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H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

→ STELLANTIS DUE TO SELL HYDROGEN VANS FROM END OF 2021

→ INTERVIEW WITH STOCK MARKET PUNDIT DIRK MÜLLER – AKA MR. DAX

Hydrogen Regions, Part V: HyStarter Rügen-Stralsund

IT'S ALL ABOUT THE COLORS … AGAIN

Dear readers

I could be wrong, of course. But I feel like more and more members of the hydrogen community have had enough of people constantly talking about their favorite colors. During the past several months, we've seen debate after debate about the pros and cons of green, blue and turquoise hydrogen. First in Germany, now in Brussels.

Other variants don't get nearly as much attention. That shouldn't be a surprise. After all, there's still disagreement about whether nuclear-sourced hydrogen is red or pink. Orange, on the other hand, indicates production from biogenic sources, gray from steam-reformed natural gas. White is the color for hydrogen seeping naturally from the ground. For the moment, however, none of them is generating as much press, or controversy, as the blue variant.

Don't get me wrong. I may be annoyed by what's going on at the moment. But I strongly believe we should examine and thoroughly discuss every production pathway we have at our disposal. In fact, I would welcome a closer look at biogenic hydrogen, for example.

What vexes me, though, is the eagerness of some to turn the debate about the blue variant into an ideological tussle. Representatives for natural gas companies in particular have begun to use many of the online events to ask all kinds of supposed experts, from industry stakeholders to the Norwegian ambassador, about their thoughts on blue hydrogen. And then watch them extol its virtues and praise the alleged safety of carbon capture and storage technology.

If there's one thing we've learned from decades of interacting with – or, should I say, having to deal with – large interest groups, it's that industry-backed information events and studies won't give you the whole picture. We know now that it wasn't just tobacco firms and automakers, or nuclear and coal lobbyists, that started expensive PR campaigns – and sometimes presented false evidence – to whitewash their sectors' image and prevent social change. Oil corporations and electricity providers did that too.

Maybe it's unfair to point to these bad experiences and paint another group of companies with the same broad and ugly brush. But it doesn't look to me as if the gas industry is encouraging an open and honest debate.

The simple fact is that the German government has made its choice of color abundantly clear. Green hydrogen is the only variant, aside from orange maybe, that will receive public funding. If companies want to use blue or turquoise hydrogen, no one will be standing in their way. They just won't be getting money from the government for when they do. It's a stance that leaves little room for interpretation.

And yet, gas associations are launching essentially one weeks-long information campaign after another, each focused on blue hydrogen. Are companies in the industry really so cash-strapped that they need ordinary citizens to fund their ventures? Are we seriously considering dumping the tax revenues from small businesses and retirees in Germany into the construction of natural gas caverns in Scandinavia?

To be clear, it will take years until we have a large enough amount of green hydrogen available. That's why we need to act, and act now, said Veronika Grimm, one of the German government's economic advisors. I agree.

If industrial businesses firmly believe producing blue hydrogen is necessary for the time being, let them. But they should do so at their own risk. Even some representatives for the gas industry are coming around, saying we don't need to prop up outdated natural gas and CCS technology on the taxpayers' dime. Or, as consulting firm Deloitte's Johannes Trüby put it: "You can let the market sort it out. Taxpayer funding isn't the answer. A good regulatory framework is. Everyone needs to see clean energy production is a profitable business."

Never again should a country or its citizens be asked to provide a safety net for a whole industry. We've seen how that worked out, many times. Corporations breaking promises. Corporations ignoring commitments they signed. Corporations lying and manipulating to keep market shares and grow profits.

Humanity will have to face up to the fact that it has allowed corporate greed to flourish for quite a while. It's why young people – in Germany and around the world – have started to organize to push back against the status quo. They'll be the ones suffering in the end. How can they be sure that there won't be lock-in effects? That CCS is really safe? Or that gas pipelines won't be used longer than necessary to deliver fossil fuels?

I understand the youth's distrust of the business world. I, myself, am often wondering how many stakeholders will seize the opportunities hydrogen technology presents to keep doing business as usual. I fear some will exploit the clean image of the gas just to make a quick buck, without regard for what that will do to the industry as a whole.

I'm also very worried a future hydrogen economy will experience what is known as a rebound effect. In that case, ever-growing demand for resources and energy will simply cancel out the enormous potential the technology has for creating a cleaner environment.

The conversation around colors has become so tiring because any argument not in favor of the blue variant will be quickly brushed aside. Says the gas industry: "Let's put all this talk about colors to rest." To me, that looks more like an attempt to stifle debate and force the – supposedly carbon-free – blue hydrogen into the spotlight.

Which makes the current public exchange of ideas that much more important. We need to fully examine all the options on the table. What we don't need are people with entrenched opinions, ready to shut down the discussion – even if that discussion is exhausting at times. ||

Best wishes

Sven Geitmann
Editor of H2-international

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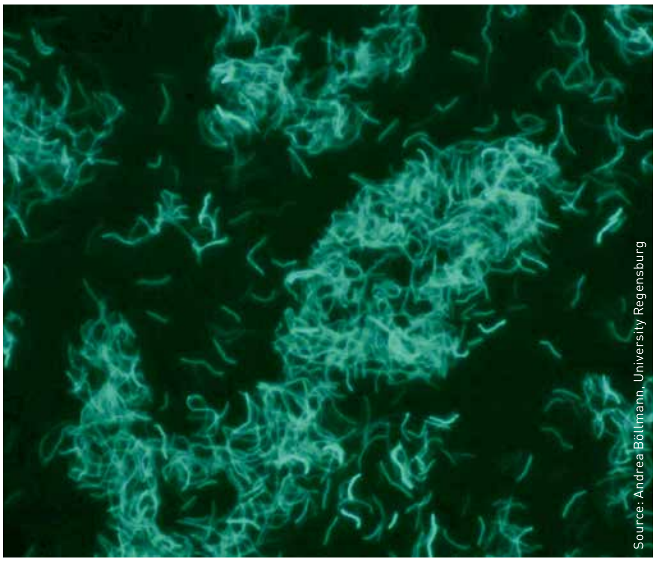

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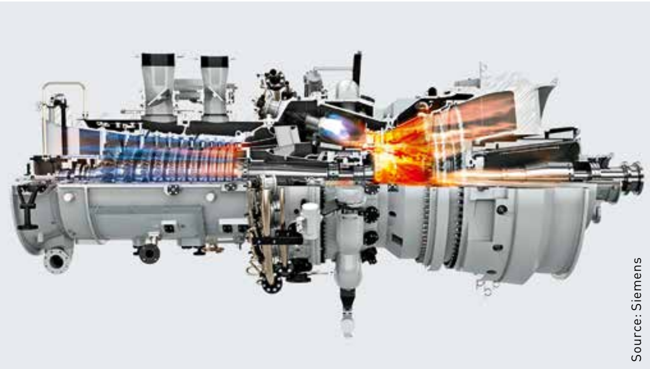
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NUMBER OF HYSTARTER APPLICATIONS NOW AT 65

HyStarter remains as popular as ever. Like the competition's first round, the second attracted the interest of much more organizations than the German transportation ministry was able to fund. By May 14, the ministry's NOW office had received 65 applications for funding local hydrogen economies as part of the HyLand program. Few of the organizations had already applied the first time around.

An expert panel will likely select a total of 10 winners, which will be announced in late July. One Hyland contest still open for submissions is HyExperts, which funds larger projects. HyPerformer, on the other hand, will restart in the second half of this year and invite applicants to submit ideas for bringing hydrogen technology to market. ||

A GUIDE TO HYDROGEN INNOVATIONS

Where have we made considerable progress in developing hydrogen technology? In what market are there still hurdles to overcome? Where do we still need to remove roadblocks to innovation? Answering questions like these is the task of Hydrogen Compass, a two-year project launched by the German education and economy ministries and funded with EUR 4.2 million.

As part of a large-scale communications campaign, the project team will structure available information about hydrogen technology in a way that helps the hydrogen and fuel cell sector achieve rapid progress while not losing sight of the environmental, economic and social aspects of technology advancements. Coordinated by acatech and DECHEMA, the project will most likely also receive input from the National Hydrogen Council and the Hydrogen Research Network.

"Research and innovation will remain key to turning Germany into a climate-neutral hub for cutting-edge technology," German economy minister Peter Altmaier said. "To achieve this, we'll have to come up with a hydrogen roadmap that can serve us in the long term. We need innovative ideas. But we also need to make sure those ideas make it from the lab to the market. This is where Hydrogen Compass could be a great help to us." ||

HYDROGEN REPUBLIC GERMANY, PART III

This spring saw the start of the first Hydrogen Republic Germany idea competition, created and funded by the German education ministry. As part of the initiative, a total of EUR 56 million will go to 71 partner organizations involved in 16 basic research projects. Additionally, three industry-led hydrogen flagship ventures named H2Giga, H2Mare and TransHyDe will focus on answering fundamental questions about hydrogen economies, in order to provide a scientific basis for new product developments and application scenarios.

"I want to see Germany become the world's foremost center of knowledge on green hydrogen. […] The development and global sale of hydrogen technology will present us with a huge opportunity to maintain our competitive edge while fulfilling our commitment to creating a sustainable economy," said German education minister Anja Karliczek. Stefan Kaufmann, a member of Germany's parliament and the country's green hydrogen innovation commissioner, added: "Some of these projects will investigate new electrolysis methods. Some will look for promising ways to establish a climate-friendly chemical industry or improve the design of fuel cells powering heavy-duty trucks. And some will seek new, more precise and faster approaches to identifying suitable locations for green hydrogen production around the world."

Over 100 additional ideas for hydrogen projects were submitted during the competition's second round and are now under review. The third round, which has a total budget of EUR 600 million, is still open for applications. ||

→ www.wasserstoff-leitprojekte.de

62 GERMAN IPCEI PROJECTS

Source: BMWi

"The 62 projects selected today will receive more than EUR 8 billion in federal and state funding. They cover the entire value chain, from the production and transport of hydrogen to its use in the industrial sector," German economy minister Peter Altmaier said in late May, reaffirming the government's aim to have Germany become "the world's number one in hydrogen technology."

Together with German transportation minister Andreas Scheuer, he then announced the names of the big hydrogen ventures that will receive the largest possible amount of funds from the Important Projects of Common European Interest – IPCEI program. Scheuer said: "We need and want to push forward with the transition to climate-friendly solutions. […]

Across all modes of transportation, green hydrogen and fuel cells are the ideal addition to all-electric vehicles." Hopes are that the EUR 4.4 billion and EUR 1.4 billion in funding, provided respectively by the economy and transportation ministries, and the financial support by individual German states will lead to EUR 33 billion in private sector investments. However, the money coming from the federal government will be taken from funds that are already available. In response to an inquiry by H2-international, the economy ministry said that "the IPCEI Hydrogen will be funded with state resources and money from the federal stimulus package, which saw EUR 7 billion earmarked for supporting projects nationwide."

More than 230 project outlines were up for consideration. The 62 picked by the government will now be discussed with officials from up to 22 partner countries to determine if they can be combined with other national IPCEI ventures to benefit all involved and set up a unified hydrogen economy across Europe. The results from these discussions will reportedly be announced in late 2021 or early 2022. The list of participating companies so far includes Airbus, ArcelorMittal, BASF, BMW, BP, Daimler, ElringKlinger, Faun, Gasunie, Linde, OGE, Ontras, RWE, Salzgitter Stahl, Shell, Siemens, Tennet, Thyssenkrupp, Vattenfall, Volvo and Wacker.

Altmaier called IPCEI Hydrogen an "endeavor that has never been tried at this scale in industry," adding that Germany is "on its way to becoming the world's number one in hydrogen technology. I know of no other country making a similarly targeted and comprehensive effort to introduce this important resource – that is, green hydrogen – to the market." The 62 large-scale projects will now be submitted to the EU Commission. Altmaier said there is "a high probability they'll be funded in their entirety." The relevant guidelines had already been prepared during Germany's European Council presidency in the second half of 2020, he added. According to him, more than 500 IPCEI projects could be implemented across Europe. ||

NEW HYDROGEN AND FUEL CELL PARTNERSHIPS

The time has come for new collaborations in the hydrogen sector. As noted in this year's May issue, the number of reports about company mergers and new partnerships has increased steadily over the past months. One example of this is the partnership formed by electrolyzer manufacturer **Nel** after its recent foray into the solar market. In early May, the group announced that one of its subsidiaries, Nel Hydrogen Electrolyser, is now working with **First Solar,** a manufacturer of PV modules, to design integrated solar-hydrogen power plants.

A short time later, news broke that Danish hydrogen business **Everfuel** and Norwegian aluminum maker **Norsk Hydro** signed a memorandum of understanding to improve conditions for electrolyzers in Europe. The agreement contemplates installing the Hydrogen Distribution Centers that are being developed by Everfuel at electrolyzer sites near Norsk Hydro's aluminum smelters to ensure the fast and safe refueling of the latter company's hydrogen trailers.

Meanwhile, Danish wind energy giant **Ørsted** has been looking to South Korea for forging new alliances, teaming up with national steelmaker **POSCO** on a large offshore wind project. Their MoU, signed in late May, also includes a promise to explore a potential collaboration on renewable hydrogen projects, with POSCO's vice president, Jung-Son Chon, saying his company is working to identify new "opportunities for green hydrogen."

Fig.: Luca de Meo (Renault Group, left) and Andy Marsh (Plug Power) join forces on a new venture [Source: Renault]

In the same month, **Toyota** said it entered into partnership with Japanese energy business **Eneos** to advance hydrogen-powered transportation and move forward with its new Woven City flagship project, where hydrogen is said to play a major role. The city, which will be constructed at the bottom of Mount Fuji, is hoped to become a living laboratory that uses smart, connected and sustainable technologies to allow residents to live in harmony with nature.

In early June, **Renault** and **Plug Power** (see also p. 52) set up the joint venture they announced back in January. Called HYVIA, the new French company will have employees at four locations and provide complete transportation solutions, ranging from light hydrogen-powered commercial vehicles to carbon-free hydrogen gas supplies.

As early as April, German auto supplier **Schaeffler** had already formed a strategic alliance with Chinese fuel cell maker **Refire.** At Auto Shanghai 2021, representatives for both then inked a deal to collaborate on the development of important fuel cell components, including bipolar plates and thermal management systems.

Automotive electronics manufacturer **EPH,** on the other hand, bid the market farewell, shutting down all of its fuel cell-related activities at the start of the year. ||

ACCURATE OPTICAL SENSING

Hydrogen sensors have been the focus of research for many years. Scientists working for the University of Georgia and South Carolina's Savannah River National Laboratory have now found a way to make it extremely easy to detect even minute traces of the gas. A research article about their new optical method for hydrogen sensing was published in the Nature Communications journal in April. "Our spark-free, optical-based hydrogen sensors detect the presence of hydrogen without electronics, making the process much safer," said Tho Nguyen, an associate professor in the university's Franklin College of Arts and Sciences and, together with the laboratory's George Larsen, the co-principal investigator on the project.

The sensors take advantage of the propensity of thin metal films to absorb hydrogen, leading to changes in light transmission. These subtle changes are large enough to be picked up by a detector in the blink of an eye, producing a signal. The units' response time and sensitivity can be adjusted to fit the material used (e.g., palladium or cobalt) and the size of the metal film.

"With our intensity-based optical nano sensors," said Nguyen, "we [can detect hydrogen] at 2 parts-per-million," adding that the response time of the new units is 0.8 seconds. That makes them 50 times more sensitive than other optical hydrogen sensors and 20 percent faster than the best available optical device reported in the literature. ||

KASTEN JOINS DWV'S SENIOR LEADERSHIP

Fig.: Thorsten Kasten [Source: DWV]

In April, gas and water industries association DVGW tapped Thorsten Kasten, 52, to co-lead hydrogen and fuel cell organization DWV. By unanimous vote, the DWV executive committee later confirmed the DVGW's candidate as its new co-chair of the board. Kasten now serves alongside Werner Diwald, who has led the DWV since 2014.

Before joining the DWV, Kasten was CEO of VNG Innovation Consult and parent company VNG's head of business and community development. He stressed his commitment to "getting the word out on the advantages of hydrogen in all its forms and promoting its use in as many sectors as possible." When asked by H2-international which forms of the gas Kasten was referring to, the DWV replied: "Green and climate-neutral hydrogen."

The DVGW's right to the co-chair position was part of an agreement the two German associations signed late last year to intensify their collaboration (see H2-international, February 2021). Following Kasten's appointment, DVGW Chairman Gerald Linke announced that the two organizations will now act as "the biggest voice for the hydrogen industry in Germany." ||

WILL METHANOL FUEL CELLS SEE A COMEBACK?

In the 1990s, methanol was seen as a possible new source of power for fuel cell electric vehicles. And yet, at the turn of the century, it nearly fell out of favor altogether, as the equipment needed to burn the fuel was much more complex than systems that used hydrogen only. Still, the past few years have seen renewed efforts to bring methanol fuel cells to market. Some weeks ago, Roland Gumpert, the engineer who spearheaded the development of Audi Quattro's four-wheel drive, was back in the news, talking about his latest project, a sports car named after his daughter Nathalie (see H2-international, April 2019).

In spring, several outlets reported that the electric coupé, which, according to Gumpert, offers buyers a comparatively affordable way into the world of sports cars, had been certified as roadworthy. Gumpert presented a prototype of the vehicle at the Geneva International Motor Show in early 2019. His company, Gumpert Aiways Automobile, initially announced that the first vehicles – each costing around EUR 400,000 – would roll out of the factory near the end of 2019, but that was then delayed to last summer. So far, H2-international has only been able to verify a handful of customers who could take delivery of their cars.

Despite this, a button on the company's main page still urges visitors to "Get your Nathalie!" A click on the button will direct prospective buyers to a subpage explaining how they can get their hands on the new car, from paying a EUR 5,000 reservation fee to signing a lease agreement. The company also posted several teaser videos at the beginning of the year. While promotionally effective, they have since invited questions and criticism as well. In response, Gumpert told efahrer.com in late May that "Nathalie was designed to be a showcase of our team's abilities, a marketing tool. That's a common strategy for automakers. The main goal is to highlight the technology that powers the car."

Generating less buzz but arguably more solid prospects are German special purpose vehicle maker C&S' efforts to convert a Mini Moke to run on the same methanol-water blend as Gumpert's sports cars. A fuel cell extends the range of the new buggy, called CSE Morris, to around 500 miles (800 kilometers). The buggy is being developed in collaboration with staff from Baden-Württemberg state's network of publicly funded university campuses and Bavarian fuel cell maker Siqens.

Fig.: Electric buggy powered by a methanol fuel cell (orange box in the back) [Source: Dino Eisele]

A cobalt-free lithium iron phosphate battery provides the utility vehicle with 20 kilowatt-hours of energy, giving it a range of 87 miles (140 kilometers). To extend the range, the car also features an Ecoport 800 module and a 40-liter tank, which are used to recharge the battery. The system combines the benefits of liquid fuels, i.e., fast fill-up and high energy density, with those of an 800-watt fuel cell, which reforms the methanol-water mixture to produce pure hydrogen for powering the electric motor.

Volker Harbusch, Siqens' chief executive, said: "Engine designs consisting of a small battery and a fuel cell to extend the range are an especially good choice for long-range utility vehicles that need to power a whole host of components, including cooling systems." ||

HANDELSBLATT MAGAZINE'S HYDROGEN SUMMIT

Driven in part by the recent decarbonization aims of multiple countries and businesses around the world, there is now pressure on every stakeholder in the sector to establish a global hydrogen economy as fast as possible. That much was clear to those attending German Handelsblatt magazine's online Hydrogen Summit on May 26 and 27. An oft-discussed issue also brought up at the summit was the color of future hydrogen supplies. In response, Wolfgang Büchele, who was Linde's chief executive from 2014 to 2016, said, roughly, that the color of the gas – be it green, blue or gray – was not nearly as important as the speed at which a steady supply of hydrogen could become a reality. He then pointed to South Korea, where he said the public is much more open to the use of hydrogen than is the case in Germany. Many also named the Middle East as an example of a region with a progressive hydrogen agenda. Countries such as Oman, the United Arab Emirates and Saudi Arabia (see also p. 57) may soon be able to produce clean hydrogen for USD 0.015 a kilowatt-hour. One statement to which all speakers at the summit could agree was that electrolyzers should be installed in places where electricity generation is cheap. That electricity could then be used to produce hydrogen for on-site consumption, delivery via pipelines or export by sea, if stored in ammonia or methane.

Reimund Neugebauer, president of the German Fraunhofer research institutes, called on stakeholders to seize the opportunities offered by hydrogen but also be aware of the challenges ahead. To create a sustainable economy, he said, it is high time market actors scale up the technology and try to generate as much added value in Germany and Europe as possible. As for demonstration projects such as living laboratories, they will now need to be turned into industrial parks. Of course, he added, the transition to a hydrogen economy will take a while. This means that in the foreseeable future, natural gas will continue to play a role in shoring up energy supply.

A key takeaway from the summit was that 75 countries around the world have so far agreed to become climate-neutral by 2050 and 50 leading industrial nations have implemented a hydrogen strategy. At the same time, the number of collaborations – or, more specifically, joint ventures (see p. 7) – in the energy sector is rising, as is the number of alliances between companies around the world. One example of the latter is the recently established partnership between Shell and Daimler Truck. The hydrogen industry has already been catering to some large markets, including those for primary raw materials, chemicals, cement and steel, plus the market for commercial vehicles (with heavy-duty trucks playing the most vital role, as seen on p. 26, while boats and ships, and then planes, will follow later). One opinion shared by everyone who attended the summit was that blue hydrogen will, for now, be the only variant capable of satisfying demand from these markets. And while natural gas will most likely remain an important source of energy in the near future, it will mainly be used to displace coal.

Regulations was another topic of discussion at the summit. Despite a EUR 9 billion budget, the German government has so far spent only EUR 3 million on growing the national hydrogen industry. And besides, there should be some help for consumers, who will be the ones paying for higher carbon prices. Calling on policymakers, the leadership of some of Germany's biggest corporations noted that the entire debate needs a dose of realism. A good deal of the hydrogen required will have to come from abroad, presenting German companies with enormous opportunities in many markets around the world. But what Germany lacks right now, they said, is people with sector-specific expertise.

An oft-mentioned phrase at the event was "technological neutrality," to ensure new technical ideas and concepts are not being sidelined. There were also calls for cutting the red tape that prevents government agencies from a quick response to new developments in the sector. That will require policymakers listen more closely to stakeholders, to encourage more constructive and inventive approaches to establishing a hydrogen economy and fighting climate change. Green hydrogen is not an energy source for the rich. It's a gas that, at some point, each and every one will be able to afford in any amount and any market – maybe even more quickly than expected. ||

Author: Sven Jösting

NIEDERER SUCCEEDS FÜRST

Fig.: Thomas Niederer
[Source: Hydrospider]

Hydrospider, a joint venture of H2 Energy, Alpiq and Linde/PanGas, has appointed Thomas Niederer, 56, to lead the company starting June 1. Hydrospider specializes in the production of clean hydrogen. Niederer previously worked for food retailers, logistics companies and transportation firms. He succeeds Thomas Fürst, who is turning his focus back to managing Alpiq Hydro Aare. ||

OLYMPIC H_2 FLAME

The Olympic flame is to burn with hydrogen for the first time at this Olympics. H_2 gas is already being used in the "baton", which is modelled on a cherry blossom, during the torch relay – at least on some stages. The green hydrogen needed comes from Fukushima. An official from Japan's energy agency said: "This will raise public awareness of the important role hydrogen is to play in the future."

The 121-day run for the "Tokyo 2020 Olympic Games in 2021" started – one year late – on 25 March 2021 at J-Village, the national soccer training facility in Naraha, Fukushima. On 23 July, the Olympic flame will be lit in the cauldron of the Olympic Stadium in Tokyo, after some 10,000 runners have carried it through all 47 prefectures. ||

Category: Politics | **Author:** Sven Geitmann

GREEN HYDROGEN COMES OUT ON TOP

Germany plans to overdeliver on EU targets

Climate change has become a hot topic in the runup to the German election, with politicians imbued with a new sense of urgency. In April 2021, Germany's constitutional court published its ruling on the country's Climate Change Act, triggering the need for swift action to toughen up emission targets: In just a few days the federal cabinet agreed to a new climate law which then quickly received its blessing from the powers that be. Preparations to implement European RED II legislation have also been progressing at speed. So what does this mean for the hydrogen and fuel cell sector?

