North America
June 14-15 2022, Houston, Texas, USA
www.hydrogen-expo.com/

Hydrogen & P2X 2022
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

H2-international

H2 international
THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

ISSN 2367-3931
Issue / Years 8. (2022) / Issue No. 2, May 2022

Publisher
Hydrogeit Verlag
Sven Geitmann
Gartenweg 5
16727 Oberkraemer, Germany

VAT ID No. DE 221143829

Legally Responsible for Content Dipl.-Ing. Sven Geitmann
Phone / Fax: +49 (0)33055 213 ext. 22/20
Email info@h2-international.com
Web www.hydrogeit-verlag.de, www.h2-international.com

Editorial & Research
Eva Augsten, Aleksandra Fedorska, Sven Geitmann, Sven Jösting, Michael Nallinger, Niels Hendrik Petersen

Design Dipl.-Des. Andreas Wolter, Weimar
Typesetting Dipl.-Des. Henrike Hiersig, Berlin

Adverts Uta Mummert, creating relations, Lablachère, France

Translation
Nicola Bottrell Hayward, the hydrogen translator, Bristol, United Kingdom
Karlee H. Archer, Biedenkopf, Germany

Frequency	4 digital issues per year
Single issue	USD 10 / EUR 8 (excl. VAT)
1-year sub	USD 40 / EUR 35 (excl. VAT)
Shipping	D: USD 2.50 / EUR 2.00, World: USD 5.00 / EUR 4.00
Students	50 % off standard prices
Termination	At any time

News articles that show an author's name represent the opinions of said author and do not necessarily represent the views of the editorial board.

H_2YDROGEIT Verlag

Cover image: Hydrogen Poster
[Source: Liliane L., Kulturaustausch Hamburg-Übersee e.V.]
Photo on p. 3: derBildmacher, Rüdiger Tesch-Zapp

HYPOTHESIS XVII

September 26-29, 2022
GIS Taipei Tech Convention Center
TAIPEI. TAIWAN

Call for Papers: January, 2022
Start of Early Bird Registration: April 1, 2022
Abstract Submission Deadline: July 10, 2022
Notification of Acceptance: July 31, 2022
Early Bird Registration Deadline: August 15, 2022

https://www.hypothesis.ws/

HYPOTHESIS2022@gmail.com

THE FC
台灣氫能與燃料電池學會
Taiwan Association for Hydrogen Energy and Fuel Cell