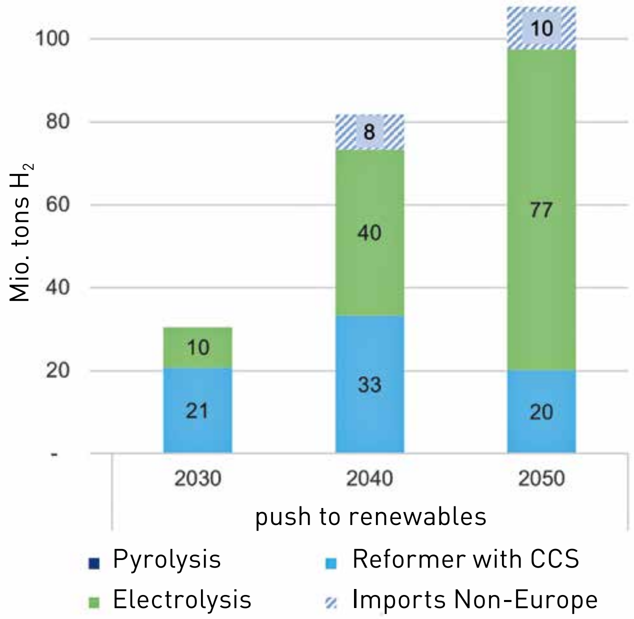

Fig.: Trend in hydrogen production in the EU – scenario: push for renewable [Source: Hydrogen4EU]

It had long been expected that the German government would set out measures to enable the country to implement the European Union's Renewable Energy Directive, RED II. On May 20, 2021, the German parliament passed an amendment that resulted in the 2030 greenhouse gas reduction target for fuels rising from 6 percent to 25 percent. The previous goal had been a 22 percent decrease in emissions. The new law envisages the share of renewable energy as part of overall energy consumption increasing within the transport sector from 10 percent to 32 percent by 2030. This compares to the EU's requirement for road and rail transport of 14 percent.

The German environment ministry, which deemed the RED II agreement a "good compromise," stated: "Along with strong incentives for the use of green hydrogen and support for charging points, our future intention is also to offer support particularly to advanced biofuels that are produced from waste and residue." According to proposals, biofuels made from palm oil will be prohibited from 2023 while targeted funding will be made available for synthetic fuels in circumstances where there are no alternatives to fossil fuels, for instance in aviation. Furthermore, a system of double accounting will be employed to promote the use of green hydrogen in road transport and in refineries. The direct use of power in electric cars is also being encouraged through triple accounting within the greenhouse gas quota.

German economy minister Peter Altmaier explained: "We are prepared to shoulder more than we have promised to do up until now." He also asserted: "I would like us to raise the expansion targets for renewables." While that may be the case, it was Altmaier who had contributed significantly to the decline in the solar industry, and then also the wind industry, by reining in renewable expansion plans in the past.

WHAT DOES "GREEN" ACTUALLY MEAN? To date, refineries have almost exclusively used hydrogen that is derived from fossil energy sources. Now that the use of green hydrogen and orange hydrogen from biomass will be factored into the reduction quota in future, this should increasingly force fossil fuels out of the market for the transport sector as a whole. For aviation, a minimum quota of 0.5 percent will come into force in 2026 for liquid fuels, produced using power-to-liquid technology. The target will then increase to 2 percent from 2030 onward. According to Stefan Kaufmann, innovation commissioner for green hydrogen at the German education ministry, most of Germany's planned 5-gigawatt electrolyzer capacity would be needed to achieve the 2 percent target by 2030, which is why there would hardly be any capacity left for power-to-x fuel production for other sectors.

The day before, the German cabinet had redefined its interpretation of what constitutes green hydrogen. Consequently, hydrogen is designated "green" if it is produced "electrochemically," in other words by means of electrolysis. This new definition is intended to give more clarity when dealing with Germany's redrafted renewable energy law EEG 2021.

In addition, politicians have decided to allow an exemption from the EEG levy for operators of electrolyzer plants producing green hydrogen for an initial 5,500 full load hours. Previously, an exemption of 6,000 hours had been mooted. Nevertheless, critics had warned that such a high figure runs the risk that, instead of just surplus power being used for electrolysis, electrical energy could be siphoned off from the electrical grid. After all, a year is only 8,760 hours long. Hence Greenpeace Energy had requested relief on just the first 3,000 hours.

NO AID FOR BLUE HYDROGEN It has since become increasingly apparent that the German government is focusing its efforts on the use of green hydrogen. Specifically this means that, while blue or turquoise hydrogen will not be banned, green hydrogen alone will be on the receiving end of tax-

> "This decision will see Germany leading the way in renewables within the transport sector. The new quotas for climate-friendly fuels and renewable energy in transport mean that we are going far beyond EU requirements."
> *German environment minister Svenja Schulze*

STARTING SIGNAL FOR THE HEIDEKRAUTBAHN

Instead of the end of 2020, the handover of the funding decisions took place on May 3, 2021. Both the Federal Minister of Transport Andreas Scheuer, and the Brandenburg Minister of Economics, Prof. Jörg Steinbach, as well as the Minister of Infrastructure, Guido Beermann, appeared at the small railway station in Basdorf to hand over the letters of approval for 25 million euros live on site.

This "hurdle-laden project", as Steinbach put it, is about the development of a regional hydrogen infrastructure in the north of Berlin (see H2-international, May 2021, July 2019 and January 2018) as well as the reactivation of the main line of the Heidekrautbahn. Three subprojects are now being funded for the realisation, which has been in progress since 2017: The project developer Enertrag is to receive 13 million euros for the construction of a hydrogen plant, the Niederbarnimer Eisenbahn-Aktiengesellschaft (NEB) will receive 9 million euros in funding to be able to use fuel cell trains on the regional railway line RB27 when the timetable changes on 15 December 2024, and the Kreiswerke Barnim will receive 2.5 million euros for the construction of an H_2 train filling station. A total of about 100 million euros is to be invested in this joint project.

Minister of Transport Scheuer explained: "It's not just the vehicles that are to be moved with hydrogen, but also all the surrounding equipment". According to the current planning, this includes not only a total of six H_2 railcars, but also four hydrogen-powered waste collection vehicles, as Christian Mehnert, managing director of Kreiswerke Barnim, confirmed. According to NEB Executive Board Detlef Bröcker, one hundred per cent of the hydrogen required is to be produced in the Oberhavel district with the help of renewable energies from wind and sun. ||

Fig.: State Minister for Economic Affairs Jörg Steinbach is looking forward to the maiden voyage in 2024

payers' money. Kaufmann explained: "We will not use the multibillion-euro program to support blue hydrogen but we will, nevertheless, see other colors." Simon Marr from the German environment ministry commented that in his department's view there would "only be support for green hydrogen"; the use of other types of gas, however, remains on the table.

The upshot could therefore be that use of gray or possibly even blue hydrogen will continue initially, albeit without the benefit of state assistance, until such time that sufficient quantities of green hydrogen are readily available. Veronika Grimm from the German Council of Economic Experts stated that, at the beginning, there would not be enough green hydrogen which is why blue hydrogen could also be deployed. In her opinion, this "transformational pathway" is necessary. This is a sentiment shared by Martin Daum, chairman of Daimler Truck, who said: "At the start there will only be a very few [hydrogen] trucks on the road, so that it does not matter if this hydrogen is blue or gray."

Rainer Baake, director of Climate Neutrality Foundation, warned that this could lead to "misdirected investments in fossil-based energy." He said: "We must consider where we use public funds. Everyone in this market economy can do what they like, but on their own account."

This standpoint is echoed by members of the gas industry. At the presentation of the Hydrogen4EU study by industry body Zukunft Gas, Johannes Trüby from the consultancy Deloitte expressed agreement, saying: "That can also direct a market. The key point is not the question of public funding, it's about the right framework. It needs to be made clear that clean technologies are worthwhile." ||

Category: Politics | **Interview partner:** Christiane Averbeck

DIRECT ROUTE TO GREEN HYDROGEN

Interview with Christiane Averbeck of Climate Alliance Germany

Discussions around Germany's approach to hydrogen are in full progress. Although several members of the German government regularly emphasize that green hydrogen will benefit the most from public funding, there are also those who want to see blue and turquoise hydrogen playing a key role – with some of those voices coming from Germany's National Hydrogen Council. Two environmental associations, BUND and Climate Alliance, have now distanced themselves from this view by declaring their opposition to the use of fossil-based hydrogen and natural gas. In this interview, Christiane Averbeck, executive director of Climate Alliance Germany, outlines her objections to the strategy discussed by the hydrogen council this spring. Climate Alliance Germany is made up of around 140 organizations from all sectors of civil society. Averbeck has been a member of the National Hydrogen Council since June 2020.

Fig.: Christiane Averbeck [Source: Climate Alliance Germany]

Ms. Averbeck, the National Hydrogen Council – the German government's advisory body – formulated a hydrogen road map in mid-May 2021 and will be presenting this to the government at the beginning of July. You support the resolution, yet you have issued a statement of dissension in the name of Climate Alliance Germany. Why?

Averbeck: Overall, we have developed a good work culture within the hydrogen council. Although its members come from very different institutional backgrounds, they have come together on many issues. However, views regarding the use of fossil-based hydrogen and natural gas as "bridging technologies" strongly differ. We have decided to highlight this with our statement on the recently formulated "hydrogen road map."

Our advice to the incoming government is to concentrate all development funds on the production of green, renewables-based hydrogen. If we want to achieve a carbon-neutral energy system as quickly as possible, we need to have clear prioritization in this regard. That is the point that Climate Alliance and BUND want to make with the joint statement of dissension.

The 27 members of the hydrogen council don't only represent companies who are hoping for new business opportunities from a hydrogen economy, they also include renowned environmental scientists. Did they not share your views or support them at least?

The members of the hydrogen council do have a shared vision of the future – a carbon-neutral, hydrogen-based energy system. But opinions are divided on how quickly this can be achieved and what compromises need to be made to facilitate the industry's transition to a green hydrogen economy. We strongly believe that we should choose the direct route with green hydrogen. Others are more skeptical about this.

Green hydrogen is now being seen as the key resource for an economy and a way of life in which fossil fuels are replaced by carbon-neutral ones and where little else needs to change. What are your objections to this type of solution?

What's clear is that even in a hydrogen economy, we still need to continue finding ways to use energy more efficiently. We will also achieve this aim faster if we fly less and use the car as little as possible. The discussions around green hydrogen – a commodity which is still scarce – indicate that we need to continue examining other patterns of consumerism and behavior. But where we want to see very little change is on jobs, specifically good, secure industrial jobs. Many branches of the economy will need to adjust and adapt due to the climate crisis. And I understand the industrial sector's desire to modernize and protect value chains by means of investment in a carbon-neutral industry.

Don't climate activists face somewhat of a dilemma when it comes to hydrogen? Even now, it's fairly certain that there won't be enough renewable electricity in Germany by 2030 to produce the necessary amounts of green hydrogen. What other option do we have than to use intermediary solutions such as blue hydrogen or natural gas, which at least will significantly lower carbon dioxide emissions?

That entirely depends on which hydrogen demand you define as necessary. If we launch an extensive attempt to rescue the combustion engine through the use of synthetic fuels, the amount of green electricity produced in Germany certainly won't be enough. But by clearly focusing on certain applications, for example the steel industry, Germany may very well be in a position to take its first steps into the hydrogen economy independently. At the hydrogen council, we all agree that the 2030 target of 5,000-megawatt electrolyzer capacity announced by the current government is not enough. If we double this to 10,000 megawatts, it should be possible to cover the steel industry's expected demand for green hydrogen in 2030, which is forecast at 20 billion kilowatt-hours.

In a position paper, your organization limits the use of hydrogen to the truly essential sectors in industry, long-distance travel and heavy transport as well as shipping. At present, Germany can't by itself produce the quantities of hydrogen required even for this. How can we solve this problem?

In the long term, green hydrogen will be an internationally traded commodity. That much is undisputed. The key concern is to steer this development onto a sustainable path. For this, we need to create exemplary production frameworks here in Germany, so that we can incorporate these in the development of European standards. That will certainly take a few years. The frequently cited assertion that international supply sources are more readily available has remained unsubstantiated to date. In fact, the planned cooperation between Germany and Morocco actually revealed that the domestic requirements of potential producer countries don't leave any scope for exports in the foreseeable future. Those who want access to large quantities of green hydrogen by 2030 will most likely need to create their own solutions.

Following on from the coal commission, the founding of similar commissions with involvement of environmentalists was very much in vogue. But both in the agricultural commission and in the case of hydrogen, the inclusion of environmental and climate activists appears to be more akin to greenwashing. Isn't it time to fundamentally rethink the involvement in such committees?

It's difficult to provide a general answer to this, because each of these committees has a different mandate and a different structure. I think it's generally useful to get a wide range of associations and institutions to communicate with each other. For the government, this process can provide new insight. But in order for this to happen, the various interest groups also need to have equal influence on the work carried out by the committee. When industry and industry-related institutions have a structural majority – as is the case in the hydrogen council – it undermines the potential for a well-structured and pluralistic political decision-making process. The incoming government should therefore reevaluate the work of the hydrogen council and possibly reform it.

Interviewer: Jörg Staude, klimareporter.de

Category: Politics | Author: Sven Geitmann |

PRELIMINARY DECISION TAKEN ON HYDROGEN CENTER LOCATION

Bavaria enters final round as clear favorite

The process for selecting the site for Germany's planned hydrogen technology and innovation center ITZ is entering its next stage. Much anticipation had surrounded the announcement of the contest's shortlist. In all, applications had been received from 15 regions. This number then had to be whittled down to just three. On April 28, 2021, the German transportation minister Andreas Scheuer declared that the clear favorite Pfeffenhausen had made it through – as expected (see H2-international, May 2021) – along with the cities of Chemnitz and Duisburg. The intention is now to commission feasibility studies for the finalists in order to better assess the precise potential of each proposal.

Fig. 1: Plan for the hydrogen technology application center WTAZ [Source: Hynergy]

Since the application from Bremerhaven-Stade-Hamburg was judged to be of exceptional interest, Scheuer said, the judging panel decided to grant this project access to additional funding. It is therefore expected that cash will also be made available for a feasibility study to look into the project's main area of focus: hydrogen-fueled aviation and shipping. The 11 unsuccessful applicants will, however, not be left completely high and dry, according to reports. They should be on the receiving end of suitable support as part of Germany's national hydrogen and fuel cell innovation program NIP or through the HyLand initiative.

DIFFICULT DECISION Attendees of the press conference, however, came away with a reinforced impression – not least due to Minister Scheuer's wording – that Pfeffenhausen in Bavaria was the best qualified candidate for the job and could potentially emerge the overall winner at the end of the tendering process. After all, the HyBayern region – home to the Landshut district in which Pfeffenhausen is situated – is already a HyPerformer area and therefore has excellent backing from local industry as well as the region's political establishment.

In response to the question put forward by H2-international about how the contest would ensure that there would be no conflicts of interest within the CSU-led transport ministry, Scheuer only indicated that "we will look at all applications very closely." Yet at the same time he talked about the southern German candidate using phrases such as "impressive application," "the consortium's high level of dynamism" and "proximity to the sites of large automotive companies."

PFEFFENHAUSEN, DUISBURG AND CHEMNITZ Those involved in Bavaria's proposed hydrogen technology application center WTAZ have been working on the design for two years and – it has been hinted by participants – had themselves urged that there should be a tender that generates a lot of additional work but also gives opportunities for other applicants.

A major factor separating the Pfeffenhausen proposal and the technology and innovation center for hydrogen technologies TIW in Duisburg is that many facilities and avenues of support are already present in the area surrounding the ZBT Duisburg – the fuel cell technology center which submitted the application. These include hydrogen laboratories, pipelines, staff and the university as well as a specially trained fire service. Clear plus points for North Rhine-Westphalia on the infrastructure side. In total, over 100 partner organizations have joined together to back the ZBT application.

By contrast, the Bavarian consortium, formed of Hynergy, TÜV Süd, LBST and 70 other supporters, has put forward a greenfield location as the site for the anticipated liquid hydrogen facility which would need to be built from scratch. This is a distinct advantage for Bavaria in terms of securing sufficient land for construction.

LASCHET VERSUS SÖDER? The battle between the regions takes on a particular poignancy due to Germany's forthcoming federal government election in September, with Pfeffenhausen located in the home region of Bavarian Minister President Söder while Duisburg falls under the territory of Armin Laschet, head of government in North Rhine-Westphalia. The two statesmen, who were both recently contenders for the German chancellorship candidacy, brought their regions into the fray at the beginning of the year. For example, Laschet, along with his cabinet, had pledged considerable

"The regional government expressly supports the candidacy of the fuel cell technology center ZBT as a leading institute of a North Rhine-Westphalian consortium in its bid to become the location for a technology and innovation center for hydrogen technology at Duisburg-Hüttenheim."

Armin Laschet, governor of North Rhine-Westphalia

"We will, as the state government, support the Bavarian consortium in its application so that the center comes to the state of Bavaria. Thanks to its hydrogen infrastructure along with numerous research and application projects, Bavaria is best qualified to be a pioneer in hydrogen technology."

Hubert Aiwanger, Bavarian economy minister


Fig. 2: Minister Andreas Scheuer

regional funding. Commenting on this in January 2021, North Rhine-Westphalia's economy minister Andreas Pinkwart said: "If the bid is successful, we want to make up to EUR 50 million in support available through to 2025 for the development of the technology and innovation center for hydrogen technologies." The TIW hydrogen hub would then be built on the site of the Hüttenwerke Krupp Mannesmann HKM steelworks in southern Duisburg.

In a similar move, the Bavarian economy ministry had brought the market town of Pfeffenhausen into the running – almost certainly with the endorsement of Minister President Markus Söder. If a decision were now to go in favor of one of these two candidates so close to the national parliamentary election, it would undoubtedly also have political consequences.

The Hydrogen and Mobility Innovation Center in Chemnitz, Saxony, meanwhile, can apparently only gaze at the action from the sidelines. While it's true to say that the city has submitted a well-considered application, with initially only 25 partner organizations supporting its candidacy compared to the other two heavyweights it would appear that Chemnitz is only "ticking the box" in terms of eastern German representation. That said, Thomas von Unwerth, the university professor leading the charge for Chemnitz, has since indicated that around 60 supporters have announced their backing, among them the state's governor, Michael Kretschmer, and his economy minister Martin Dulig.

So it is perhaps still possible that Chemnitz could emerge victorious from the shadows. North Rhine-Westphalia with its battery factory and three HyExpert regions and Bavaria, which boasts one HyPerformer and three HyExpert regions, are already well funded, while the entire eastern area of the country still remains a blank canvas.

DECISION PRIOR TO NATIONAL ELECTION? Officially, the decision has not yet been taken as to who, in the end, will be able to invest hundreds of millions of euros in their desired location. A demonstration of how not to proceed was clearly provided in mid-2020 during the selection process for the site of a new German battery factory. In that case, the bid was won by the North Rhine-Westphalian town of Ibbenbühren, coincidentally located in the electoral district of German research minister Anja Karliczek who also oversaw the tendering process. In the play out of events, North Rhine-Westphalia gained the upper hand over Ulm in Baden-Württemberg (see H2-international, October 2020) despite the fact that its rival had been, for many observers, the favorite to win.

While admittedly Scheuer's own electoral district is not in Landshut but in Passau (likewise in the administrative district of Lower Bavaria), in the face of last year's experiences it seems all the more important that maximum transparency comes to bear in this current tendering process. For, in addition to the purely financial implications, the political and social fallout potentially caused by grubby dealings could be dramatic should there be any doubt as to the unpartisan nature of the decision-making.

Given that the selection procedure is continuing just as Germany is preparing to go to the polls, the commissioning of feasibility studies appears to be a wise move in order to calmly ensure the complete transparency and traceability of all steps and decisions taken. Should the knock-on effect be that the announcement of the winner is postponed to 2022, at least that would make it crystal clear that there has been a serious attempt to avoid a potential conflict of interest.

And if two or even three victors were selected, with the subsidy pot split accordingly, the benefits of sharing the prize would far outweigh the disadvantages – an appealing scenario also given the great knowledge boost that each German state would experience as a result. The National Organisation Hydrogen and Fuel Cell Technology, or NOW, has for its part signaled that it would be entirely plausible for the decision to be made in favor of several locations, each with a different focus.

SUPPORT BY NOW AND PTJ Information from the German transportation ministry indicates that the 15 submitted proposals were checked and evaluated "neutrally and according to objective criteria" in a dual-control procedure by NOW and the project management agency Jülich, or PtJ for short. The ministry chose the final contestants, it said, on the basis of the prioritization from NOW and PtJ. The planned feasibility study will be reportedly carried out by an external service provider in close consultation with the relevant project leader. Which external provider will undertake this work, H2-international is led to believe, is currently being determined by PtJ via a tendering process which is close to completion.

The transportation ministry is expected to make the final decision on the location by September 2021 once the feasibility studies have been reviewed and assessed by PtJ and NOW. The ministry is intent on keeping to this schedule, it claimed. What's more, the ministry has said it anticipates that the additional feasibility study due to be carried out on the proposed aviation and shipping technology cluster for the Stade, Bremen/Bremerhaven and Hamburg area will provide valuable information about the implementation prospects such a cluster might offer. ||

GERMANY'S TRANSITION TO A HYDROGEN NATION

At the end of April 2021, German transportation minister Andreas Scheuer kicked off a new HyExperts bidding process under the slogan "Germany's transition to a hydrogen nation." German regional bodies had until mid-June 2021 to submit their applications in the second round of the HyLand contest. Previously, a second round of bidding had also taken place for potential HyStarter areas which aim to support the development of networks. The second half of the year is due to see the opening of a new HyPerformer round for applications from larger consortiums (see H2-international's series on Germany's hydrogen regions on p. 24 and H2-international, May 2021).

Category: Politics | Authors: Claudia Kemfert, Sophie Schmalz, Gregor Jaschke, Alexander Franke

HYDROGEN IN CLIMATE PROTECTION: CLASS INSTEAD OF MASS

SRU formulates recommendations to policymaker

For hydrogen to contribute to climate protection, it should be produced in an environmentally friendly way and used sparingly. This is what the German Advisory Council on the Environment (SRU) recommends in a new statement. Accordingly, the market ramp-up should focus on green hydrogen from the outset and be subject to strict sustainability criteria. In the Council's view, the use of hydrogen only makes sense in certain areas.

As the combustion of hydrogen is locally emission-free, it is currently often considered as a climate protection option. Currently, hydrogen in Germany and worldwide is primarily produced from fossil raw materials, especially natural gas. High CO_2 emissions are released in the process. In addition, methane is emitted during natural gas production and transport, a greenhouse gas that is about 84 times more effective than CO_2 (based on 20 years). This so-called gray hydrogen is therefore out of the question for climate protection.

ONLY GREEN HYDROGEN CAN BE SUSTAINABLE Some stakeholders are therefore calling for the use of natural gas-based blue hydrogen. In this process, the emitted CO_2 is partially captured and stored (carbon capture and storage, CCS). In the view of the German Advisory Council on the Environment, however, this is not a recommendable technological path. The CO_2 cannot be completely captured; the methane emissions in the upstream chain cannot be prevented either. Moreover, CO_2 storage is associated with environmental and health risks. Blue hydrogen is not available in the short term because the corresponding infrastructure for CO_2 transport and storage is lacking and would have to be newly built.

Substantial investments in technologies and infrastructures would be needed, which are not compatible with the future greenhouse gas-neutral economy. In the SRU's view, investments and state funding instruments should address green hydrogen exclusively from the outset. This plays an important role in the future energy system and can be produced from water by electrolysis without greenhouse gases using renewable energies such as wind and solar energy.

MINIMIZE THE ENVIRONMENTAL IMPACT OF H_2 PRODUCTION The production of green hydrogen requires large amounts of renewable electricity, as it involves high conversion losses. One third of the energy used in electrolysis is lost at current efficiencies. The losses are even higher for downstream products of hydrogen such as synthetic methane, synthetic fuels, or ammonia (see Fig. 1).

Renewable energies also have negative environmental impacts: large areas of land, raw materials and high amounts of water are consumed. This is all the more serious with hydrogen production, as significantly more energy is required than for direct electricity use due to the conversion losses. Accordingly, the effects of energy production also increase significantly. In order to minimize environmental impacts and social consequences, clear requirements should apply to hydrogen production from the outset (see Fig. 2).

GREEN HYDROGEN REMAINS SCARCE AND VALUABLE If the market ramp-up for green hydrogen in Germany is to succeed, the expansion of renewable energies must be massively accelerated. In the SRU's view, the slump in wind energy expansion is particularly problematic and requires timely solutions. If no new and additional solar and wind energy plants are built for the production of hydrogen, the development of the hydrogen economy will even lead to higher greenhouse gas emissions in the energy system. The opinion therefore shows that the criterion of additionality must be ensured.

As suitable land for renewable energy is limited in Germany, domestic hydrogen production is not expected to be able to fully meet long-term demand. Thus, the import of hydrogen and derived products would also be necessary. However, since renewable energies are also needed in the potential export countries first for the decarbonization of the domestic energy system and not just for green hydrogen, hydrogen will remain a scarce energy source for the foreseeable future.

It is true that the prices for green hydrogen will fall significantly and, in the best case scenario, cost parity with blue hydrogen will be reached as early as 2030. Nevertheless, hydrogen will remain a valuable energy source. Hydrogen will always be more expensive than electricity, as long as taxes and duties are based on the CO_2 and energy content of the energy sources. This is due to the significantly higher primary energy input, which is reflected in higher generation costs.

TARGETED USE OF HYDROGEN Hydrogen can theoretically be used in many areas, but it remains foreseeably scarce and

	Direct use of electricity	Hydrogen	Power-to-Liquid	Power-to-Gas	Ammonia
Renewable electricity	100 %	100 %	100 %	100 %	100 %
Electrolysis		~67 %	~67 %	~67 %	~67 %
PtX process[1]			~70 %	~80 %	~80 %
Overall efficiency	100 %	~67 %	~47 %	~54 %	~54 %

[1] Power-to-Liquid and Power-to-Gas: including Direct Air Capture (DAC)

Fig. 1: Production side efficiencies [Source: SRU]

expensive. In the SRU's view, therefore, its use only makes sense in areas where it brings the greatest benefit for climate protection and no alternative decarbonization options exist.

Particularly in parts of industry and in international transport, there are hardly any alternatives to achieve greenhouse gas neutrality.

Hydrogen will play an important role in industry. To produce steel, the primary steel route from the blast furnace can be converted to hydrogen-based direct reduction. The chemical industry also needs hydrogen as a future raw material base when the use of fossil resources is discontinued. In some industrial sectors, extensive reinvestments are due in the coming years. Due to the long investment cycles, it is crucial that these are channeled into greenhouse gas-neutral technologies.

According to the statement, the use of hydrogen and synthetic fuels also makes sense in international air and shipping traffic. For international maritime transport, ammonia based on green hydrogen as a fuel is an option. Synthetic paraffin could be used for international air traffic, whereby the carbon used for fuel production would first have to be taken from the atmosphere.

In the winter months, hydrogen can also be used to store electricity. However, seasonal electricity storage systems are only necessary when the share of renewable energies in the electricity system is very high. If there is hardly any wind and little sunshine over a longer period of time, green hydrogen could be converted back into electricity and thus balance out the supply and demand for electricity.

TOO INEFFICIENT FOR PASSENGER CARS AND HEAT The SRU, on the other hand, takes a critical view of the use of hydrogen for passenger cars and the provision of heat in buildings, as more efficient alternatives exist. Battery electric vehicles are clearly advantageous: Vehicles with fuel cell drives require (well-to-wheel) two to three times more primary energy input, while vehicles powered by combustion engines using synthetic fuels require as much as five to six times more primary energy input. Heat pumps can be used for the building heat sector. Even assuming a moderate annual performance factor of 3, these require four to six times less primary energy input than heating with hydrogen or synthetic gas. In addition to decentralized heat pumps, heating grids based on renewable energies are also an important component, especially in densely populated areas.

Despite the obvious disadvantages, some stakeholders are pushing for hydrogen to be used in passenger cars and for heating buildings. The SRU recommends that the Federal government send clear signals that the use of hydrogen is not expedient here and will not be promoted.

BUILD UP INFRASTRUCTURE ACCORDING TO DEMAND Initially, hydrogen will probably be produced close to industrial consumers, but to keep things in perspective, a transport infrastructure is required. The SRU does not consider blending into the natural gas grid to be a good idea. Green hydrogen is scarce and mixing it with natural gas would be tantamount to wasting the scarce energy source. In addition, those consumers who need pure hydrogen for their processes and who have no climate-friendly alternatives to hydrogen use would be excluded. In addition, blending in larger quantities can cause problems for parts of the infrastructure and some consumers.

The conversion of natural gas pipelines to pure hydrogen pipelines is also technically non-trivial and requires

Dimension	Environmental and social requirements
Electricity consumption of electrolysis	o New, additional renewable energy plants o System-friendly operation of electrolysers by geographic proximity to renewable energy production and avoidance of additional bottlenecks in the grid
Other emissions related to production and transport	o Greenhouse gas accounting of hydrogen and products derived from it (PtX) for all process steps o For low-carbon hydrogen (via steam reforming): Accounting for both upstream emissions and emissions in CCS process
Additional environmental impacts	Reduction of environmental impacts along the full value chain, for example by o Excluding certain terrestrial and aquatic areas from potential sites for electricity generation, hydrogen or PtX infrastructure, and avoiding damage to these areas (e.g., protected areas, biodiversity-rich ecosystems, or areas hosting rare, endangered, or threatened species or ecosystems) o Assessing and avoiding environmental risks, for example through environmental assessments o Efficient and environmentally friendly use of land and water resources o Environmental requirements for resource extraction and for construction, operation and disposal of facilities (e.g., for electricity or heat generation, desalination of sea water, electrolysis, carbon capture) o Terms and conditions for the extraction of surface or ground water, considering local water availability
Social impacts	Establishing social standards along the full value chain, for example, avoiding negative impacts on the local population in countries producing hydrogen with respect to o Drinking water supply o Food security o Health, human rights, labor rights, access to natural resources including informal and formal land and water rights

Fig. 2: Criteria for H_2 production [Source: SRU]

further research. How large the future hydrogen grid is to be depends on the areas in which hydrogen is used. Therefore, directional decisions for the consumption sectors are also crucial for the development of the hydrogen infrastructure. Overall, however, it can be assumed that the hydrogen grid will be significantly smaller than the current natural gas grid.

INITIATE OIL AND GAS PHASE-OUT So far, the agreed climate protection targets have not been sufficiently taken into account in the planning of natural gas infrastructure. However, adequate infrastructure planning should be guided by compliance with climate and sustainability goals. The conversion of natural gas pipelines to hydrogen pipelines must not be used as an argument to continue investing in the already oversized natural gas infrastructure. In the view of the SRU, the Federal government should initiate the phase-out of the use of oil and natural gas in the coming legislative period. The phase-out of fossil energy sources must be linked to the switch to renewable energies. This requires an overall concept for decarbonization that is cross-sectoral and oriented toward the climate goals. Clear political signals can reserve green hydrogen for sensible uses from the outset, prevent structural breaks and prevent further misinvestment in fossil technologies and infrastructure. ||

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Category: Stationary systems | **Author:** Sven Geitmann |

METAL HYDRIDE AS H_2 STORAGE FOR ALPINE RESIDENTIAL BUILDING

Seasonal storage of hydropower

Fig. 1: The Miner's house with Hy2green energy supply (see p. 19) [Source: GKN]

Up to now, hydrogen has generally been stored in a gaseous state – both in the mobile and stationary sectors. But there are other possibilities: For example, a group of companies has applied the same technology to a South Tyrolean residential building that is also used in fuel cell-powered submarines: Metal hydride storage. With their help, a seasonal energy transfer of hydropower from summer to winter is being tested as part of a demonstration project.

Instead of storing hydrogen at high pressure (gaseous hydrogen, GH_2) or at low temperatures (liquid hydrogen, LH_2), the H_2 molecules can also be incorporated into metal compounds. The volumetric storage density in such metal hydride storage tanks is relatively high compared to compressed gas cylinders.

In 2019, a 10 kW energy system with such a metal hydride storage system was installed in the Miner's house in Prettau and has since been tested. If the metal hydride is filled with hydrogen, heat is released (exothermic). If the storage system is to release H_2 gas, it must be heated (endothermically) so that the molecules break away from the lattice structure. The thermal energy for desorption (H_2 release) is taken from the fuel cell system to desorb the stored hydrogen from the lattice structure of the metal hydride. In addition, a wood pellet stove for heat supply and four lithium iron phosphate accumulators with around 10 kWh storage capacity for uninterruptible electricity supply are installed.

The Miner's house in the Ahrntal is located at 1,400 m above sea level and has no public electricity connection. Instead, the extensively renovated and expanded building in the Italian Alps is supplied with energy via a Pelton water turbine (8 kW). However, since the water inflow is lower in winter due to frost, there used to be an oil generator for which an alternative should be found.

With the solid storage facility realised in 2019, hydrogen can now be produced by electrolysis from the purified spring water using electricity from the turbine and stored in the metal pellets (iron-titanium alloy). On demand – especially in winter – the chemically stored energy can then be converted into electricity and heat with the help of a polymer electrolyte membrane fuel cell. The compact unit is throttled to around 6 kW of electrical power and supplies electricity and heat with an efficiency of around 50 percent.

The Hy2green metal hydride storage consists of eight storage bottles, each filled with 82 pellets of pressed metal powder. The metal reacts with hydrogen to form metal hydride and stores the hydrogen chemically at a maximum of 40 bar. Each bottle weighs around 100 kg and can store around 1 kg of hydrogen with an energy content of 33 kWh. Alfons Geueke from Business Development Hydrogen Storage at GKN put the H_2 storage density at 1.7% by volume and explained that this relatively small amount of hydrogen in terms of volume is one reason why the company is focusing on the stationary sector.

For comparison: In a fuel cell car, this amount of energy is sufficient for a driving distance of about 100 km. In the Miner's house, it can be used to take a hot shower for about an hour and also to wash clothes 16 times. The total capacity is sufficient to supply a four-person household with electricity for about twelve days and heat for an additional six days. According to GKN employee Martin Beikircher, the benefits of this system are high purity of the gas, short control times and high efficiency.

GKN LAUNCHES H_2 BUSINESS UNIT The powder metal solutions provider is increasingly focusing on the hydrogen sector. In mid-May 2021, for example, the company, which belongs to the British investment company Melrose PLC, opened a new, fourth business unit, GKN Hydrogen in Bruneck, which is to be dedicated in particular to the storage of renewable energies via hydrogen. The company promotes this technology as "reliable", "robust" and "safe". It is said that H_2 storage in metals is a compact solution for storing hydrogen in the long term for a wide range of applications. Even storage over months and years is possible almost without loss.

According to GKN managing director Peter Oberparleiter, this technology is marketable, albeit still very expensive. So far, the company has three storage sizes on offer: HY2MINI (10 to 25 kg_{H2}), HY2MEDI (60 to 120 kg_{H2}) and the HY2MEGA (260 kg_{H2}, see Fig. 2).

Another larger hydrogen project is already being planned in the Puster Valley. In addition, GKN is in contact with a major Italian shipbuilder who wants to build a hydrogen-based test ship. ||

Fig. 2: The HY2MEGA storage system with a capacity of 4.5MWhel. [Source: GKN]

> "When I visited this hydrogen house, I had the feeling that this pilot project will still make history in the development of a sustainable energy supply."
>
> *Winfried Schneider, Managing Director IBN*

Category: Energy storage | **Author:** Franz Josef Radermacher

METHANOL AS A CENTRAL BUILDING BLOCK OF A SUSTAINABLE ENERGY FUTURE

Guest commentary by Prof. Dr. Dr. Dr. h.c. Franz Josef Radermacher

Germany focuses too much on national goals in the fight against climate change (climate nationalism). However, these are of little relevance in the global context. This focus leads to unfavourable strategies, for example in the areas of green electricity, green hydrogen and synthetic fuels. All considerations are dominated by scarcity and too high costs. Because in Germany people want to produce themselves what should be imported wisely. Just as 70 per cent of energy has been imported up to now.

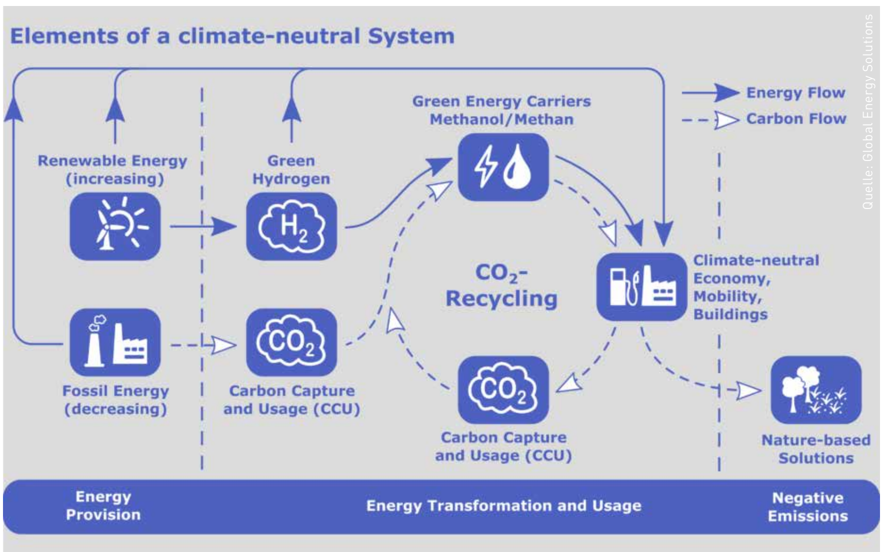
The topic of climate protection is extremely complex. Global CO_2 emissions continue to grow. The Paris Treaty contains ambitious targets, but no matching commitments and measures. The negative dynamics in the climate sector result from the understandable economic aspirations of many poorer countries towards catch-up prosperity.

China is leading the way, but is subsequently emitting a third of global CO_2 emissions and continuing to increase them. In parallel, the world population is growing at a rapid pace. By 2050, about 2.5 billion people will be added, once the population of the Federal Republic of Germany each year.

German and European climate policy is not very concerned with these issues. We are primarily concerned with reducing our own CO_2 emissions. This is of little relevance to the world's climate, but it requires all our attention and enormous financial and intellectual resources. We are fully committed to electro-mobility, not to climate-neutral synthetic fuels for passenger cars, among others for the global existing fleet. Nuclear power is rejected across the board, as is the capture and use of CO_2 from industrial plants and coal-fired power stations.

SYNTHETIC ENERGY SOURCES ARE AN ALTERNATIVE Would there be alternatives? Yes, because Germany is a high-tech country and the world needs new technical solutions. Huge amounts of cheap green electricity from the great sun deserts, green hydrogen as a by-product from these regions, derived synthetic energy sources such as methanol and methane for use everywhere in the world would totally change the situation.

Siemens Energy and Porsche are currently pursuing this path in the Haru Oni project in Chile. In this context, the recycling of CO_2 from power plants and industrial facilities and their conversion to climate neutrality using green methanol and methane as an energy source is also interesting. From the above follows a three-step approach leading from green electricity via green hydrogen to synthetic fuels, especially methanol.



GREEN ELECTRICITY Over the last decades, the possibilities to produce green electricity, i.e. renewable energy in electricity form, have greatly improved, especially via large installations of photovoltaic plants and via large onshore and offshore wind power. Particularly interesting – also from a development perspective – are the potentials in the world's great sun deserts. Germany is not a good location for green electricity. Despite a very high subsidy via the EEG, the yield is only seven percent of the useful energy used. The high volatility of production drives the cost of electricity very high in terms of total cost of ownership. This blocks the widespread use of green electricity for a variety of downstream productions, especially for green hydrogen.

The world needs cheap green electricity in huge quantities if a climate catastrophe is still to be prevented. The author calculates up to 400,000 TWh for the whole world in 2050. This includes the further growth of the world population, the hoped-for further increase in prosperity (especially in poorer countries) and the lower energy efficiency in poorer countries. The energy losses when green electricity is transferred to other forms of use (e.g. e-fuels) are also taken into account. Total electricity production in Germany today, including electricity from coal, is around 700 TWh. The German Federal Minister of Research, Anja Karliczek, wants to cover about 800 TWh of Germany's energy needs from green hydrogen by 2040. She recently presented the Potential Atlas, which shows a potential for 165,000 TWh of green electricity per year in West Africa alone.

What does this imply? The community of states should ensure that a great deal of this green electricity is produced around the world in the right places, and at a cost that is not much higher than the current cost of energy use in an international comparison. Ultimately, this green electricity and its downstream products (such as green hydrogen) must largely replace today's primary energy sources of coal, gas and oil.

Reasonably, the green path should be made so attractive primarily via cost arguments, only secondarily via temporary public subsidies, that, among other things, the corresponding corporations, industries and states coming from the fossil energy sector no longer put their money into the exploration of fossil energy sources (so far about 600 billion US dollars per year), but instead produce large volumes of green electricity (and subsequently also green hydrogen) in suitable places – above all in the sun deserts of the world – for the reason that it pays off.

GREEN HYDROGEN In many applications, energy is required in a form that is not electrical and detached from a conduction system. Today, fossil energy sources play a central role in this context, partly used to generate electricity, but also in a completely different form (e.g. as fuels). Green hydrogen opens up new options in this context. Therefore, it was always clear and is becoming increasingly clear that green hydrogen is urgently needed as another component alongside green electricity, and in large quantities. This is now also part of the German debate.

With this broadening of the view of the topic, the path to a new world of energy no longer stands on one leg (green electricity), but on two legs (green electricity and green hydrogen), whereby very large amounts of green electricity are needed for the production of green hydrogen, not least because of the conversion losses (about 30 percent) compared to the direct use of green electricity. Green hydrogen is therefore a by-product of green electricity, which in particular is great for energy storage. Many applications need energy in a form other than electricity. This is how green hydrogen and its derivatives come into play.

From a German perspective, there is the problem that we cannot supply ourselves with either green electricity or green hydrogen – just as we cannot currently supply ourselves with fossil energy sources locally. In addition, green hydrogen is far too expensive in our country to make it possible to use it competitively worldwide. Politicians are addressing this problem in the German hydrogen strategy with funding programmes for green hydrogen (e.g. H2 Global), but also by promoting a green "ramp-up" in Germany.

From the author's point of view, the debate on green hydrogen in Germany and Europe is still far too much determined by the unrealistic idea of some stakeholders that the renewable energy we use should be produced to a large extent in Germany or Europe. We don't have the land or the right sunlight for that. Ultimately, it is hard to understand why there is such a fixation on the production of energy sources locally. Oil, gas and coal are also imported – to our own benefit, because our technology is exported in return. As the "export world champion", our balance of payments has always contained considerable surpluses. It is hard enough for the world to bear.

SYNTHETIC FUELS (E-FUELS) However, green electricity and green hydrogen alone are not enough for a global climate-neutral future. With international production, transport problems remain, which are serious in the case of hydrogen, especially when transporting it across large oceans. That is why we need a third pillar in addition to green electricity and green hydrogen. This third pillar leads to e-fuels or also reFuels (regenerative fuels).

Because of the geographical and climatic conditions alone, we need this third component, namely as an energy source, in order to be able to store and transport the energy. Synthetic fuels, such as green methanol, green methane and green ammonia, are suitable for a wide range of applications and can be manufactured from green hydrogen. Various synthesis methods exist for this. For example, there is the direct synthesis pathway and the Fischer-Tropsch line.

For various reasons, the author finds the technology path via the direct synthesis of methanol and methane particularly attractive. Both substances are very good for energy storage and comparatively easy to transport. The methanol track in particular opens up a broad field in the direction of diverse applications. The green methane track – like the methanol track – leads in the direction of gas applications, e.g. heat/cooling in houses or (coal) power plants, but also to the topics of steel and cement. The topic of heating/cooling is of central importance, as we all know, and there are smarter, and above all cheaper, solutions for this than focusing exclusively on the expensive energy refurbishment of buildings, namely the use of climate-neutral synthetic heating oil.

Starting from methanol, the paths to synthetic petrol, diesel, paraffin, marine fuel and heating oil are promising. It is these reFuels that help to transform our civilisation towards climate neutrality at a sustainable cost. The recycling of CO_2 from industrial facilities and power plants and the use of CO_2 for the production of synthetic fuels play a major role in this. This is a great advantage of the path described here.

In particular, such reFuels offer a realistic option for moving the total number of vehicles with combustion engines worldwide in the direction of climate neutrality. Individual mobility plays a central role here, as does individual heating and cooling. In the mobility sector, we are talking about around 1.3 billion vehicles worldwide, which release a total of around 5 billion tonnes of CO_2 into the atmosphere every year. This is almost double the CO_2 emissions within the EU.

Overall, the path described is embedded in an environment that has been worked on for decades, for which the term methanol economy is also used. Methanol is the second most synthesised energy fluid in the world today (albeit in "black" form). The world market leader is China. Methanol from coal is used there to reduce the import requirements for oil. ||

GLOBAL ENERGY SOLUTIONS E.V.
The association Global Energy Solutions e.V. tackles the topic in a very fundamental way. A lot of supplementary information can be found on the homepage, in particular a one-pager and a graphic that presents the approach in its entirety.

→ https://global-energy-solutions.org

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Category: Energy storage | Authors: Moritz Kühnel, Sylvia Schattauer, Nora Denecke, Sebastian Schmidt

FRAUNHOFER HYDROGEN LABS

Test centres for industrial hydrogen technology start operation

The industry needs reliable technologies for the broad application of green hydrogen. In the Hydrogen Labs, the Fraunhofer-Gesellschaft is pooling its expertise in the generation and use of green H_2 and creating a unique research infrastructure for practical performance and load tests on an industrial scale in order to decisively advance the development of H_2 technologies suitable for mass production and thus the market ramp-up.

Fig. 1: Test area of the Hydrogen Lab Leuna [Source: Fraunhofer IMWS / Moritz Kühnel]

The national hydrogen strategy has placed green hydrogen as a key component in the focus of the energy turnaround. The annual production capacity of 14 TWh of green hydrogen targeted by 2030 poses enormous challenges for existing technologies, which can only be overcome by a significant research and development push. In addition to the scaling of electrolysers into new performance classes, the development of more efficient and cost-effective components and the establishment of series production, operational reliability and economic efficiency in real operation play a decisive role in the targeted market ramp-up.

Electrolysers are preferably operated at static load to maximise efficiency and economic efficiency with predictable degradation. In order to produce green hydrogen, however, electrolysers must be powered exclusively by electricity from renewable sources, the availability of which is subject to strong fluctuations. Extensive tests under such dynamic conditions are indispensable for an accurate prediction of service life and economic efficiency in long-term operation under fluctuating loads.

However, test facilities with the necessary infrastructure are rare, especially for the electrolysers in the MW range, which are becoming increasingly important. In addition to a sufficient supply of ideally green electricity and, depending on the type of electrolyser, water or steam, the sensible use of the hydrogen produced on a considerable scale (a 1 MW electrolyser produces over 200 Nm^3 H_2 per hour) plays an important role, both for reasons of safety and from an economic perspective.

Many companies – especially small and medium-sized companies that drive new technologies with high innovation potential – cannot afford the high investment costs for their own test infrastructure. The Fraunhofer-Gesellschaft has set itself the task of providing an open-technology test platform for plants for H_2 production and related processes such as storage, compression, purification, transport, utilisation, etc., including scientific support, and is thus making an important contribution to the rapid implementation of the hydrogen strategy in practice.

LEUNA – GREEN HYDROGEN FOR THE CHEMICAL INDUSTRY In the Central German Chemical Triangle, the Fraunhofer-Gesellschaft has now given the go-ahead for a new generation of test infrastructure that can precisely serve this demand with the commissioning of the Hydrogen Lab Leuna (HLL, see Fig. 1), which is funded by the state of Saxony-Anhalt and the EU. Embedded in the materials network of the Leuna Chemical Park, the HLL offers four test stands for electrolysers with a connected load of up to 5 MW, which are supplied with deionised water, steam, compressed air, nitrogen, hydrogen and CO_2. The green hydrogen produced is analysed and processed on site and can be fed directly into the 157 km long H_2 pipeline, distributed to the industrial sites in the region and used there in chemical processes.

At the HLL, industrial-scale electrolysers of any type – whether PEM, AEL, AEM or SOEC – can be tested in continuous operation around the clock, with dynamic load profiles simulated when operating with electricity from photovoltaic plants and wind energy plants in order to investigate performance, economic efficiency and long-term behaviour in real operation. This data provides the basis for future certification, which gives buyers certainty about the reliability and efficiency of such plants.

The expertise of the Fraunhofer IMWS in microstructure analytics make it possible to trace back degradation phenomena on critical components such as membranes, bipolar plates or power electronics to material properties and to use these findings to continuously develop materials and components together with the manufacturers. To this end, additional test stands for electrolysers up to 50 kW will enable the investigation of new components as well as operation under particularly challenging conditions (mechanical and thermal load) in an attached pilot plant.

Together with the Fraunhofer IGB and its CBP department, the hydrogen generated green at HLL can also be used on site on the Hy2Chem scaling platform to validate power-to-X processes for the sustainable synthesis of chemical feedstocks such as methanol from CO_2, also on an industrial scale. Thanks to the integration of the HLL into the Leuna chemical site and its materials network, model processes for sector coupling can thus be demonstrated directly at the chemical industry site and tested under realistic conditions.

BREMERHAVEN – WIND ENERGY FOR GREEN HYDROGEN

The Hydrogen Lab Bremerhaven (HLB) focuses on the interaction of wind energy plant with electrolytic H_2 generation. The increasing decentralisation of electricity generation through the integration of renewable energies places high demands on the power grids, which have so far been designed for the parallel operation of centralised large-scale generators. Particularly in the context of offshore wind farms, the development, assessment and operation of which are part of the core expertise of Fraunhofer IWES, there is a considerable need for optimisation to ensure security of electricity supply.

Direct onshore and offshore production of green hydrogen has a high potential to increase the safety of supply in decentralised power grids by smoothing supply and demand peaks through the production and reconversion of H_2. When the HLB, which is funded by the state of Bremen and the EU, is completed in 2022, this very approach will be tested there on ten test plots for electrolysers with a total output of up to 10 MW, which will prospectively be supplied with electricity by an 8 MW wind turbine installed on site, among other things.

The electrical properties of electrolysers in interaction with the fluctuating power feed-in from wind energy can be investigated on PEM and alkaline electrolysers in order to gain insights into how electrolysers and their power electronics must be constructed in order to have a grid-stabilising effect and thus make the power grid of the future reliable and flexible. For this purpose, the electrolysers are connected to the virtual 44 MVA medium-voltage grid of the Dynamic Nacelle Testing Laboratory (DyNaLab), the leading facility for grid integration testing of wind turbines, which allows real operation to be simulated.

The areas for the test operation of electrolysers will be available for interested industrial companies. Currently, the Fraunhofer IMWS and IWES, among others, are developing electrolysers for offshore operation together with industry as part of the BMBF joint project H_2Mare. The HLB also focuses on integrating the production, storage and use of hydrogen to build a local H_2 economy. Thus, not only are H_2 gas tanks and fuel cells kept on hand, but local project partners are also investigating the use of H_2 in the food industry as well as the production of SNG and methanisation processes.

GÖRLITZ – SUSTAINABLE STRUCTURAL CHANGE WITH GREEN HYDROGEN The energy turnaround towards an economy without the use of fossil raw materials heralds a profound change in energy-intensive industry. To achieve this, a number of technologies must be combined into an H_2 value chain, starting with the development of efficient electrolysers and fuel cells for mobile and stationary applications, via practicable methods for storage and transport, to the cost-effective series production of such plants. In order to develop holistic solutions for this complex of topics, the Fraunhofer IMWS and IWU are jointly realising the Hydrogen Lab Görlitz (HLG, see Fig. 2), which is scheduled to start operations in 2022.

The construction is supported by the Sächsische Aufbaubank and the BMWi. In close cooperation with Siemens Energy, the transformation process of the turbine manufacturing site there is to become an innovation epicentre in the middle of the Lausitz lignite region and serve as a blueprint for successful structural change throughout Germany and Europe. The HLG creates a unique research and development platform for the power-to-H_2-to-power value chain, which is crucial in the industrial and mobility sectors. For this purpose, a multi-strand chain of electrolysers, pipeline systems, H2 storage facilities and fuel cells with a total capacity of 12 MW will be installed, in which individual links can be replaced by test plants in order to evaluate their real operation in the overall context of the value chain.

In addition to test operations, the focus of research activities is on the development of components and manufacturing technologies for electrolysers and fuel cells that are suitable for large-scale production, as well as on the digitalisation of H_2 technology. For the automatic identification of optimisation potential, digital twins of the components to be examined are to be created automatically with the help of suitable sensor technology. For this purpose, hierarchical models are developed and parameterised on the basis of measurement data. In addition to networked further development of electrolysers and fuel cells, digital twins enable real-time monitoring of production as well as predictive control of plant operation with the aim of maximum economic efficiency and longevity.

CONCLUSION The Hydrogen Labs offer a versatile, digitally networked and thus uniquely powerful test infrastructure with over 25 MW of connected power for all key technologies and application fields of the hydrogen value chain. The Fraunhofer-Gesellschaft is thus sending a strong signal as a pioneer for the green energy transition. ||

The Hydrogen Labs are being created in cooperation with the Fraunhofer Institute for Microstructure of Materials and Systems IMWS, the Institute for Wind Energy Systems IWES, the Institute for Machine Tools and Forming Technology IWU and the Institute of Interfacial Engineering and Biotechnology IGB.

→ www.hydrogen-lab.de

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Category: Energy storage | **Authors:** Johannes Gulden, Romy Sommer, Gunnar Wobig

BUILDING A HYDROGEN ECONOMY ON THE BALTIC SEA COAST

Fifth part of the Regions series: HyStarter Rügen-Stralsund

What role can the production of green hydrogen play in the future for regional added value creation in a rural, structurally weak, but large area region with a high share of renewable energy production capacities? Which generation paths make sense at different locations, and which framework conditions must be fulfilled in order to achieve this? Where is there potential for hydrogen applications in the district of Vorpommern-Rügen? With these questions in mind, the HyStarter Region Rügen-Stralsund started a one-year strategy process in December 2019 to develop a vision, define fields of action, analyse selected locations and technology concepts, and adopt a roadmap until 2030 that describes a whole bundle of measures to be implemented in the future.

Fig. 1: Rügen Bridge Dänholm [Source: LEKA]

With the Institute for Regenerative Energy Systems at Stralsund University of Applied Sciences, there has already been expertise and experience in hydrogen technology in the Vorpommern-Rügen region for over 25 years – both in teaching and research. In the HyStarter region of Rügen-Stralsund, however, the implementation of this technology is still in its infancy. Vorpommern-Rügen is a coastal region, characterised by port industry, ship and boat building, tourism and agriculture. Here, where there is a unique natural setting with several large, protected areas and sustainability plays an important role, there is potential to promote emission-free mobility on the water as well as on land. Due to its geographical location, the region is an important renewable energy generation site. High capacities of installed wind power capacity offer ideal conditions for the production of green hydrogen.

There are currently 230 wind energy plants (WTs) in 67 wind farms in the district with an installed capacity of 378.4 megawatts. In addition, 2,187 photovoltaic plants (PV) with a capacity of 352 MW have been installed in the district so far. In addition, there are 49 biomass plants that are used in particular for the supply of heat. Although electricity can increasingly be generated from renewable energies, there are major challenges to be overcome with sector coupling.

There are many potential hydrogen consumers in the district: The existing maritime economy wants to reduce emissions in the long term, and tourism has a strong sustainability claim. New mobility solutions have to be found, especially for the busy summer with its high traffic volume. The high proportion of individual mobility as well as the greater distances for public transport and logistics providers pose particular challenges for mobility here. There is also pressure to decarbonise the heating sector, which is primarily characterised by fossil energy sources.

The business landscape is characterised by a small-scale structure. The district of Vorpommern-Rügen has the lowest industrial density in Mecklenburg-Vorpommern. The most important industrial sectors include the maritime industry, the food industry, mechanical and plant engineering and the production of metal products. The production and regional utilisation of hydrogen would create new potential for the establishment of companies and the development of a new branch of industry. In particular, the transformation of the local ports into energy locations and the development of green business parks are overarching goals. This is where HyStarter, with the support of Spilett, Becker Büttner Held Consulting, the Reiner Lemoine Institute, the Choice Group and Energy Engineers, comes in to take advantage of this starting position.

VISION AND OBJECTIVE In a total of six HyStarter strategy dialogues, the following fields of action and a large number of proposed measures for hydrogen production and utilisation as well as preparatory site development concepts were defined, which are located in the H_2 ideas map below:

- Hydrogen production (from wind and photovoltaics, from post-EEG plants, from plasmalysis)
- Hydrogen use in mobility (acquisition of FC buses in local public transport, in regional fleets, agricultural vehicles and for trains)
- Hydrogen use in the heat sector (H_2-ready CHP plants for building energy supply, neighbourhood concepts and integration into heat grids, alternatives for gas and oil heating)

> "Hydrogen must be considered holistically, i.e. from production to consumption."
> *Prof. Dr Johannes Gulden, Head of the Institute for Regenerative Energy Systems at Stralsund University of Applied Sciences*

> "Not only do we have a good network and numerous ideas, but we can also move promptly into implementation."
> *Gunnar Wobig, Managing Director of Landesenergie- und Klimaschutzagentur Mecklenburg-Vorpommern GmbH*

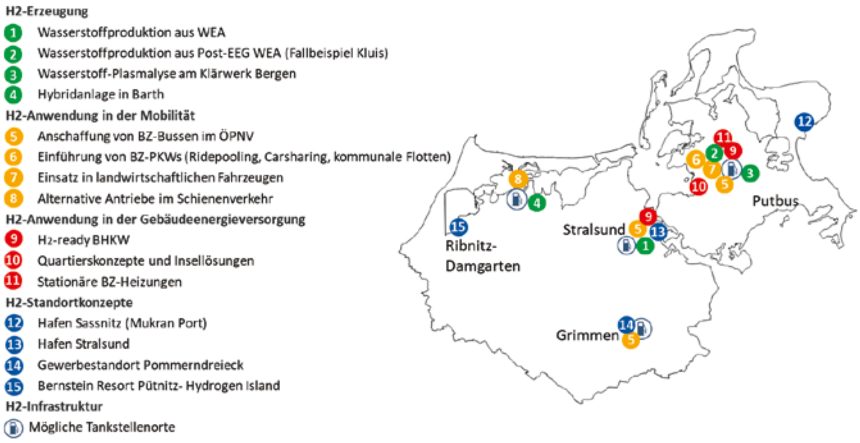

Fig. 2: Ideas map [Source: LEKA]

- Hydrogen site concepts for the ferry port of Sassnitz as a future PtX pilot location, the seaport of Stralsund as a hydrogen port, the commercial location of Pommerndreieck as a producer location and H_2 hub as well as the Bernstein Resort Pütnitz

IMPLEMENTATION It is a long way from "wanting" to "doing". Legal framework conditions are still an obstacle, as are the comparatively low costs of fossil energy sources, which continue to compete with the calculated hydrogen production costs. Therefore, the planned measures have different priorities and time horizons. The work in the hydrogen region Rügen-Stralsund has also shown how important it is to network regional stakeholders on the production and consumer side and to accompany emerging project ideas.

Up to now, this support has been provided by a team of advisers commissioned by NOW. In order for the proposed measures to be implemented and the network to be sustainable in the long term, capacities must be made available in the municipalities and companies. The first step for the HyStarter Region Rügen-Stralsund is now to establish a hydrogen coordinator in the district who will hold together the active network with currently 16 core team members and a growing number of interested stakeholders and attract new partners from the business community. The Stralsund University of Applied Sciences is available as a scientific partner to provide advice. A newly established generator consortium consisting of Mukran Port, Seehafen Stralsund, Stadtwerke Stralsund and EnergieWerk Rügen is already planning the next steps to prepare concrete investments. A first measure is a HyExperts application, which is submitted by the consortium. ||

→ www.leka-mv.de/themen/wasserstoff/

THE HYSTARTER CORE TEAM OF THE RÜGEN-STRALSUND REGION

EnergieWerk Rügen e. G. | Hansestadt Stralsund | Hochschule Stralsund / Institut für Regenerative EnergieSysteme | Landesenergie- und Klimaschutzagentur Mecklenburg-Vorpommern (LEKA MV) | District of Vorpommern-Rügen | Mukran Port (Fährhafen Sassnitz GmbH) | Nachhaltigkeitszentrum Rügen e.V. | SWS Seehafen Stralsund GmbH | SWS Energie GmbH | Tourismusverband Rügen e.V. | UmWeltSchule Rügen e.V. | Weiße Flotte GmbH | Wirtschaftsfördergesellschaft Vorpommern GmbH | Verkehrsgesellschaft Vorpommern-Rügen mbH (VVR) | Zweckverband Wasserversorgung und Abwasserbehandlung Rügen (ZWAR)

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

HIGH EXPECTATIONS FOR H_2 TRUCKS

Two truck heavyweights become partners

Volvo and Daimler have substantiated their plans to use hydrogen for large long-distance trucks. During an online presentation event at the end of April 2021, Martin Lundstedt, President of the Volvo Group, specifically named the high possible payloads and the long ranges as decisive criteria for the use of fuel cell technology. He also held out the prospect of large-scale production starting after 2025 and a gigafactory for fuel cells being built by then. Initially, pre-series production is to take place in Esslingen near Stuttgart. The final location question is to be clarified in 2022.

Martin Daum, Chairman of the Board of Daimler Truck AG, announced that in 2040 – or earlier – the last combustion engines would be sold, i.e. that from then on the company would be CO_2-neutral. He stressed the need for a second energy storage system in addition to batteries. He said: "We need a second source of energy – and that source is hydrogen." According to him, 2027 will be the year when things "really start happening". In concrete terms, this means that initial road tests are planned for the next few months, followed by customer trials in 2023 and the first series production vehicles of the GenH2 truck from 2027. Larger numbers are therefore not expected until the end of the decade at the earliest. Regarding a competitive situation with Volvo, Daum explained: "We are competitors in terms of vehicles, but when it comes to the H_2 power unit, we work together."

To date, the FC fleet has mainly consisted of passenger cars, but will be increasingly supplemented by commercial vehicles in the coming years (see Fig. 2). In terms of consumption, H2 Mobility expects the light-duty vehicle (LCV) sector and, especially towards the end of the decade, the heavy-duty sector to decrease significantly. According to the study, of the 9,000 fuel cell vehicles expected in Germany by 2025, 16 percent will initially be trucks and then 38 percent by 2030. Light-duty vehicles are projected at 25 per cent in the medium and long term, with the total number of FC vehicles potentially exceeding 100,000 by 2030. "The stock of trucks larger than 3 t will exceed the stock of buses by 2025. In Switzerland, you can already see the monthly delivery volumes for a truck in regular operation," Nikolas Iwan, managing director of H2 Mobility, told H2-international.

GENH2 FUEL CELL TRUCK BY MERCEDES-BENZ

- For 40 t total weight
- Service life: at least 1 million kilometres
- Two stainless steel tanks with 40 kg capacity
- 300 kW FC system consisting of two stacks with 200 individual cells each
- High-voltage battery, between the two tanks (400 kW)
- Two electric motors with 230 kW continuous output
- More cooling capacity than a diesel vehicle
- Size of the FC system comparable with a diesel unit
- Continuous operation of the fuel cell; peak load via accumulator

> "This is nothing less than the beginning of a new era. […] Our clear preference is liquid hydrogen."
> *Sven Ennerst, Member of the Board of Management for Development at Daimler Truck AG*

It is currently unclear who will produce the expected 2,000 LCVs and 1,500 trucks by 2025. Iwan's bets include Stellantis, which he says is "already aiming to produce several thousand by 2023", and Faun, which is aiming to "scale to several hundred refuse collection vehicles per year by 2024". He also expects Hyundai's FC trucks to enter the German market.

The European Commission expects 110,000 FC trucks across Europe by 2030. In its study "Fuel Cells Hydrogen Trucks", the business consultancy Roland Berger arrived at 59,500 new registrations per year in the base scenario at the end of 2020 – provided that hydrogen is offered for less than 6 Euro per kilogram by then.

Regarding the amount of hydrogen required (see Fig. 3), Iwan explained: "At H2 Mobility filling stations, 200 to 250 tonnes will be sold this year." However, four fifths of FC buses alone refuel at "non-public depots".

Iwan went on to explain that more financial resources would be needed to build the required medium-sized filling stations that would be designed for commercial vehicles in the future, which is why he is hoping for more shareholders to join H2 Mobility, especially from the commercial vehicle sector.

GH_2, LH_2 OR CcH_2 One obstacle to the development of an H_2 infrastructure for commercial vehicles is probably the fact that there is still no agreement on the state of aggregation. Daum was initially clearly in favour of LH_2 when it came to the choice of fuel: "There can only be one." However, this was put into perspective by his press office a short time later (see below). Some other competitors rely on GH_2, others on pure electric. Adian Vălean, EU Commissioner for Transport, said from Brussels that the declared goal in Europe is 500 H_2 stations by 2025 and 1,000 by 2030 – without specifying the aggregate state. H2 Mobility boss Iwan was also open. However, due to the higher energy density, liquid cryogenic hydrogen is likely to be used to supply the filling stations, he believes.

Then, in mid-May 2021, the Stuttgart-based company created new facts by announcing a cooperation with Shell. As a Daimler spokesperson confirmed to H2-international, Shell New Energies NL B.V. will henceforth take care of the H_2 infrastructure. Namely, a fuelling station network for green hydrogen is to be established first between the three production sites in Rotterdam, Cologne and Hamburg, so that heavy FC trucks can be operated in this 1,200 km corridor from 2024. Starting from this Dutch-German region, further expansion is then planned so that from 2030 onwards 150 stations can be served by around 5,000 H_2 heavy-duty trucks from Mercedes-Benz alone.

When asked by the editors whether these would then be GH_2 or LH_2 stations, they said: "Both liquid and gaseous hydrogen will be part of the planned cooperation with Shell." They went on to say that a uniform standard for hydrogen

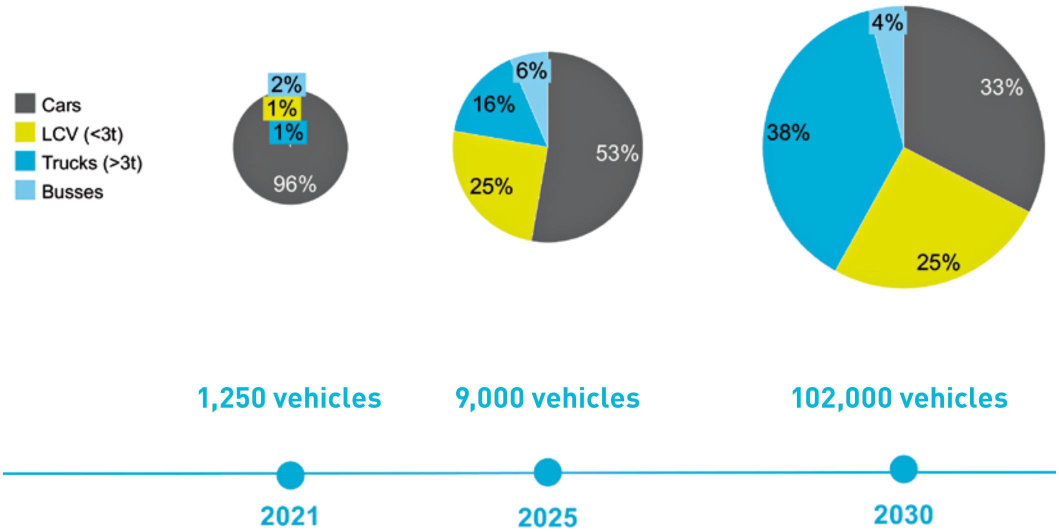


Fig. 1: Expected number of FCHVs by 2030 [Source: H2 Mobility]

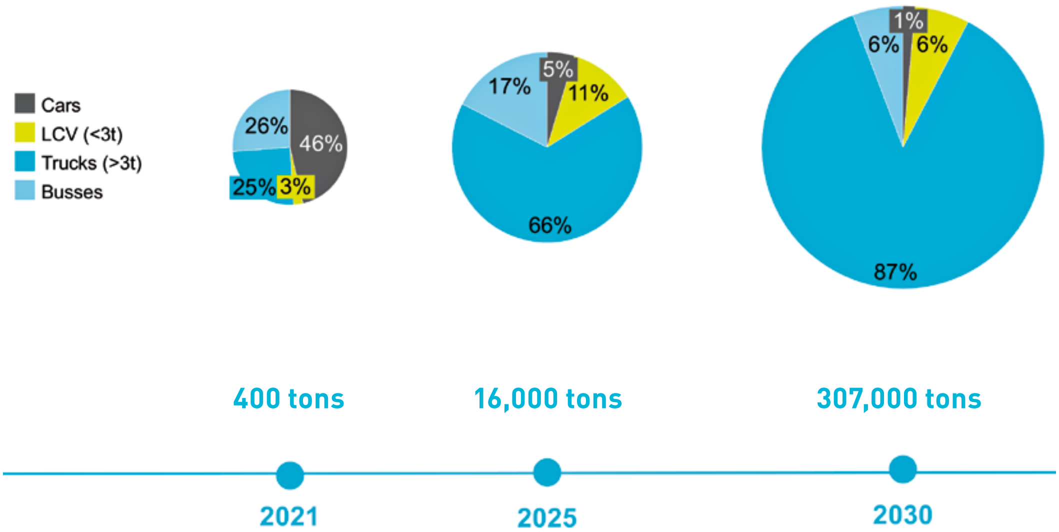


Fig. 2: Expected H_2 demand until 2030 [Source: H2 Mobility]

trucks is to be established, similar to the already existing refuelling protocol for H_2 passenger cars. Specifically, it is stated: "Other potential partners are invited to join this effort [...] to define the interface and interaction between trucks and filling stations, enabling customer-friendly, cost-efficient, reliable and safe hydrogen refuelling [...]."

So far, there is no refuelling protocol for LH_2. Here, the industry is practically still at the very beginning of development. What is clear is that the robotic refuelling that BMW tried out twenty years ago didn't really work out well and is probably not practical today either. Daimler and Volvo have not yet provided an answer to the question of what LH_2 refuelling might look like today. Instead, Martin Daum had stated that Daimler itself would not build or offer infrastructure solutions. According to the business economist, the solution to this task lies with the mineral oil and energy companies.

The current motto seems to be that the next one to two years should be used to calmly clarify which fuel is favoured in Europe. In addition to LH_2 and 700 bar GH_2, 500 bar GH_2 and CcH_2 (cryo-compressed hydrogen – hydrogen compressed at -240 °C) are also possible. Critics complain that Daimler is – once again – playing for time with its pre-commitment to LH_2 as a fuel alternative for commercial vehicles by initiating a lengthy decision-making process in order to be able to do business as usual for the time being. Observers in the H_2 community are already drawing parallels between the development of FC passenger cars, which has now lasted over twenty years, and the announced market entry of FC trucks. In the automotive sector, the Stuttgart company had always presented itself as progressive and future-oriented, but to date has not put a major series on the road. >>

140 H_2 STATIONS FOR TRUCKS

According to calculations by the Fraunhofer ISI, a network of 140 filling stations for fuel cell trucks could be sufficient to cover the entire hydrogen demand for a nationwide H_2 supply in Germany. The costs would amount to around nine billion euros per year. Prof. Martin Wietschel, Head of the Competence Center Energy Technologies and Energy Systems at Fraunhofer ISI, explained in October 2020: "According to EU regulations, emissions from trucks are to be reduced by 30 per cent by 2030 compared to 2019. In order to enable the helpful use of fuel cell trucks for this purpose, it is necessary to establish many filling stations at an early stage: For just under 50,000 vehicles in 2030, 70 hydrogen filling stations, some of them smaller, are already needed for spatial coverage. This comparatively high number of filling stations compared to hydrogen sales shows that there is a great demand for suitable business models. The question of state subsidies for hydrogen filling stations for trucks must also be clarified quickly."

Fig. 3: Dr Matthias Jurytko took over the management of the Daimler-Volvo joint venture cellcentric, which will supply the stacks in the future, on 1 June 2021. [Source: Daimler]

TARGET DEFEAT IS NOT AN OPTION Prof. Christian Mohrdieck, Managing Director of Daimler Truck Fuel Cell GmbH & Co. KG, sketched a somewhat different picture than Daum. While he confirmed that there is a much greater compulsion and need for the use of fuel cells in trucks than in passenger cars, in terms of fuel choice he did not want to commit to LH_2, but to wait for the discussions just described.

Mohrdieck, who is also managing director of Mercedes-Benz Fuel Cell GmbH and chairman of the board of trustees of the ZSW, and who joined the supervisory board of Pajarito Powder in autumn 2020, revealed that Daimler plans to use two 150 kW FC systems for the heavy-duty vehicles, while the simple L-modules are designed for both light-duty and stationary applications (see cooperation with MTU and Rolls-Royce-Power-Systems for back-up systems). He is particularly proud of the low platinum content that has been achieved over three decades and the fact that 97 per cent of the precious metal can be recycled. In addition, the modules are now designed for large-scale production.

Mohrdieck said he was confident that this technology could achieve the tightened climate protection targets (15 per cent less CO_2 by 2025/26, 30 per cent less by 2030). In doing so, he stressed that failure to meet these targets was not an option, because otherwise severe penalties would become due. Daimler would have to pay a three-digit million Euro amount annually if the targets were missed by one to five percent.

BATTERY OR FUEL CELL The so-called economy wise Prof. Veronika Grimm, who is also a member of the National Hydrogen Council, told dpa: “It is utopian to believe that battery-based electric-mobility will be the sole solution.” The goal must be to build an infrastructure from which passenger car traffic can later also benefit. “The development can, for example, initially take place via regional alliances, which can then be successively expanded later.” And Grimm went on to explain: “Abandoning the rapid ramp-up of hydrogen would mean putting important export markets at risk – because German companies are excellently positioned to produce key components for the hydrogen economy, such as vehicles, fuel cells, logistics and filling station infrastructure.”

To ensure that an H_2 truck fleet can actually establish itself from the middle of the decade, Federal Transport Minister Andreas Scheuer announced that his ministry will cover 80 percent of the additional costs compared to comparable conventional models. Scheuer had already declared 2020 at the presentation of Daimler’s GenH2 truck in Berlin in September: “Where the battery reaches its limits, the fuel cell is just getting started. [...] Hydrogen is a good alternative to diesel and a fuel of the future. [...] It can also be the fuel of the future. [...] It’s about time.” On this occasion, Daum had made it unquestionably clear that it would “only work with green hydrogen” – “not grey” – and that Daimler supported an H_2 infrastructure, “no natural gas and no overhead lines”. ||

H_2 AND FC ALLIANCES IN THE TRUCK SECTOR

In 2020, Daimler Truck, OMV, Shell and Iveco have joined forces and launched **H2Accelerate**. The consortium of companies will serve as a central platform to drive the introduction of hydrogen-powered commercial vehicles in Europe.

As a kind of counterpart, BMW, Hyundai, Toyota and Stellantis joined forces in a **GH_2 alliance** on 26 April 2021. They sent a joint statement to the Executive Vice-President of the EU Commission Frans Timmermans in which they advocated that the expansion of the existing network of 700-bar stations across Europe be continued. They referred to studies by the globally active Hydrogen Council and received support for this initiative from H2 Mobility, among others.

Nikola and Iveco, meanwhile, have joined forces with Open Grid Europe (OGE). On 14 April 2021, they signed an agreement to jointly develop an **H_2 infrastructure for commercial vehicles**. The production, distribution and supply of hydrogen will be taken over by the US-based FC truck manufacturer – including the construction of H_2 stations – while OGE will take care of the construction of a pipeline infrastructure from the production to the distribution sites.

StasHH was launched in February 2021. 25 companies and organisations from the hydrogen sector have joined forces as part of an EU-funded project to work out, develop and test a European standard for fuel cell modules in heavy-duty transport. This consortium includes stack manufacturers, OEMs and research, testing and scientific institutes (including Alstom, EKAT, Freudenberg Sealing Technologies, Solaris, Hydrogenics, Nuvera, Toyota Motor Europe, Volvo Construction Equipment, and VDL). The “HH” in the project name is analogous to the battery size designation “AA”.

On the supplier side, major players such as AVL, Bosch, FPT Industrial and Johnson Matthey founded the EU-funded consortium **IMMORTAL** (IMproved lifetiMe stacks fOR heavy-duty Trucks through ultrA-durabLe components) to develop durable components for heavy-duty trucks with more than 30,000 operating hours.

In order to be able to establish standards for trucks – just as in the passenger car sector – eleven companies (including Air Liquide, Engie, LBST, MAN, Nikola, Shell, Toyota, and ZBT) came together in Paris as early as February 2020. The **Prhyde consortium** (Protocol for heavy-duty hydrogen refuelling) intends to establish a refuelling protocol that enables communication between vehicles and filling stations. Among other things, this involves whether the refuelling control is taken over by the H_2 station or by the vehicle, or whether there is a division of tasks.

Fig. 1: Search image: Which animal feels well protected by the Mirai 2?

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

THIS SHOULD BE A LEXUS

Driving report on the Toyota Mirai 2

The first impression immediately conveys that this Mirai is no ordinary Toyota. Its design is much more pleasing to European tastes than that of its predecessor – and it is bigger, fancier, and more refined than the Mirai 1. This impression is underlined by the statement of the director of the Berlin representative office of Toyota Motor Europe, Ferry Franz, that this model was actually supposed to be a Lexus.

Lexus is Toyota's luxury brand, playing in the same league as Mercedes, BMW and Audi. The Japanese manufacturer does not have to hide behind European suppliers, because the Mirai 2 is a sporty saloon car that makes a good impression with its good workmanship and elegant design. The coupé shape elicits words of praise even from die-hard BMW lovers, especially since the Mirai 1 had an unusual shape for Western tastes – similar to the Toyota Prius hybrid vehicle, which is not particularly popular with many German drivers simply because of its Asian design.

While the Mirai 1 was a mid-range car, the Japanese are moving into the luxury segment with its successor. Originally, it was planned by Toyota Motor Corporation that Lexus would offer its own FC model. During the North American International Auto Show in Detroit in January 2018, the Lexus LF-1 Limitless was presented as a concept study of a crossover model that should offer limitless possibilities (see H2-international issue Apr. 2018). This model was derived from the LF-FC (Lexus Future – Flagship Car/Fuel Cell, see H2-international issue Apr. 2017), about which it was said at the time that its features could be offered in the LS luxury sedan with fuel cell from 2019. Now it is 2021 and has become a Toyota, but the similarity between the Mirai 2 and the LF-1 is not coincidental.

SPORTY, POWERFUL Special features of the five-seater are a remarkable length of 4.975 metres and a rear-wheel drive instead of the often common front-wheel drive. The most lasting impression on this car is made by the 20-inch rims. Three out of four interested parties who wanted to know more about this vehicle praised its design. These comparatively large tyres are mainly for visual reasons. According to >>

Fig. 2: Recognition effect – the fuel cell-powered Lexus LF-FC announced in 2016 [Source: Lexus]

Fig. 3: Mirai (left) is happy about her "own" car [Source: Matti B.]

Ferry Franz, the Mirai 2 runs even more quietly with 19-inch rims and also with ten percent less hydrogen; they are also much cheaper.

But the Mirai 2 also looks much better than its predecessor in other respects. The coupé shape is well received, even if the car looks much bigger on the outside than it is on the inside. With five people, the streamlined Grand Tourismo is very cramped, and the low height means that even tall people in the front quickly bump into the headliner, while only curved seating positions are possible for them in the rear.

With its 133 kW (182 hp), the fuel cell drive unit accelerates the 1,900 kg unladen weight of the Mirai swiftly to 100 kilometres per hour, even when fully loaded. ("Just like on an airplane!" said a fellow passenger) The hydrogen stored in a total of three 700-bar pressure tanks (two transversely, one longitudinally arranged) enables a 30-percent further driving distance than with the predecessor model.

The handling is smooth, but when braking at the latest, the moment of inertia of the almost two tonnes comes into play. Unusual, however, is the torque at standstill: If the brake pedal is not pressed hard enough at the traffic lights, the car rolls slowly or continues to roll.

An eco-rebate is only paid for new electric cars whose net list price for the base model in Germany is below 65,000 euros.

The FC car is particularly popular with the younger generation. So whooped a two-year-old test driver: "Cool car!" As a highlight, the H2-international editorial team was able to bring together two very different Mirai for the first time during the test drives: Namely, the two-year-old girl Mirai successfully completed a test drive in the Mirai 2 (see Fig. 3). Mirai is Japanese and means "future".

EXPENSIVE, BUT FUNDABLE With their two H_2 passenger cars, Hyundai and Toyota now cover precisely the two vehicle categories for which fuel cell drives – if at all – are likely to come into question in the passenger car sector in the future: SUVs (Hyundai Nexo) and sedans (Toyota Mirai 2) in the premium sector. While the South Korean's list price of 79,000 Euros (750 km range) is above the mark up to which an eco-rebate is granted, buyers of the Japanese (63,900 euros, 650 km range) can look forward to a 7,500 Euro subsidy.

However, Toyota is certainly not breaking even with this price. Similar to the marketing of the Prius hybrid model, the company is paying extra for each of the first two generations. From the third generation onwards, however, the price could be on a par with today's hybrid cars, according to Matthew Harrison, Sales Director Europe.

REDUCING COSTS BY INCREASING THE NUMBER OF UNITS In order to reduce unit costs as quickly as possible, Toyota is also planning to use its fuel cell units in trucks (see p. 28), buses, trains, ships and stationary units. In 2018, the carmaker had expanded its production capacities for fuel cell stacks for this purpose with the construction of a new eight-storey high-tech building near its plant in Honsha. At the beginning of 2021, it was said that the compact FC system modules produced there (approx. 250 kg, 60 or 80 kW) would be offered to potential partners, such as the bus manufacturer Caetano in Portugal.

After California and the domestic market, the Federal Republic of Germany is one of the Japanese company's target regions. According to Ferry Franz, however, signifi-

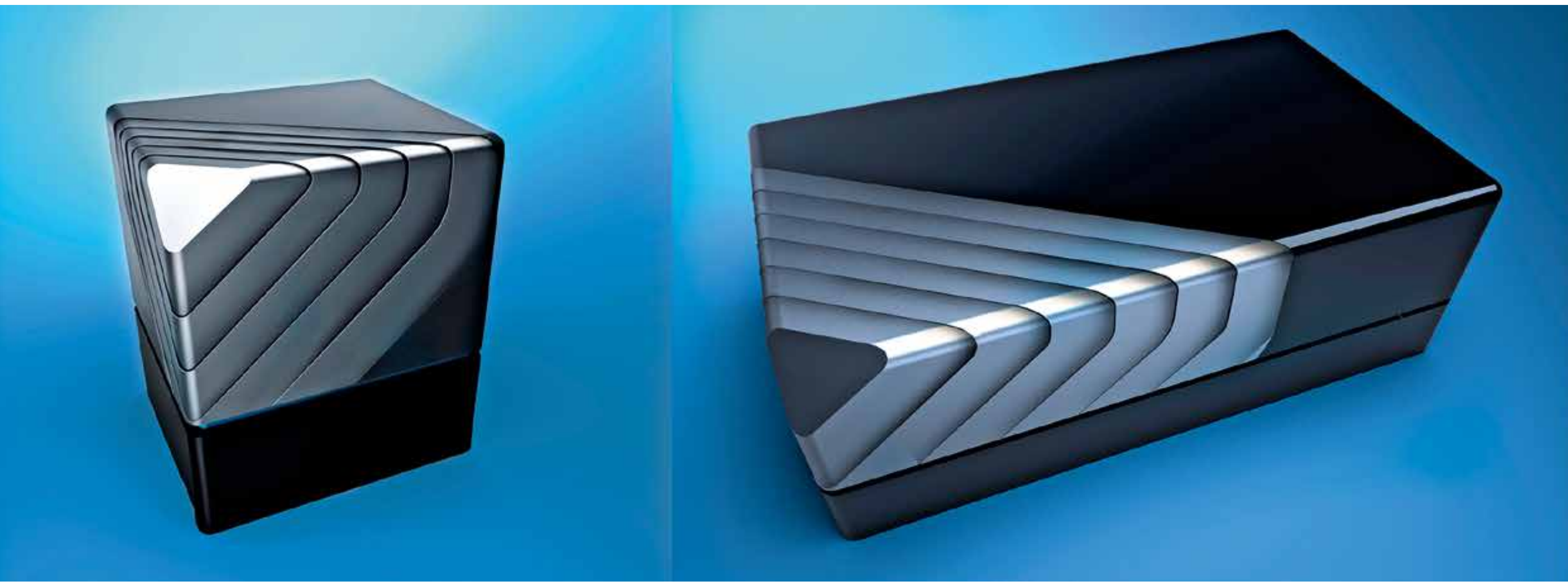


Fig. 4: FC modules from Toyota – vertical and horizontal design [Source: Toyota]

cant quantities will also go to Poland, the Netherlands and France. According to Toyota, about 10,000 Mirai 1 units had been sold within five years. There will initially be a few hundred Mirai 2s in Germany, and about 1,000 per month in Japan. Overall, the Asians are planning for future sales of 30,000 per year worldwide. The Mirai 2 has been available in Germany since this spring. One of the first customers was – once again – Nikolaus W. Schües, Hamburg shipowner and co-founder of the Hydrogen Society Hamburg.

TOYOTA TESTS H_2 ENGINE The latest news from Japan at the moment is that Toyota is also active in the field of H_2 combustion engines. For endurance races in Fuji, the company wants to develop a hydrogen racing car based on the Corolla model. Under the type designation GE16-GTS, a 1.6-litre inline 3-cylinder engine with turbo charging and inter cooler is to be used, which is supplied from 700-bar H_2 pressure tanks. Participation in the 24-hour race at Le Mans could take place in 2024.

And when, at the end of the trial period, your own daughter asks: "Can we keep it?", then there is a lot to be said for the fact that at least a part of the coming generation feels addressed by this vehicle. ||

MIRAI 1

The Mirai 1 did not have many supporters in Europe because of its design: It took some getting used to for European eyes with its large radiator and Japanese outfit. Nevertheless, this model made it into the Pope's fleet: A Mirai has been converted by Toyota into a hydrogen-powered papa mobile and handed over to the pontiff in autumn 2020. However, this has since been replaced by a battery-powered e-car.

Source: Toyota

STELLANTIS LAUNCHES H_2 VAN ON THE MARKET

Fig. 1: Citroën ë-Jumpy Hydrogen [Source: Citroën]

After years of silence regarding Opel's fuel cell activities, the German automobile manufacturer came back in mid-May 2021 with an H_2 van Vivaro-e Hydrogen (see Fig. 2) – and with it the French sister companies Peugeot and Citroën, both of which also belong to the parent company Stellantis. The major corporation designed its own "mid-power plug-in hydrogen fuel cell electric system" for the three brands, consisting of a 100-kW drive combined with a 45-kW fuel cell from the French manufacturer Symbio and a high-voltage power storage unit.

The three manufacturers plan to supply the first fleet customers this autumn, as soon as the basic electric vehicles have been converted at the Stellantis Hydrogen and Fuel Cell Competence Centre in Rüsselsheim. This conversion is carried out without any changes to the bodywork, so that the entire load volume is retained.

The compact van, which is available in two lengths, has three 700-bar pressurised gas tanks (in total 4.4 kg_{H2}) and rechargeable batteries (10.5 kWh), ensuring a WLTP range of 400 km. The lithium-ion batteries, which come with an eight-year warranty, also function as a range extender should the H_2 tank be empty.

On 27 May 2021, Peugeot showed the e-Expert Hydrogen, which will initially be offered to professional customers in France and Germany from the end of 2021. The French carmaker advertises that its e-Expert Hydrogen, which is based on Peugeot's Efficient Modular Platform (EMP2), retains "the proven properties of the combustion engine".

Citroën presented its ë-Jumpy Hydrogen (see Fig. 1), a fuel cell-powered van that uses the same technology as its counterparts, on 3 June. They chose the battery-electric ë-Jumpy, which was presented last year and is produced at the SevelNord site (former joint venture of Peugeot and Fiat) near Valenciennes, as the base model.

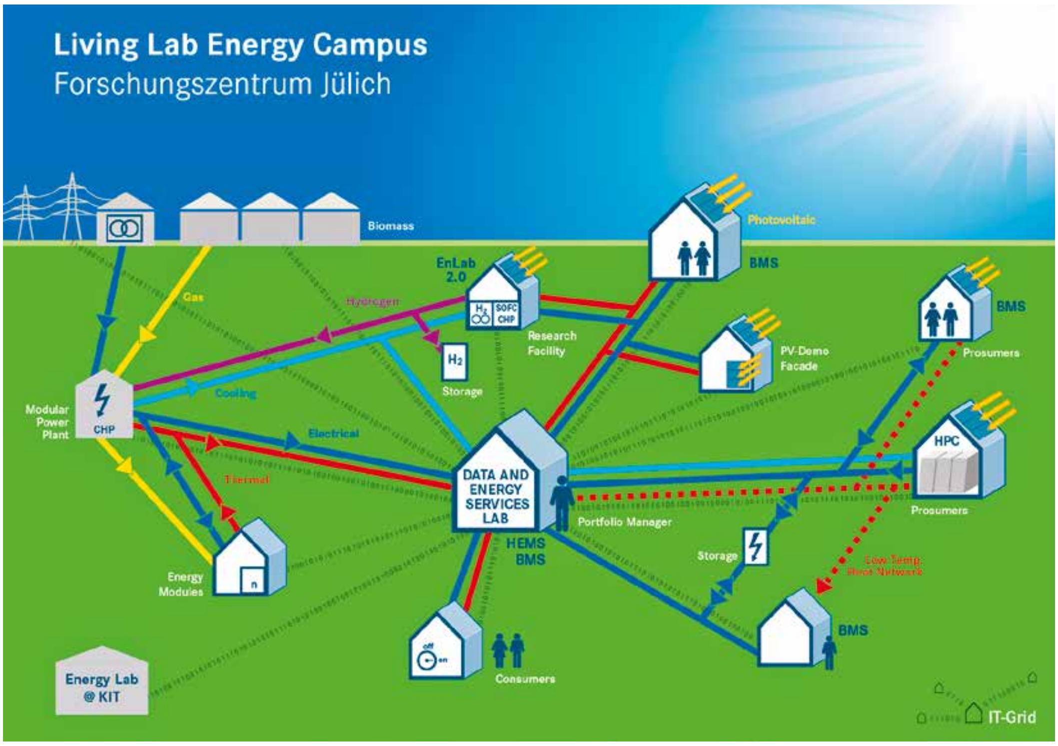
Opel boss Michael Lohscheller explained: "Hydrogen is a forward-looking solution for an efficient energy system free of fossil fuels." ||

Fig. 2: Opel Vivaro-e Hydrogen [Source: Opel Automobile]

Category: Development | **Author:** Michael Nallinger

FIRST ENDURANCE TESTS FOR ALKALINE FUEL CELLS

AFC projects at ABB and FZ Jülich



Alkaline fuel cells, with their very low use of precious metals, are an alternative to PEM fuel cell technology. Another benefit is the higher tolerance to impurities in the supplied hydrogen. The focus of their work is particularly in the stationary sector. Two current projects with systems from AFC Energy bring dynamism to the still rare project landscape with alkaline fuel cells: The cooperation with ABB on their HPC charging solution for electric vehicles and the future project LLEC at the Jülich Research Centre.

Alkaline fuel cell technology has already been around since the 1960s. It was used in space travel as part of the Apollo programme. Over the decades, various companies have been involved with AFCs (alkaline fuel cells). Today, alkaline fuel cells are sold commercially by GenCell from Israel and AFC Energy from the UK.

AFC Energy in particular has recently attracted attention with projects, also in this country. For example, at the end of last year the British company entered into a strategic partnership with ABB to develop a new high-power charging (HPC) solution for e-vehicles and locations with limited grid access. This is based on the CH2ARGE off-grid charging solution and combines an H_2 fuel cell system for electricity supply with a battery for energy storage. This system is to be combined with energy storage and fast charging technology from ABB in the course of the cooperation.

According to AFC Energy, the agreements give the company a multi-year right of first refusal to supply H-PowerTM fuel cell systems into ABB's high-power charging network at international customers where there is no equivalent on-site power demand or where additional resilience is required. Both companies want to market the integrated product together and are developing a communication strategy for the branding and use of the system, according to the AFC website.

In addition to charging stations, the two partners are also looking at other applications. These include logistics hubs and distribution centres, public and private local transport (including bus depots), as well as maritime transport including ports or vertical take-off and landing air units.

BENEFITS OVER PEM AND SOFC A major benefit of AFC technology is that the catalysts are platinum-free and therefore cheaper than, for example, polymer electrolyte membrane (PEM) fuel cells. In addition, the hydrogen required does not have to be ultra-pure, unlike with PEM technology. This property also tipped the scales in favour of using an AFC fuel cell in the Living Lab Energy Campus (LLEC) future project at the Research Centre Jülich (FZJ). "We see the potential of alkaline fuel cells in stationary applications with long runtimes. The benefit here is the minimal use of precious metals compared to PEM technology," explains Martin Müller. In addition, the LLEC team leader for hydrogen production emphasises the lower temperature level and the resulting easier start-up behaviour compared to the solid oxide fuel cell (SOFC).

The LLEC project is a comprehensive conversion of the energy supply system at FZ Jülich. In the process, a selected part of the centre will first be converted into a sector-coupled supply infrastructure with as large a share of renewable energies as possible. The infrastructure currently being built acts as a model for long-term reconstruction, according to the plan. In addition to the 100 kW fuel cell from AFC, various

Fig. 2: Martin Müller, LLEC team leader hydrogen production at FZJ: "We see the potential of alkaline fuel cells in stationary applications with long runtimes." [Source: FZJ]

other building blocks are also used. These include a 400-kW next-generation electrolyser for efficient hydrogen production, an HCP waste heat utilisation of the Jülich supercomputer JUWELS for building heating, and a novel LOHC storage system (Liquid Organic Hydrogen Carrier; see box).

The alkaline 100 kW fuel cell unit in the LLEC will be used to convert hydrogen back into electricity. According to Müller, the main argument in favour of AFC Energy as the supplier of the alkaline fuel cell was the performance class. While GenCell sells fuel cells below 10 kW, AFC Energy offers electrical power in the 100 kW range.

FIRST DIRECT HYDROGEN USE The fuel cell in the LLEC is initially operated with hydrogen, which is produced by electrolysis with electricity from renewable energies. After completion of the LOHC system, the hydrogen stored there will then be used directly for supply.

Both processes differ in the purity of the hydrogen. "The hydrogen from electrolysis is very clean to begin with. There can be impurities here with water vapour and with traces of oxygen," explains FZJ employee Müller. The situation is different for the H_2 gas stored in the LOHC. According to Müller, the release of hydrogen by means of dehydrogenation of LOHC after condensation of evaporated LOHC can result in various impurities, which include toluene, methylcyclohexane, cyclohexane, benzene, water, methane, carbon monoxide and carbon dioxide. Müller emphasises that quality 3.0 hydrogen can be achieved without further cleaning steps.

He assumes that the stored hydrogen is easier to use with the AFC than with PEM fuel cells, even without purification. "This could save or simplify purification stages in LOHC technology and thus help to reduce costs," he surmises. These topics are to be evaluated successively in the further course of the project.

The situation is different on the oxygen side. Due to the sensitivity of the alkaline electrolyte to CO_2, the alkaline fuel cell requires air preparation. Here, too, Müller already has a solution in mind: "If it is possible to use oxygen, which is also produced in electrolysis, then this can simplify air preparation." At the LLEC, they also want to investigate the use of oxygen in the long term. "This opens up development perspectives for this technology in particular," Müller has stated.

CORONA-RELATED DELAYS The original plan was to put the fuel cell system into operation in the third quarter of 2021. However, as with many projects, the Corona pandemic has caused delays. How long the project will have to be stretched out is currently being clarified.

Since the new full heat supply centre (WVVZ) is to supply the FZJ completely with heating, cooling and also electricity in future, trouble-free operation must be ensured. For this, a careful commissioning with a three-month trial operation from August to October 2021 is planned. Due to further possible delays in this work, the commissioning of the fuel cell can probably only take place from the beginning of 2022 independently of the trial operation of the WVVZ.

The tender for a hydrogen infrastructure is currently underway, with the help of which hydrogen produced in the EnergyLab can be processed, stored and transported to the AFC in the long term. The production site is about 200 to 300 metres away from the new WVVZ. Completion of the hydrogen supply is planned for mid-2022, so that the fuel cell can then be supplied with hydrogen from the EnergyLab.

Hydrogen expert Martin Müller is generally optimistic about the future viability of alkaline fuel cells. In general, these could be an interesting topic for future projects. In doing so, he emphasises: "In addition to analysing the operational behaviour of the systems, our Institute for Electrochemical Process Engineering is always interested in the further development of the system, stack and cell components. We are taking a cross-scale approach to this."

As with all fuel cells, costs play an important role here. Müller is certain: "In order to become competitive with other non-electrochemical technologies for electricity and heat generation, alkaline fuel cells, like other fuel cells, need to have their overall costs reduced." ||

LOHC HYDROGEN STORAGE

LOHC are organic compounds that can absorb and release hydrogen reversibly in catalytic reactions and are liquid at ambient conditions. LOHCs consist of at least one low-hydrogen and one high-hydrogen compound. In the LLEC project, the compound benzyltoluene represents the low-hydrogen LOHC and the compound perhydro-benzyltoluene represents the high-hydrogen LOHC. Benzyltoluene is commercially marketed as a heat transfer medium as a mixture of isomers, for example under the brand name Marlotherm LH.

The loading of the low-hydrogen compound with hydrogen takes place in a heterogeneously catalysed exothermic hydrogenation. After hydrogenation, the hydrogen is bound in the high-hydrogen form of the molecule. The loaded LOHC can easily be stored or transported in ambient conditions. Due to the chemical bonding of the hydrogen, no material hydrogen losses occur over the storage period. The release of the hydrogen takes place in a heterogeneously catalysed endothermic dehydrogenation. Here, at least the same amount of heat energy must be added as is released in the hydrogenation process. After dehydrogenation, the LOHC is again in the low-hydrogen form and can be loaded with hydrogen again. The LOHC is not consumed and can be used over several storage cycles.

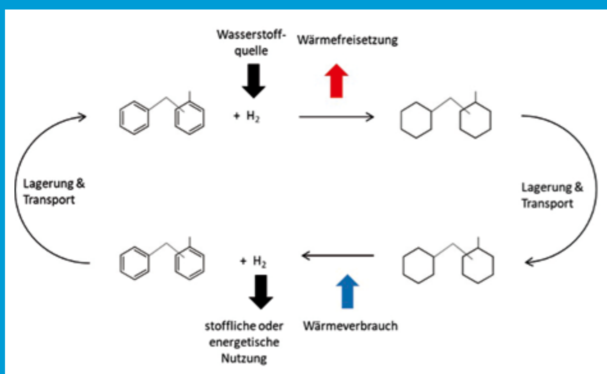


Fig. 3: LOHC loading and unloading [Source: M. Geiselbrecht]

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

GOODBYE COAL, HELLO HYDROGEN

Hamburg's new hydrogen hub

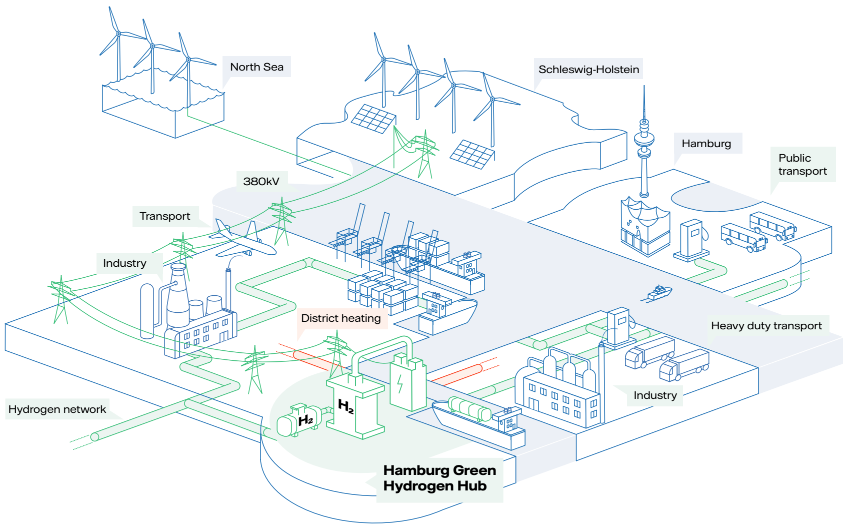


Fig. 1: Hamburg Green Hydrogen Hub [Source: Wärme Hamburg]

At the end of 2020, the German city of Hamburg said goodbye to its Moorburg coal power station. The site on which the now-defunct plant was built will soon be transformed into a hydrogen hub. Nobody could have picked a more ideal location to embark on such a venture. For one, all the infrastructure you could hope for is already in place, including connections to Hamburg's 110-kilovolt and Germany's 380-kilovolt transmission lines. For another, the site is situated within the city's port area, making it easily accessible to large sea vessels, which can use the quay and its surroundings to drop off imported hydrogen. Additionally, the nearby industrial area is home to many prospective customers, which have shown a keen interest in the project. Even the waste heat released during electrolysis will not actually be wasted but be injected into the city's district heating grid. In short, the city is on pace to become one of Europe's prime locations for hydrogen technology.

Unsurprisingly, the last months saw stakeholders in the region discuss a flurry of new ideas for hydrogen projects. Several of those stakeholders later formed a consortium named Wasserstoffverbund Hamburg to apply for grants from the Important Projects of Common European Interest program, which allows for exceptions to European Union restrictions on national funding opportunities. What the IPCEI does not have, however, is a funding budget. Instead, support will come directly from member states.

GOVERNMENT APPROVES 62 IPCEI PROJECTS A statement made by German economy minister Peter Altmaier in late May brought good news for most of the consortium's members. Nearly all their projects had made it onto Germany's IPCEI shortlist. Which of these will get the final nod will now be decided in consultation with representatives for other European countries. Each project greenlit in this second stage will then be eligible for federal and state support. The total amount Germany has set aside for IPCEI is EUR 520 million. According to Hamburg's economy ministry, a sizeable chunk of this, EUR 100 million, will go toward putting up a 100-megawatt electrolyzer and a Green Energy Hub in Moorburg, including new hydrogen import facilities.

The Moorburg venture is a collaboration between several companies and Hamburg's government, which has been pushing for the project for quite some time. As the former operator of the Moorburg coal power station, Vattenfall will provide the location for the hub and clean electricity for the electrolyzer. Mitsubishi Heavy Industries, which was involved in constructing Moorburg, will be in charge of removing the coal plant. Wärme Hamburg, which runs the city's district heating grid, will sell the waste heat produced on site. And Shell will handle the logistical requirements of transporting liquid and gaseous hydrogen and delivering it to fleet operators downstream.

A feasibility study is still underway but, according to Hamburg's economy ministry, will be completed no later than the end of July. At around the same time, the ministry will also issue a request for proposals for designing the electrolyzer. The hub is planned to come online by 2025 and produce 11,500 tons of hydrogen a year. In a recent presentation, the consortium said that at some point, the site will have 10 times its initial capacity, i.e., 1,000 megawatts, available to make hydrogen. An exact date for when that will happen has not been announced yet, however. And although the increase in capacity is sure to have a significant impact on production output, it won't be enough to meet the needs of every potential client in the industrial area if hydrogen really is to be used as widely as possible.

A NEW HYDROGEN GRID FOR HAMBURG Gasnetz Hamburg will deliver the hydrogen produced at Moorburg to customers via a new 37-mile (60-kilometer) pipeline network called HH-WIN (see H2-international, May 2021), set for completion by 2030. This subproject will receive a bit more funding than the hub, the company noted, albeit without revealing how much more. Hopes are that construction on the first grid section, which will provide delivery points for steelmaker ArcelorMittal and aircraft maker Airbus, can start within the next two years.

ArcelorMittal will employ hydrogen as a reducing agent to remove oxygen from the iron(III) contained in iron ore. Supported by IPCEI funds, the corporation also plans to build a pilot system for making 100,000 tons of sponge iron a year and, by 2025, have put this system through its paces over a six-month period. Airbus, on the other hand, wants to use the gas during its Hydrogen for the Infrastructure and Production of Aeronautics in Northern Germany project, better known as WIPLiN.

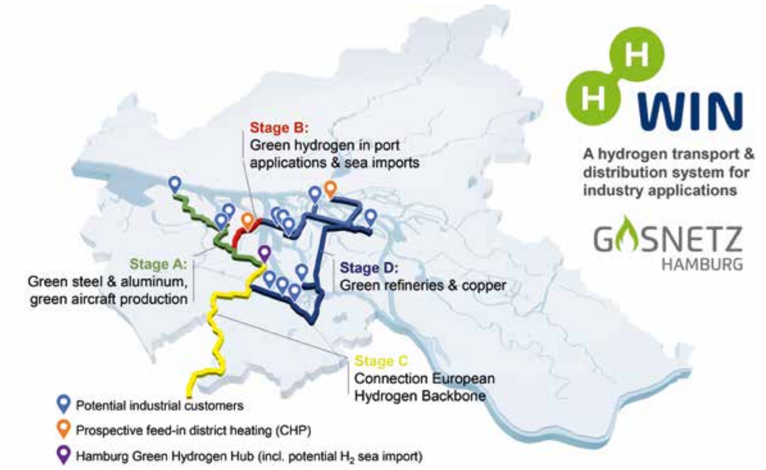


Fig. 2: Planned hydrogen grid expansion at Hamburg's port. The first customers are already lining up.

The second grid section will then connect to four different types of subprojects at the Port of Hamburg. One of them will be Hydrogen Logistics Applications & Distribution, or H2LOAD. Set up by logistics firm HHLA, it aims to construct and operate several kinds of fuel cell-powered heavy-duty vehicles, including big rigs, straddle carriers, yard trucks, forklifts, empty container handlers, reach stackers and a switcher locomotive.

Another will be Hydrogen Port Applications, or HyPA for short, launched by the Hamburg Port Authority, the public sector company in charge of maintaining the on-site infrastructure. This project wants to install hydrogen fueling stations for rolling stock, watercraft and heavy-duty trucks at the port. It will also build and run multiple hydrogen-powered vessels.

Yet another will be H2HADAG, initiated by HADAG, which operates the passenger ferry service that is part of Hamburg's mass transit system. H2HADAG will convert three new vessels to run on both diesel and hydrogen, as well as put the same hybrid engine into two new ferries, where the engine will serve as the basic means of propulsion with no prior conversion.

Lastly, GreenPlug's H2SB will design a hydrogen-fueled towboat capable of pushing 2,400 tons at a speed of 10 knots. The direct current system that will drive the vessel's propeller will run off batteries and fuel cells supplied by onboard hydrogen tanks. As soon as the first test of the watercraft proves successful, GreenPlug intends to build another nine towboats and charter them out.

In the third stage, HH-WIN will be linked to a cross-border pipeline system named H2-Startnetz. In mid-May, Gasnetz Hamburg confirmed that this system will run from the Netherlands via the German state of Lower Saxony all the way to Hamburg, the same route now shown on the IPCEI map. According to the company, H2-Startnetz is planned to come online in the middle of this decade.

The fourth and final stage will then see multiple refineries and copper manufacturer Aurubis get hooked up to the grid. Aurubis will use the hydrogen as a reducing agent in its rotary furnaces, to displace natural gas. Extracting copper works in much the same way as reducing iron ore. Both times, oxygen is removed from a compound with the help of hydrogen. In late May, Aurubis announced the successful completion of an initial series of tests using hydrogen supplies.

LIVING LABORATORY CROSSOVER April marked the launch of the Living Lab Northern Germany, one of 20 federal economy ministry-funded living labs for climate change. Led by Hamburg's HAW university, the five-year EUR 52 million venture is an offshoot of the Northern German Energy Transformation 4.0 project. Its members include several research organizations and public sector companies based in and around Hamburg.

One of them is municipal waste management company Stadtreinigung Hamburg. Like Aurubis, it is a member of both the living labs program and the city's hydrogen consortium. The company had originally planned to launch a Waste to Hydrogen project to produce the gas via electrolysis at its new Center for Energy and Resources. But the project didn't get onto the IPCEI funding list. Stadtreinigung Hamburg has since said that it is looking for additional implementation options and funding opportunities.

By contrast, Airbus' project to use hydrogen in its manufacturing facilities will receive funding from more than one source. Besides IPCEI support, the manufacturer will get almost EUR 1.4 million in funds from Hamburg's Green Future for Aviation program. By the end of 2022, Airbus and multiple research partner organizations want to draw up a list of where in Hamburg's Finkenwerder neighborhood hydrogen-fueled systems make technical and economic sense. Potential areas for application include aircraft production, factory supply, and the use of liquid hydrogen for powering cabin electronics and aircraft engines. Airbus expects to have a hydrogen airplane ready for the market by 2035. ||

IZK POWER STATION

The IZK power station (Ikonografisches Zukunftskraftwerk – HH2Europe) is another good example of an innovative hydrogen project in Hamburg. It was announced by a consortium made up of HH2E, Uniper and Siemens Energy shortly before the end of the IPCEI application period.

Like the hub, the IZK will be erected at the Moorburg site and produce hydrogen, district heat and waste heat. The sale and distribution of gas products is also part of the project outline. But while the consortium building the hub relies on tried-and-tested solutions, IZK members intend to deploy next-gen technology. The plant will reportedly receive only around 4 hours' worth of electricity a day (at most 200 megawatts) but produce a ton of hydrogen an hour. The key technology behind this new approach is an intermediate zinc electrolyzer, a quasi-hybrid energy generation device consisting of an electrolyzer and a zinc battery. The thermal energy generated by the plant will be stored at up to 650 °C in a high-temperature storage system equipped with steel rods made by Berlin-based Lumenion. Hopes are that this new kind of system will be better able to meet ups and downs in electricity, process steam and district heat demand. And an innovative gas turbine, capable of generating a few hundred hours' worth of electricity from hydrogen or biomethane, will be used to cover peak loads.

Several days prior to the IPCEI funding notification, the consortium said Uniper will provide "millions of euros" to advance the project. Following the IPCEI's decision not to support the venture, the consortium members announced they will, among other things, seek out national funding opportunities for individual components.

Category: Development | **Author:** Michael Nallinger

MICROBIAL BIOMETHANE ON THE WAY TO INDUSTRIAL MATURITY

ORBIT field test successfully completed


Fig. 1: General view of the plant in Ibbenbüren [Source: M. Thema]

In December, the test operation of the ORBIT biomethanisation plant in Ibbenbüren ended and with it a research project for the further development of power-to-gas technology, which is becoming more and more important. ORBIT stands for "Optimierung eines Rieselbett-Bioreaktors für die dynamische mikrobielle Biosynthese von Methan mit Archaeen in Power-to-Gas-Anlagen" or "Optimisation of a trickle bed bioreactor for the dynamic microbial biosynthesis of methane with archaea in power-to-gas plants" in English. The research project had been running since July 2017 and was funded by the Federal Ministry for Economic Affairs and Energy (BMWi) with 1.14 million euros. Within a short time, it was possible to set up a functioning system. This is now to be expanded into a complete system for industrial use in further development steps.

Methanation is a process in which regeneratively produced hydrogen and CO_2 are converted into biomethane by methane-producing archaea. These micro-organisms are among the oldest living organisms on earth. Methanogenic archaea occur naturally in oxygen-free habitats such as bogs and swamps, geothermal springs or the deep sea, but also in the digestive tract of humans and other mammals.

The overall goal of the joint project was to develop new technological options for the biological methanation process with archaea. Efficient energy storage and sector coupling technology should be taken to the next level and a new process developed therein from scratch, from technology maturity level (TRL) 3 to 7.

In contrast to technically mature chemical-catalytic methanation, there is still potential here for optimising process engineering and biological processes. On the one hand, the focus was on optimising, simulating and setting up a trickle bed bioreactor and preparing it for upscaling. On the other hand, optimally suitable micro-organisms were selected and their behaviour and suitability in the reactor and for the process were analysed.

18-MONTH TEST OPERATION The project was divided into several phases. After the initial construction of the methanation plant at the FAU Erlangen-Nuremberg, it completed a successful 18-month test operation on the joint campus of the OTH and the University of Regensburg. "In the early phases of the project in Regensburg, various micro-organisms were tested in the laboratory in interaction with different material samples from the structural part of the plant, while in the meantime the plant was set up in Nuremberg and then structurally further developed in Regensburg," project coordinator Martin Thema explains the first project steps. Afterwards, the project partners further developed the interaction of process technology and biology for semi-automated operation in the pilot plant. The gas supply in this project phase was by bottled gas.

Finally, from September to December 2020, the system was tested in the field at a gas pressure regulating and measuring station of Westnetz GmbH in Ibbenbüren, Westphalia, in endurance tests to determine its readiness for use (see Fig. 1). Here, the approximately three-metre-high plant with a reactor output of around 0.6 kW drew the green hydrogen from an ITM Power electrolyser powered by renewable electricity, which is part of Westenergie's Designetz project, as well as endogenous carbon dioxide from bioethanol production. The ORBIT plant fed the biomethane produced into the gas network of the Tecklenburg region.

HYDROGEN REPUBLIC OF GERMANY BECAME REALITY "In an interdisciplinary team, all components of a biomethanisation plant were coordinated from scratch and brought to a feed-in development status," sums up project coordinator Martin Thema. The methane content reached values of up to 97.75 % with a methanol production rate of 0.35 $m^3CH_4\ h^{-1}\ m^3R^{-1}$ in continuous operation. According to Thema, about 5.5m^3 of methane was injected during the 283-hour operating period of the field test. This was done by continuously determining various parameters, such as the gas composition, the vitality of the organisms and compliance with specified feed values.

Prof. Michael Sterner, head of the Energy Networks and Energy Storage Research Unit at OTH Regensburg, was surprised by some of the results: "Some of the micro-organisms have endured more than was initially suspected." For example, the pH value was very high in places, but the system did not collapse completely and could be stabilised again through appropriate measures. Sterner's overall conclusion is also positive: "This is where the Hydrogen Republic of Germany became a reality. Through constructive and interdisciplinary cooperation, we were able to get a functioning system, from basic research to application in the field, within a short time."

MINISTERIAL SUPPORT This positive assessment was echoed by Federal Research Minister Anja Karliczek during an on-site visit to Ibbenbüren: "The power-to-gas plant is an example of how we can build the climate-neutral energy supply of the future: With innovation, energy and cooperation between science and business. Forward-looking solutions like these create new added value and jobs – and ensure that we can pass on a world worth living in to our children and grandchildren".

For Andreas Feicht, State Secretary at the Federal Ministry for Economic Affairs and Energy, hydrogen and its derivatives are key elements in completing the energy turnaround: "For this, we need projects like ORBIT that transfer innovative approaches into application. This is how we can make the market ramp-up of hydrogen technologies a reality and achieve our ambitious goals. The success of the project also shows that we can make an important contribution with our support for energy research," Feicht emphasised in Ibbenbüren.

FURTHER OPTIMISATION STEPS IN VIEW Despite these successes, further steps are needed to technologically optimise the process. The project partners first mention the identification of suitable packed archaea-industrial gas combinations in order to enable a broadly based range for use in many areas. If the combinations are only suitable for certain educt gases, it should be possible to provide customised methanation plants for different industrial sectors. In addition, the scope of flexibility of the plant is being investigated in order to be able to respond to the requirements of different farms. Another challenge to be overcome, especially in connection with the upscaling of the technology, is the improved transportability of the plant. Here, for example, a container-based design is being considered.

Fig. 2: Federal Research Minister Anja Karliczek (centre) at the commissioning of the field trial – from left to right: Dr. D. Hafenbradl, Electrochaea – Dr. A. Bellack, Uni Regensburg – M. Thema and Prof. M. Sterner, both OTH Regensburg – H. Heß, Westenergie – State Secretary A. Feicht, BMWi – Prof. J. Karl, FAU Erlangen-Nürnberg [Source: Hermann Pentermann/Westenergie]

The next steps are therefore firmly in sight at OTH Regensburg. Thus, as part of a follow-up project, the industrial use of the reactor is to be expanded into a complete system and this will then be tested in an industrial environment. Here, among other things, it is planned to supplement the trickle bed reactor with a PEM electrolyser and an intermediate gas storage tank and to integrate them into a container. Further funding is needed for this research work. Under the leadership of the OTH Regensburg, a corresponding application for a follow-up project has already been submitted.

In any case, project coordinator Thema is convinced of the competitiveness of the technology: "Each method has advantages and disadvantages that weigh more or less heavily depending on the application. Biological methanation is insensitive to impurities in the reactant gas." This is a significant benefit over the chemical-catalytic process. This positive property comes into play in the field of biogas processing, for example. After all, this is a fairly common case. As a result, Thema sees great potential for biological methanation, especially at sites where waste gas streams with no high CO_2 purity produced. In terms of cost comparison, he sees the two methods as roughly equal. ||

Project partners were the University of Regensburg with the Chair of Microbiology and Archaeology Centre Regensburg, the Friedrich Alexander University Erlangen-Nuremberg with the Chair of Energy Process Engineering, and from industry the companies Electrochaea, microbEnergy (Viessmann Group) and Micro-Pyros. As associated partners, Westenergie AG and its distribution grid operator Westnetz provided the infrastructure for field testing. The German Technical and Scientific Association for Gas and Water (DVGW) was involved as a project advisory board with its research unit at the Engler-Bunte Institute of the Karlsruhe Institute of Technology. The project was coordinated by the Energy Networks and Energy Storage Research Unit at OTH Regensburg, headed by Professor Michael Sterner.

Category: Development | Author: Niels Hendrik Petersen

SAFELY AND PRECISELY JETTED IN

First micromix gas turbines burn pure hydrogen

The Kawasaki M1A gas turbine is a milestone for the energy turnaround. It has been operating on a harbour island off Kobe since July 2020 and is the first gas turbine with complete, dry and low-nitrogen oxide hydrogen combustion, so-called dry-low NOX combustion. This is because H_2 is extremely reactive, and it is precisely this that distinguishes the combustion of a hydrogen-natural gas mixture from that of pure natural gas.

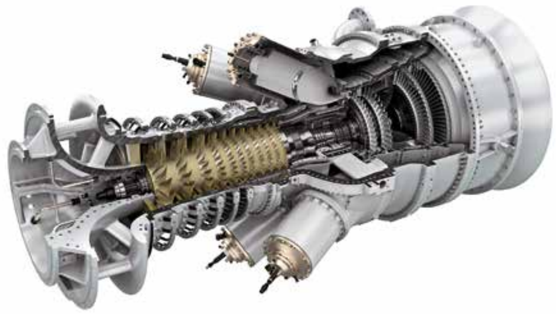


Fig. 1: H_2 turbine from Siemens [Source: Siemens]

"Other manufacturers are currently trying to increase the hydrogen content, but are keeping the previous premix technology. However, this becomes extremely difficult with volume shares of more than 80 per cent and is problematic in terms of operational safety," explains Dr Karsten Kusterer. He is the managing director of the Aachen-based company B&B-AGEMA, which offers engineering services for energy and power plant technology, among other things, and helped develop the turbine for Kawasaki.

The key technology of the gas turbine in Kobe is a newly developed combustion chamber from Kawasaki that uses the principle of so-called micro-combustion. The dry, low NOX combustion technology improves electrical efficiency compared to the conventional method. While other technical approaches rely on conventional premixed combustion systems, which always involve a residual risk of explosive states of hydrogen-air mixtures, the new micro-mixing technology achieves a high level of operational safety, according to Kusterer. That's why B&B-AGEMA, in cooperation with Kawasaki and the Aachen University of Applied Sciences, has opted for the new technology, explains Kusterer: "There are a large number of small flames in the combustion chamber. For each of these flames, there is a small H_2 nozzle that injects the hydrogen into a separate air jet in each case."

AVOIDING FLAME FLASHBACKS The fuel must burn in the air with the lowest possible nitrogen oxide levels despite higher combustion temperatures, Kusterer describes. With conventional premix burners, there is a risk of flame flashbacks, which becomes higher with increasing hydrogen content. This safety problem was solved by the micro-mixing technology, because the parameters of the air jet could be adjusted very precisely. "The currently ongoing first year in field operation is now being used to make further fine adjustments. But the basic technological implementation has been completed," says Kusterer. The technology is now being prepared for Kawasaki's larger gas turbines. The manufacturer's portfolio ranges up to 30 MW output.

In the end, the work of more than ten years of preparation was worth it. The tests prior to gas turbine deployment have been carried out in Akashi and Aachen. In Aachen, initially at the University of Applied Sciences for atmospheric tests in the development phase. Later, complete combustion chambers were run under the pressure conditions of the gas turbine on a test bench at RWTH Aachen University with pure hydrogen. Prof. Dieter Bohn set up the high-pressure test stand at the Institute for Steam and Gas Turbines (then IDG, now IKDG, Institute for Power Plant Technology, Steam and Gas Turbines) in 2009 specifically for such applications.

In Germany and Europe, many sectors will compete for the available green H_2 quantities. "Initially, therefore, only decentralised small gas turbines and lighthouse projects with a few MW of power are likely to play a role when talking about the combustion of pure hydrogen," predicts Kusterer. There will presumably initially be hydrogen islands that also provide green hydrogen for reverse power generation in a regional network. These networks would then have to gradually grow together.

Kusterer initially sees the H_2 turbine in this country more in mobile applications such as in air taxis, but also on rail and in inland waterway transport. "The hydrogen gas turbine is clearly in competition with the fuel cell here," he says and explains: "The gas turbine is more robust in operation, has no problem with contaminated hydrogen or has fuel flexibility and is also cheaper in terms of investment."

KAWASAKI'S HYDROGEN ROADMAP Japan wanted to reduce its dependence on LNG supplies early on. From 2008 onwards, there was an increased interest in converting the energy supply to a greater share of hydrogen in the long term, in as many areas as possible. That was three years before the Fukushima nuclear disaster. "The Japanese view is several years ahead of the European one," compares B&B-AGEMA head Kusterer. Kawasaki already started developing an H_2 gas turbine as early as 2010 as part of the Hydrogen Roadmap and involved German partners. Japan is working closely with Australia on this strategic roadmap. The goal is to initially produce blue hydrogen in Australia, but in the long term to produce green hydrogen from photovoltaics and wind power. Thanks to the roadmap, the H_2 infrastructure in Japan is already much further along than in Europe (see also p. 55).

HIGH FLEXIBILITY WITH AURELIA The Finnish manufacturer Aurelia is also at the beginning of the commercialisation of a pure H_2 turbine. A first model was delivered in 2020. "The Covid pandemic has unfortunately hindered or slowed down development somewhat. Nevertheless, Aurelia is already currently preparing to deliver the second and

Fig. 2: Turbine unit from Aurelia

third units in the summer of 2021," exults Sales Director Tony Hynes. There are an enormous number of orders from dealers and end consumers, which means that the manufacturer's production capacity will be fully utilised until well into 2022.

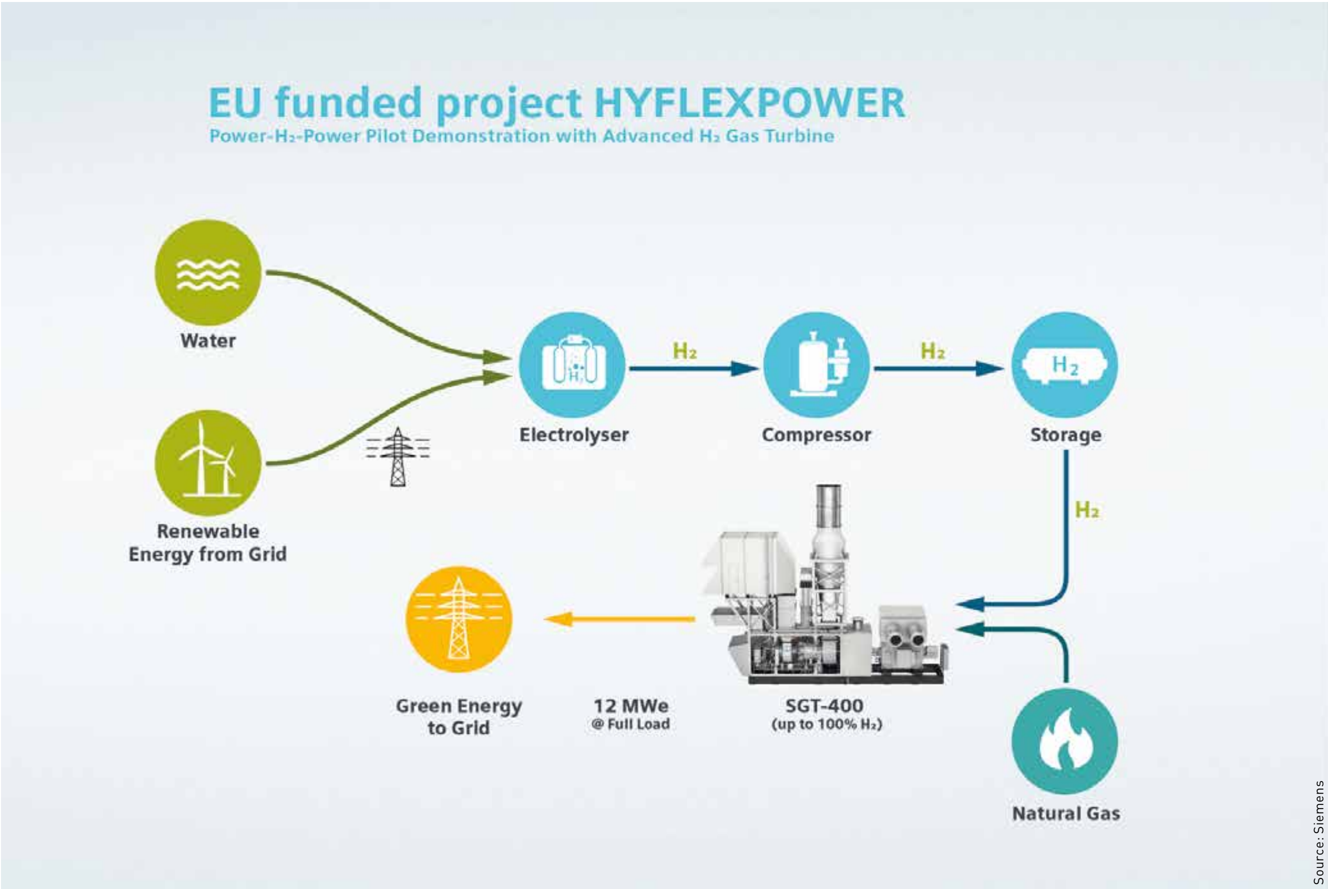
Fuel flexibility is a decisive benefit: "Our ability to work with fuels of varying H_2 content means we can cover many different applications," explains Hynes. This, combined with the absence of lubricants, low emissions, low operating costs and high efficiency, is one of the key differentiators. Technically, pure hydrogen can be burned, but besides the technical challenge of flame speed, pure H_2 gas is also more difficult to obtain, Hynes explains. Today, there are not so many reliable sources, and the distribution infrastructure is still in an early development phase.

The hydrogen market is currently growing and is also becoming more global, which offers many opportunities, says Hynes. "However, the acceptance in individual regions is very different. Europe has a strong H_2 agenda, which makes us happy," says the Aurelia manager. The company is already engaging with potential customers in Australia, China, North America and Russia.

SIEMENS: DEMONSTRATE FROM ZERO TO ONE HUNDRED PERCENT The German company Siemens Energy has also converted an existing SGT-400 industrial gas turbine for H_2 use, but relies on premixed combustion. The Hyflexpower project aims to prove that green hydrogen can be mixed with up to one hundred percent natural gas and burned in a CHP plant. The turbine works at Smurfit Kappa PRF, a company specialising in recycled paper in Saillat-sur-Vienne, France. The utility Engie Solutions operates a 12 MW_{el} CHP plant there that supplies process steam for manufacturing. The existing power plant will be modernised and optimised during ongoing operation. According to the project partners, the conversion would be significantly cheaper and quicker to realise than a new building on a greenfield site.

For future retrofits, the changes should be limited mainly to the burner as well as the fuel systems and electrical, auxiliary and ancillary systems, explains Erik Zindel, manager at Siemens Energy. "We want to demonstrate any mix from zero to one hundred per cent of natural gas and hydrogen in the plant, all with dry premix combustion."

The Hyflexpower project has a total budget of almost €15.2 million, of which €10.5 million is fully funded by the EU under the Horizon 2020 programme. During the two demonstration phases, the plant will run on a mix of natural gas and hydrogen, with the final stage in 2023 targeting operation with up to 100 per cent hydrogen. The consortium includes Siemens Gas and Power, Engie Solutions, Centrax as well as Arttic, DLR and four European universities. ||



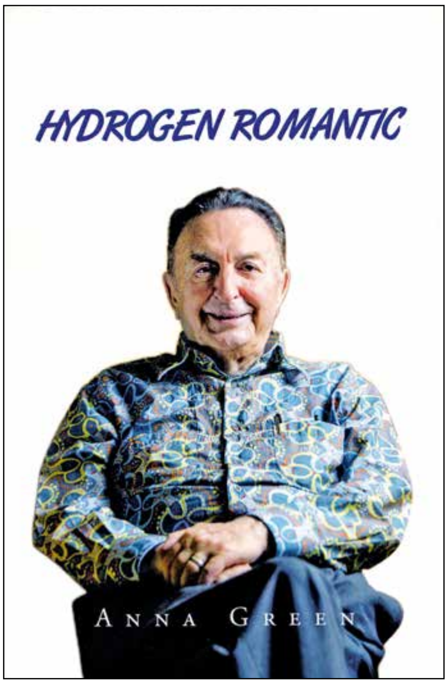
HYDROGEN ROMANTIC

Many readers, especially those who've been following the hydrogen industry for a while, will already be acquainted with the name T. Nejat Veziroglu, also known by his decades-long moniker "Mr. Hydrogen." Now over 90 years old, he rose to international prominence following his pivotal role in the growth of the global hydrogen market, including as the long-time organizer of the World Hydrogen Energy Conference.

Since the WHEC was launched in Miami Beach in the United States in 1976, it has taken place every other year, alternating with the World Hydrogen Technology Conference, or WHTC, in odd years. Both conferences are organized by international hydrogen association IAHE. Age-related health concerns made it impossible for Veziroglu to attend the WHEC's most recent iteration in Rio de Janeiro, Brazil, in 2018 (see H2-international, October 2018). But besides sending a video message to the conference, he was well represented at the event by his wife, Ayfer Veziroglu.

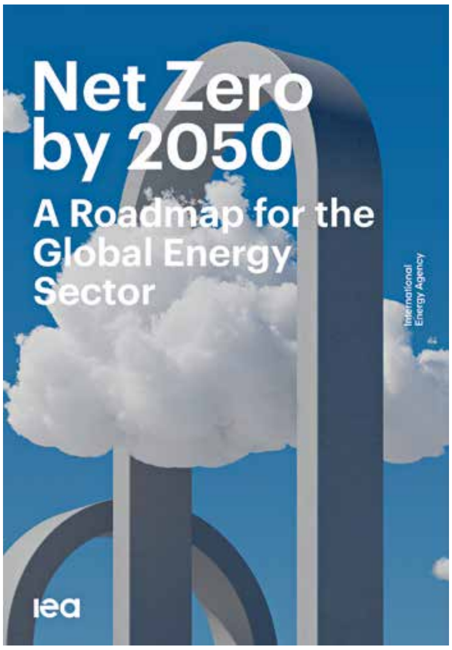
"Hydrogen Romantic," written by Ayfer Veziroglu under her pen name Anna Green, is based on a series of daily interviews she did with her husband over the span of several weeks. Drawing on her meticulous notes, she created a memorable tribute to the visionary's eventful life. Although the book's title is a direct nod to her husband's love for hydrogen, the 276-page book offers many historical and personal insights into his time spent as a young boy in Israel and as a university student in the UK. The topic of hydrogen comes up about 100 pages in, as the book turns to The Hydrogen Economy Miami Energy Conference, better known as THEME. Organized by T. Nejat Veziroglu in 1974, the event drew 750 attendees from 80 countries. A spontaneous meeting on the first conference day led to IAHE's founding, with Veziroglu serving as the association's first president.

The book, which came out at the end of 2020, is available in hardcover, pocket book and digital format on publishing platform Xlibris. It has a simple yet elegant design and contains numerous black and white photographs. ||



Green, Anna. Hydrogen Romantic. ISBN 978-1664126992. Xlibris, 2020

IEA ROADMAP



On 18 May 2021, the International Energy Agency (IEA) presented a special report that could help implement the path to an era of net-zero emissions in the energy sector by 2050. The path to be trodden for this is narrow, but it offers amazing benefits. The report is the world's first comprehensive study on how the transition to a net-zero energy system by 2050 can succeed globally. According to the study, the most important measures are the rapid expansion of renewable energies and the drastic reduction of fossil energy sources.

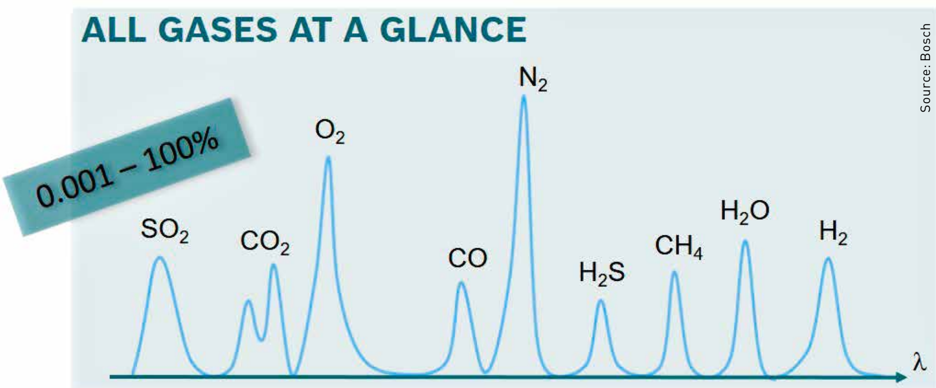
The path outlined by the IEA involves drastically high levels of investment that could create millions of new jobs and boost global economic growth. However, this would require far-reaching political measures by governments, which would have to be flanked by intensive international cooperation. For example, the IEA is calling for no further investment in fossil fuels with immediate effect and no new registrations of passenger cars with combustion engines by 2035, as well as zero CO_2 in the global power sector by 2040. Both battery and hydrogen technology are considered to be particularly effective.

Fatih Birol, Executive Director of the IEA, said: "Our roadmap identifies the priority measures needed today to ensure that the opportunity for net-zero emissions by 2050 – which is low but still achievable – is not lost. The scale and speed of effort required by this critical and daunting goal – our best chance to combat climate change and limit global warming to 1.5°C – make this perhaps the greatest challenge humanity has ever faced." ||

IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector

"Governments' climate pledges to date – even if fully achieved – would fall far short of what is needed to bring global energy-related carbon dioxide emissions to net zero by 2050 and give the world a chance to limit global temperature rise to 1.5°C. […] An energy turnaround of this scale and speed cannot be achieved without the sustained support and participation of citizens whose lives will be affected in many ways."

PORTABLE MULTI-GAS ANALYZER



Researchers working for Bosch and Linde are developing a new, portable device called an Optical Gas Spectrometer, or OGS. The unit is said to be capable of detecting nearly all types of impurities found in hydrogen and CNG and allow for a detailed analysis of gas compositions.

Despite being as small as a shoe box, the device provides the same functionality as spectrometers used in laboratories. While Linde Gas is now putting the first fully functional prototype through its paces, Bosch is looking for additional partners to improve and beta-test the unit.

The purpose of the device is to determine hydrogen or natural gas quality based on DIN EN 17124 or ISO 14687. By integrating multiple analyses into a single instrument, the OGS eliminates the need for separate analyzers to detect a wide variety of gases and hydrocarbons. These include hydrogen sulfide (H_2S), sulfur dioxide (SO_2), oxygen, dinitrogen (N_2), nitrogen dioxide, carbon monoxide, carbon dioxide, water, alcohols and aromatic compounds. Analysis takes only a few seconds, with readings given in parts per million.

While designed for an operating pressure of 10 bars, the OGS can also perform measurements at up to 30 bars at a temperature of 10 °C to 40 °C. The current aim of product development is to increase both the pressure and temperature range of the device.

If you are interested in partnering with Linde and Bosch to improve and test the OGS at your production facilities, please send an email to Franziska Seitz at Franziska.Seitz@de.bosch.com ||

Category: Market | **Author:** Elisa Reker-Gluhic

HOW CAN GERMANY AND EUROPE LEAD THE WAY IN FUEL CELL MOBILITY?

National Platform Future of Mobility reveals its position paper

The chances of fuel cell technology making a breakthrough in mobility applications are looking good. Various developments are helping the rollout, expansion and deployment of fuel cell technologies in many different areas of the transportation sector. These include the technological maturity of the automotive industry, potential synergies in connection with other hydrogen applications and sectors, considerable changes to the regulatory framework and new political ambitions, as articulated in Germany's national hydrogen strategy. But how is the German and European vehicle manufacturing industry poised when it comes to fuel cells?

If climate goals are to be reached, major new technologies will be required that have the potential to significantly reduce emissions. While battery electric power systems represent one option, electric propulsion based on hydrogen and fuel cells is another alternative which is particularly suited to applications with high performance and energy requirements or where the need to cover large distances is paramount. Example areas include long-haul and heavy-duty road transportation as well as applications in the maritime, aviation and rail sectors.

For Germany and Europe to carve out a leading role in the field of fuel cell technologies, however, there needs to be a sustained increase in the global competitiveness of vehicle manufacturing and the competitiveness of German and European industry overall. That's the stance of the recently published position paper of Germany's National Platform Future of Mobility, otherwise known as NPM. The position paper sets out a qualitative analysis of the status quo in terms of the value network for the production of fuel cells and their components, with a focus on the automotive field.

VALUE CREATION PROCESS IN THE SPOTLIGHT The first level of the analysis looked at the individual steps of value creation depth. Here, a description was given of each separate step in the process: from raw materials, membrane electrode assembly, the manufacture of bipolar plates through to stack and system assembly and recycling. For each of these central value creation stages, a second level of analysis and assessment was applied to aspects such as the scientific foundation, the development and production know-how, the recruitment and development of staff, sustainability and environmental responsibility, the basis and readiness for investment as well as issues surrounding energy use and performance. The expert assessment focuses on an evaluation of the current situation with regard to current competitiveness in Germany and Europe and also provides a forecast based on the assumptions made about future changes in competitiveness "in 10 years" within an international context. Performing the analysis were the members of NPM's Working Group 4, whose remit encompasses "securing Germany as a place for mobility, production, battery cell production, primary materials and recycling, training and qualification," and other specially invited experts from academia and industry.

ANALYSIS RESULTS AND RECOMMENDED ACTIONS The outcome of the analysis indicates that both Germany and Europe, when compared to international standards, need to regain ground in particular areas of the value chain. This is particularly the case for:

- efficiency of raw material usage and closure of raw material cycles
- development and production in membrane electrode assembly
- basic research into bipolar plates and stack assembly
- research and development, cost reductions and expansion of the supplier base for key components such as hydrogen recirculation blowers, DC/DC converters, humidifiers, tanks and electronic air compressors

By contrast, when it comes to system assembly and certain components, namely the power distribution unit, high-voltage wiring harness, tank valves and pressure regulators, European organizations are generally at least on a par with the world's major players.

Needs-based fuel cell development and production is crucial in order for the European mobility industry to attain a leadership position. This presupposes that intensive R&D and a high production share of all value creation stages take place in Germany and Europe. The effects that the changeover of power systems will have on employment within the automotive industry must be countered by requalification and adjustment programs. So as not to jeopardize the establishment of a future leadership position for Germany and Europe in the field of fuel cell technology and in order to exploit the associated innovation potential, the training of specialist staff and the recruitment of experts at universities, as well as in businesses, have an important role to play.

Last but not least, the market for fuel cell vehicles needs to be developed and made more attractive to users. Part of the solution is the expansion of the refueling infrastructure for hydrogen. It also calls for a harmonization of standards at an international level along with technology cost reductions through economies of scale and strategic partnerships.

CONCLUSION In many areas, Germany and Europe already have a solid basis for the future production of fuel cells. When compared internationally – particularly with Asia – there is, however, a need to catch up. Competitors from Japan, South Korea and China are already producing fuel cells in large quantities. This is due to an acceptance several years ago of a hydrogen-based future and has resulted in infrastructure expansion and infrastructure funding, which in turn is significantly driving development in various Japanese, South Korean and Chinese enterprises.

In China – the largest market for electric transportation – the industrial sector is currently expanding all the areas of competency required for fuel cell technology. It can be expected that China will look to achieve a dominant position in the fuel cell market, similar to the position it has already

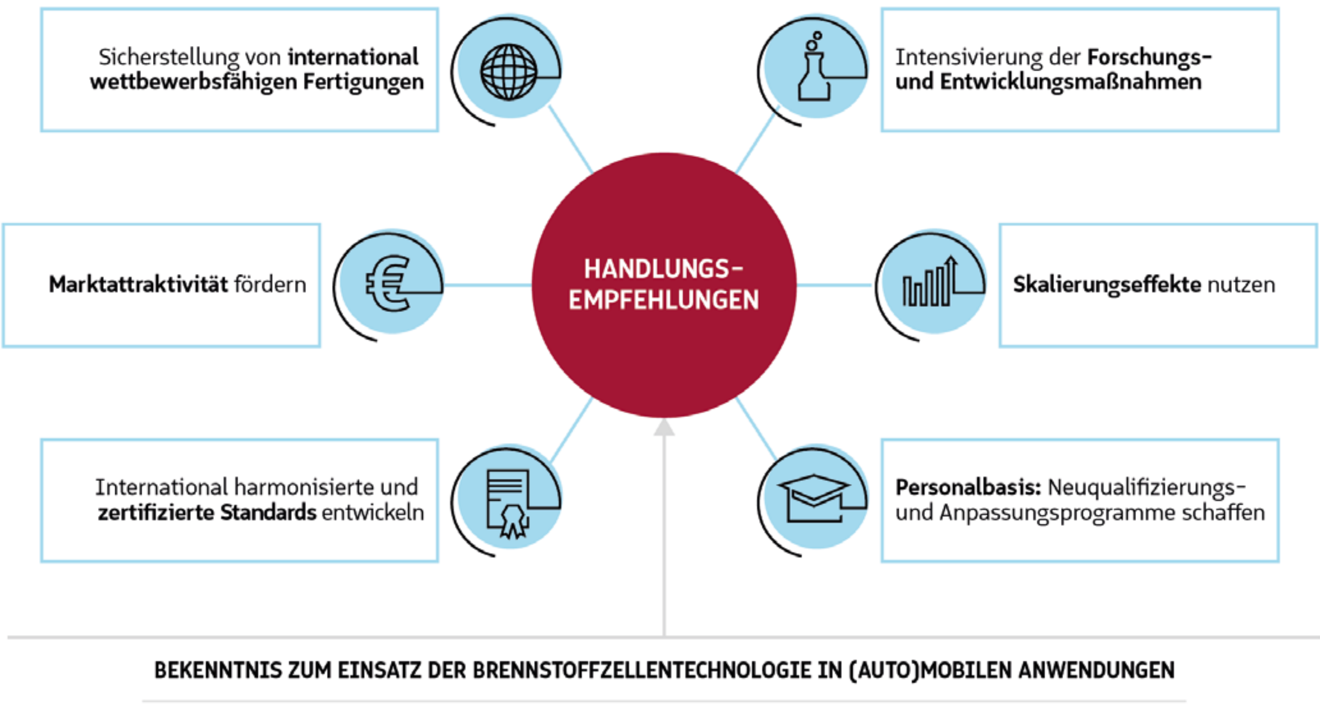


Fig. 1: Overview of recommended actions [Source: NPM]

attained for batteries. Fuel cells are, at present, one of the most highly subsidized new vehicle technologies in China. If the development of hydrogen-based vehicles in China runs a similar course to that of battery electric forms of transportation, then China could become the market leader in fuel cell vehicles in the next six years. Furthermore, there is an additional risk that the widely used practice in China of whitelisting will be introduced to favor local suppliers, as previously seen for high-voltage batteries and cells.

In order to remain internationally competitive with the present market leaders, further areas of action and short-term investment in the domestic economy are, for Germany and Europe, essential. Germany, in particular, has previously taken a wait-and-see approach in terms of pushing hydrogen. Nevertheless, the European Union's hydrogen strategy and the German government's national hydrogen strategy sent out a tangible message in 2020. It is still necessary, however, for the political establishment and industry to set clear intentions that recognize the use of the technology in automotive/mobility applications so as to create future certainty, form a sound basis for planning and thus encourage investment.

The rapid development of a functioning European hydrogen economy must take place without a preference to certain technologies and requires all climate-neutral hydrogen production processes in order to cover the increasing demand for climate-friendly hydrogen within the industrial and transport sectors and to tackle climate change effectively, instead of a one-sided focus on electrolyzed hydrogen. It is important now more than ever to establish hydrogen fuel cell technology within the transport sector and to maintain long-term competitiveness, making sure that the right approaches are used and at the necessary speed. An application-centered market activation must now be the goal in order to drive forward this key area of technology. ||

→ www.plattform-zukunft-mobilitaet.de/2download/positionspapier-brennstoffzelle/

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DIGITAL VALUE CREATION IN A GREEN HYDROGEN ECONOMY

Results of Fraunhofer's PLATON research project

Three Fraunhofer institutes in Germany – IAO, IIS and IMW – have been tackling key questions on the nature of digital value creation in relation to green hydrogen. The research comes as part of the PLATON project which has been investigating the platform economy in the hydrogen sector. The results of the project have now been published in a study. The outcome is a hybrid value creation model that helps companies to take a systematic approach to digital value creation.

Enormous political and economic effort is required if hydrogen is to become a new lead market in Germany and if Germany is to establish itself as a lead supplier for hydrogen technologies. For a lead market means cultivating green hydrogen as a new and significant economic sector within Germany and Europe over the longer term and developing an awareness of its role in ensuring our lasting prosperity. Alongside the German government's multi-billion-euro subsidy programs and the high level of investment in hydrogen technologies by businesses, a greater consideration of digital value creation is imperative to reach these targeted goals.

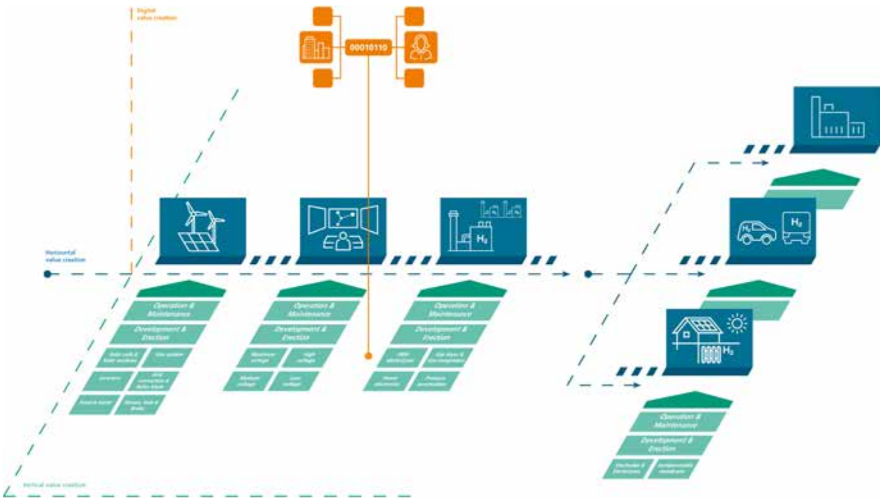

Fig. 1: Hybrid value creation model for the green hydrogen economy [Source: Fraunhofer IMW]

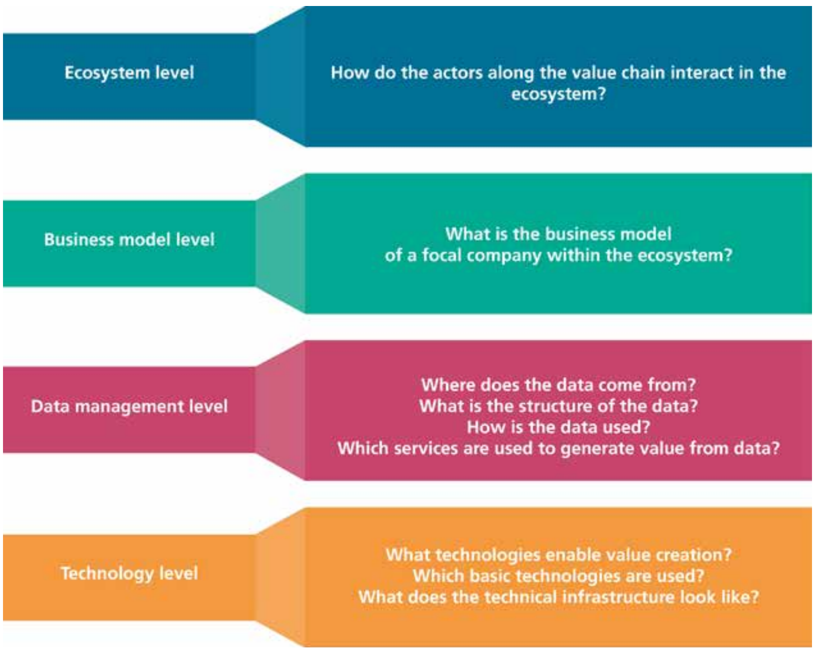

Fig. 2: Levels of digital business models [Source: Fraunhofer IMW]

THINKING DIGITALLY FROM THE OUTSET Only when the digital world is taken into account – from data generation right through to platform-based approaches – will the high level of investment in the lead market for green hydrogen pay off. This, in any case, is what experience tells us from other economic areas, e.g., manufacturing and mobility, in which the share of value created is shifting increasingly from the physical to the digital domain. Attractive profits and rapid revenue growth are often no longer achieved by companies that develop and market purely physical products and services, but are instead obtained by those that also successfully implement the ideas of the data and platform economy, invest in digital technologies, such as artificial intelligence, machine learning, big data and the internet of things (IoT), and transpose these into new business models on a large scale.

To help companies establish digital value creation within a hydrogen economy, a hybrid model based on three value creation dimensions was developed as part of the research project (see fig. 1). The first two dimensions incorporate physical value creation while the third dimension illustrates digital value creation:

- Horizontal (physical) value creation: from renewable energy to electricity to the production and utilization of green hydrogen
- Vertical (physical) value creation: from individual components to assemblies to entire systems
- Digital value creation: from data from the physical world to connectivity to data-oriented and platform-based business models

Horizontal (physical) value creation covers all direct activities, starting with generation from renewables, for example wind, solar and biomass, and extending to the production, storage and transportation of hydrogen and through to the use of hydrogen in industry, transport or buildings.

Vertical (physical) value creation encompasses the necessary upstream components, assemblies and systems for generating renewable energy, for transmitting electricity, for producing, storing and transporting hydrogen, and also for utilizing hydrogen. All these value-added activities are important since many key elements such as electrolyzer plants or fuel cells are still in development or in the process of reaching the series production and launch stages. Part of the strategy for establishing a green hydrogen economy must be the rapid further development of critical components, software applications, assemblies and systems. Value chains for the manufacture of electrolyzer plants or fuel cells need to be created and optimized.

Digital value creation represents the digital realm of a green hydrogen economy. Using digital technologies, data is generated from the physical value-added activities and is used to create value in digital business models. Such business models are frequently subsumed under the headings "data economy" and "platform economy." Digital business models benefit from the increasing availability of operating data and status information as well as from the rapid progress being made in data analysis through technologies that include artificial intelligence and machine learning. Examples of data-oriented approaches and value-added activities that have already been introduced are as follows:

- Developers and operators of wind farms and solar arrays that use data on weather conditions, including wind force and sunshine hours, to assess the attractiveness of locations for wind and solar power plants and to plan their plants more effectively
- Plant manufacturers that increasingly use machine learning to better predict failures of wind and solar power plants and to identify damage, for example through images taken by drones
- Smart grids which, by evaluating data, achieve a better interaction between power generators, power consumers and grid management so that fluctuations in the energy supply are better offset and grids are more equally balanced
- Grid operators that collaborate with software companies to achieve increased grid stability by means of artificial intelligence
- Industrial companies that generate data during nondestructive testing of components in fuel cells and electrolyzers which can be used to optimize production processes by means of artificial intelligence
- Operators or gas grids that use data analysis to identify leaks in gas pipelines more quickly, to simulate flow models and to optimize supply grids

These data- and platform-oriented approaches will become an important part of value creation within the green hydrogen economy and facilitate the route into results-oriented "as a service" business models such as "wind power as a service" or "hydrogen as a service." These appear to be inescapable in rail and heavy-duty vehicle transportation, for instance, since the sale of a hydrogen train or a fuel cell truck will not alone be sufficient to encourage companies to switch to the new technology. Rather, the supply infrastructure for hydrogen must be offered alongside it and this infrastructure must be ensured for customers. Companies therefore need to develop a comprehensive understanding of digital business models and take into account four intertwined levels:

Here, the research project demonstrates that data- and platform-based business models already currently exist at various points along the value-added activities in the hydrogen economy. In hydrogen production, by way of example, the German electrolyzer supplier Enapter evaluates the data from its electrolyzers on a platform in order to optimize en-

Fig. 3: Enapter's IoT platform, represented using the PLATON canvas [Source: Fraunhofer IMW]

ergy management. Use of the platform allows electrolyzer operators to lower their energy costs and reduce their risks, such as plant failures.

The PLATON canvas, which was developed during the course of the research project, enables the particular characteristics of platforms to be analyzed systematically:

- Interaction: Describes the reciprocal relationships between platform provider and other agents. The form of the interaction has significant consequences for the value proposition, the possibility of achieving network effects, the scaling and the revenue mechanism
- Value proposition: Illustrates how, on platforms, a value is created for customers and partners
- Network effects: Cause an increase in the value created on the platform as the number of agents rises
- Scaling: Denotes growth options by means of which the created value can be increased for agents. This is often not explicitly incorporated in traditional business model concepts. Scaling can take place on the user and the partner side
- Revenue mechanism: A considerable challenge for platforms lies in the revenue mechanism, in other words the ways and the means by which companies can generate income via the platform

The research project demonstrates that a comprehensive understanding of digital business models in the hydrogen economy and proactive engagement in their design are essential for successfully establishing green hydrogen as a lead market. At the same time, however, digital value creation in the hydrogen economy is only in its infancy. Those companies in particular that consider digital value creation at an early stage will be among the winners in the newly formed green hydrogen economy. ||

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Category: Market | **Interview partner:** Dirk Müller |

THE IMMENSITY OF HYDROGEN

Interview with stock market pundit Dirk Müller

Fig. 1: Dirk Müller [Source: Dirk Müller]

For months now, hydrogen has been dominating the conversation. But far from it being a topic of discussion confined to the energy sector, it's also a subject on the lips of many stockholders. Internet platforms have been brimming over with posts: a cacophony of news, views, speculation and rumor. And an increasing number of providers are luring potential clients with – sometimes dubious – market studies supposedly offering fresh insider intelligence with the promise of maximum stock returns. One of the best-known stock market experts in Germany is Dirk Müller – otherwise known as Mr. Dax. Many years back he predicted that hydrogen would have a major role to play not just in the energy industry but also on the stock markets. H2-international talked to Müller about his experiences, expectations and share trading strategy.

Mr. Müller, for you this run on hydrogen stocks has not come as a surprise. Back in 2018 you described the potential of this technology in your book "Machtbeben" [rough translation: Power Shake-Up]. When did you start following the hydrogen sector?

Müller: I've actually been following it for over 10 years now. Ballard Power was already in existence back then as well as quite a few other companies that were early adopters of hydrogen. But they were pretty far ahead of their time. It was still very much a niche area, yet it was already possible to see that it would become a big deal one day. We always try to keep an eye on things in the early stages and not when they are front page news. I think at Cashkurs*Trends, our stock market service for tech companies, we flagged up hydrogen 10 years ago, but of course it's only now that things are really getting interesting.

At what point did you become aware of hydrogen's potential?

It was the moment when it actually became clear that we were going to be relying more on renewable energy, and the decision was made to move away from oil – when this issue of carbon dioxide became a massive talking point, so five or six years ago. It was obvious to me that with renewables there would also be a need for a storage technology, and that could only be hydrogen. It was clear that there'd also be increasing impetus in the hydrogen sector, although hydrogen is such an immense deal that, first of all, the players position themselves and try to do as much as possible under the radar before it triggers any major change.

And what in the past few months has demonstrated to you that this is not just some new short-lived hype but that this is something big that's come along, something that's here to stay?

For me it all became very clear when I saw the ferocity of the political struggle over gas reserves around the world, Qatar being a case in point. For the past few years, no damn person has had any interest in oil, to put it bluntly. Natural gas, on the other hand, has always been a major battleground. It'll play a really, really big role for a long time to come, and, like it or not, hydrogen and natural gas are very closely interwoven. Green gas and green energy will be put at the forefront, and until at least 2050 most of the hydrogen will be produced – in my view – from fossil fuels and not from renewables. Although, of course, they're a nice fig leaf. While the emphasis will move increasingly in favor of green hydrogen over the coming decades, the transitional technology to reach that goal is gas.

Why then are the Americans so impatient to take the gas supplies to Europe away from the Russians if the word is we don't want anything more to do with gas – we want to shift to renewables. It could be said that a few cubic meters will be left to the Russians. But it's evident that things are really kicking off now in the gas market.

How do things look in the mobility sector? Volkswagen is turning itself fully toward battery-powered electromobility while Toyota and Hyundai are also focusing on fuel cell cars. What are your thoughts on this?

I think from today's standpoint, in 2021, it's impossible to say with any certainty that these companies will just do hydrogen and these companies will just do electric. Both will be used. Everyone will decide for themselves where their strategic advantages lie. These days, I wouldn't even go so far as to separate these two worlds like that.

And where do you see the fields of application?

There was a time when hydrogen propulsion made sense for industrial trucks. But when this niche product is let out, we mostly see the benefits of hydrogen in heavy-duty and long-range vehicles, and similarly for limousines. When it comes to smaller vehicles, that's where electric now has the upper hand; but even small vehicles – and this is also on the Hydrogen Council's timeline – will be powered by hydrogen too from 2025 or 2030. So at the end of the day we'll have battery and fuel cell vehicles running alongside each other. Both have their own justifications, as did gasoline and diesel. Both will find their fields of application, and that will vary between corporate groups.

In 2018 you wrote in your book that while China was then going "full throttle" toward battery-powered electric transportation, in Germany the brakes had been applied, "in order to get hydrogen onto the slopes as quickly as possible." Your opinion was that we should "let as few electric vehicles on the streets of Western industrial states as possible so as to gain time for hydrogen." Was that the case?

I wrote it in pretty bold terms because back then all you heard was electric, electric, electric. Hydrogen hardly got a look-in. It was a crackpot technology that was barely in the public consciousness. I wanted to make it clear that there were good reasons to give hydrogen a much, much higher priority. The thrust of my argument was: Don't underestimate hydrogen – which I think was quite apt.

Why should German automakers in particular take a greater interest in hydrogen over battery technology?

I'm convinced that there is a great deal of interest in our industry to push hydrogen instead of electric, simply due to the higher complexity of hydrogen powertrains and hydrogen technology because this creates greater value for companies in the Western world – that's how I described it in the book. But I think there are now more factors at play than just technology market leadership.

To want a more elaborate technology to prevail purely because there is greater potential for value creation is, in terms of resource conservation, totally nonsensical, surely?

Yes, but nobody is really interested in that. Throughout this whole discussion around resource conservation and environmental protection and so on, I have – when it comes to industry – never seen anything that's more than just a fig leaf approach. Industry has shown no interest for a hundred years and it still isn't interested now. For them, it's about making profit, maximizing gains. When a nice green fig leaf is wafted at them, then they gladly take it and use it for decoration. At the end of the day, it's all about revenue for them. Thirty years in the stock market tells me that companies actually couldn't care less. They like to tell you they do, and when push comes to shove, they'll do what's necessary. The driver is always money and power. At the most, the environment is used just as a pretext.

So in your opinion would politics need to take a more proactive role in order to change the framework?

There's a lot of misuse surrounding carbon dioxide certificate trading and ESG regulations, etc. Much of what happens politically and economically I see as green washing. When I look at which companies are getting which ESG assessments, that has more to do with issues of power than with actual environmental issues. You have to really scrutinize things, and politics is rarely cut free from the financial interests of large corporations, investors and party donors. If you look at how much influence the large corporations have in terms of lobbying in Brussels and how little influence the small environmental organizations or others have there, the cards are clearly stacked.

What's your take on China? The work there on hydrogen technology seems, in many places, to be moving forward much more rapidly than here, or what's your current take on it?

The Chinese also see that they can't get any further with all-electric and that they too need hydrogen. The needs are the same right around the world. I now have areas of application which I can't progress any further with electric. So of course they have gone full throttle into electric and tried to use this speed to outpace the Western market. It's a simple technology that China has been able to build super-quickly – more quickly than in the West with its bureaucratic hurdles. Hydrogen is more complex. That's where we're one step ahead. These days, I no longer see it as such a clear split between battery and fuel cells. Today it's a mixed model in all business areas – that's as much the case for the Chinese as it is for us.

What's the news from the USA?

I've always seen the USA as being well out in front when it comes to hydrogen, even if there have been political braking maneuvers and inference now and then. But they have been in the starting blocks the whole time. There's also the "Road Map to a US Hydrogen Economy." It sets out in great detail how the USA intends to become a true hydrogen nation. They are going to be a really key driver. Most of the growth in hydrogen vehicles in the runup to 2050 will not be in Europe or Japan, but in America – if you look at the Western world.

Where does Europe stand in comparison?

We're often the inventors of many things but when it comes to execution we lag behind. That's been the case for us for decades. I'm utterly convinced that Asia and the USA will be the forerunners with great leaps forward in development and Europe will be laboring far behind somewhere. The upshot of the crisis and the closely related 2030 agenda will be that we'll see a massive push for renewable energy, for everything that stands for sustainability, environmental protection and the like. It'll be an era that turns its full attention to this. In the end it doesn't matter a jot whether it now happens because people want to make money from it or because people are really serious about the environment: The main thing is that it happens.

In February 2021 you gave a webinar on the subject of "Energy of the future – What investors in hydrogen shares now need to know" [in German]. The interest was enormous. How do you interpret this ever-growing interest among large investors as well as private individuals in hydrogen shares?

It's difficult to judge: Private investors mostly come along when the fish is already in the net. At the start of the year they bought anything connected to hydrogen, without any thought given to the valuation. My view at the time was that this was another hype. Although it's a great technology, you can still buy the best shares at too high a price. We saw this in 1999/2000: Anything connected to dot-com was bought up, and a horrendous amount of money was lost. At the moment I see a similar trend happening for hydrogen. Until recently, all sorts of small, hapless enterprises were being traded at fantastically high prices. I should be proved right in terms of the warning I gave about this in February: Since that time, many hydrogen stocks have collapsed dramatically. The best of example of this is Plug Power, which fell from USD 70 in February to now USD 20.

You and I have written and spoken about this over the past several years: It was foreseeable but at the time only a few wanted to pick up on it because the public awareness was not there. But now, where there is interest, then the prices are, of course, at a level you'd expect them to be at when everyone is watching them. That's why at the moment it's really, really hard for a private investor to be active in this field, in my view. But as the saying goes in the stock market: Don't run after a streetcar or chance that's already departed, the next one will come along for sure. And prices gradually get closer to reality again to a point where you can reconsider an investment.

That may be, but stock prices have been really up and down for the past several months. In your webinar you pointed out that it's not unusual for peak prices like that to be followed by a slump. Are we now in such a correction phase?

The prices are already collapsing, as previously mentioned. It shows that a buyer's market for hydrogen isn't very far off, that there's not very much profit to distribute. Many weak companies will collapse because they do not have the means to finance long periods of loss. But that will also lead strong companies into difficulties since the weak ones, in their bid for survival, will try to get revenue through price dumping. Many won't survive this phase, and the strong ones will be forced to become lean and efficient. As the market corrects itself, the future champions will be discernible. And then comes the phase in which there is hope for long-term revenue sustained over many years. Only then will it become apparent which companies will benefit from it. In the early stage, it's not always so clear who will be the big winner. Many companies we rave about today may not even exist in 10 years. Others that we don't even know about or which are still insignificant, they will then become the big players in this area. We've been observing these new industry development cycles for decades, such as for the internet, wind power or 3D printing.

I'm increasingly asked by people, including neighbors, about listed hydrogen and fuel cell companies. I don't personally own any shares but I still get asked: What's your advice for private investors?

I would focus on the big companies. In the long term they will have a part in this trend. So if I'm not concerned so much about the price trend over the next two or three years, but rather five to 10 years in the future, I'll be in a very good position with them. I'll still get their stocks at a reasonable price, compared to the small, over-hyped stocks that are being traded at many times their reasonable value, and without any indication whether they will actually survive.

We now have the Hydrogen Council and Hydrogen Europe, and that means everything has assumed quite a different dimension. There are far more players on the scene than there were in 2017/18. Everything is being split wide open. It's resulted in this momentum. My impression is that we now have the breakthrough that will really accelerate hydrogen to the point that there will be no stopping it.

Shell was in on it from the beginning but it was always a wait-and-see approach. Shell is now, to a great extent, disengaging from its oil business and is focusing fully on its natural gas business and the combination with hydrogen. That's why I no longer see Shell in the braking zone but rather in the acceleration zone.

Perhaps you could give H2-international readers an insider tip?

Truth be told, I don't really go in for insider tips. I've been in the market for 30 years and at some time or other I learned to steer of such things and instead concentrate on long-term business models. Five or six years ago, as part of our stock market services, we pointed out the companies that are now hyped up, but that's something that you have to do successively. You have to go into it before anyone's interested otherwise the market is grazed down to the roots. Big players such as Royal Dutch, Equinor, Nel or even Atlas Copco with its compressors are rather conservative, long-term interests.

What's your opinion of Nikola? General Motors has pulled out but the Americans are still currently building up production capacity in Ulm.

To my mind there were too many anomalies, too many question marks. That's not what I like. I like companies that have a good, stable management that's proved it can work reliably over many years, companies that are quantifiable and deliver on what they promise. For me, anything else rings alarm bells.

Finally, I'd like to ask you for a prediction. You are well known as a highly critical stock market expert who openly speaks his mind. For example, you talk about a "small investor hype" on the one hand and the threat of a "Great Reset" on the other hand. Could you tell us in just a few words: Where do we stand today and what will be coming our way?

The Great Reset is precisely what we are experiencing. What's happening here will have dramatic economic consequences. I'm of the opinion that we are not at the end of this trend but right in the middle of it – best-case scenario. I believe we'll see even more serious disruptions in the financial markets and in the economy. It'll also be yet another massive shake-up for the stock markets. In the last 12 months we have experienced such disruption, the consequences of which we will only see in the next two or three years. There'll be a lot of tears and bloodshed – in the economy, but also among the people outside. At the end of it we'll have a completely different world based on a completely different economy. We have now arrived at a world in which we don't assume economic growth is the holy grail.

"We need growth, growth and more growth" – that's the mantra we've lived by over recent decades. Now people are saying we are stretching this planet to its limits in terms of resources. Now it's all about less consumption; politics will also gear itself toward this. Klaus Schwab from the World Economic Forum WEF writes lucidly on the subject: "We want to get away from a growth economy to a world which is based on different principles." That will, of course, mean dramatic changes for companies that up to now have had everything trained on growth. It'll have a big impact on stock valuations since our valuation models are based on the old growth assumptions. But these have not taken into account the fact that the goal is now a politically motivated change from a growth economy to "less growth please" or perhaps even to a "contracting economy": "Please buy less, go on fewer long-distance trips, stop building new homes, stop eating meat, share a car." That's a totally new dogma. Interestingly, an economy that no longer has growth as its dogma doesn't need an inflationary monetary system, but rather a deflationary one. Interestingly, Bitcoin is just that.

Fascinating prospects. Please allow me to ask one final question: What encouraged you to take this view?

I've always fought against our "exploitative industry," and for someone in my position that's rather unusual. Sustainability, environmental protection and all these other issues have always been extremely important to me – and even more so these days. My concern is that in many areas it's all about dressing things up with a fig leaf, that what finally happens is actually something quite different and the fig leaf is only used to generate a dramatic shift in power. In the end there will be a few big winners, a few big corporate groups that will dominate everything and then, through green washing, have the power to destroy all the others, to portray themselves as the big savior, and in the end have power over billions of people. At the end of the day, however, genuine environmental protection doesn't have any kind of significant role to play for them – they couldn't care less, it's just about driving others out of business. My fear is that a lot of it is just for show and you can't even say much against it because it's impossible to be against environmental protection.

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

Interviewer: Sven Geitmann

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

GROWING EFFORTS TO DECARBONIZE THROUGH HYDROGEN

Sven Jösting's stock analysis

A market report recently published by news agency Bloomberg concludes we're well on our way to a hydrogen revolution. I'd call it a megatrend. The report's authors expect USD 2.5 trillion, that is, USD 2,500 billion, will pour into the hydrogen and fuel cell sector by 2050. The International Energy Agency agrees. Between 2018 and 2020, an estimated USD 1.5 billion per year went into developing the market, a figure said to climb to USD 38 billion by 2040. By 2050, investments will reportedly grow to USD 181 billion – again, per year. All these forecasts are based on targets already set by countries, global organizations and companies themselves.

That's mighty good news for the stock market and the companies listed on it. In other words, the all-time highs the stocks discussed in this issue saw in February won't be the end of the road. That the stocks have since lost some of their value can only be a sign to start buying again. Any company that has a good positioning strategy and, thanks to its technology and business model, is able to deliver convincing solutions is sure to experience above-average growth in the near future and generate high revenues in the long run. That, in turn, will have a positive influence on its stock and the market in general, as stock prices reflect everything that has or can have an impact on business.

Fig. 1: Historical prices of the stocks discussed in this issue [Source: wallstreet-online.de] Retrieved June 8, 2021

FEBRUARY HIGHS DESTINED FOR A REPEAT The past weeks have seen multiple rallies on the market come to an abrupt end, with some companies' market caps suffering a heavy blow as a result. Now, stocks seem to be consolidating. In fact, the bottom seems to have been reached already. Prices are again on the up, albeit from a low base. The hefty drop could partly be the result of hedge funds, short sellers and other traders' attempts to bring hydrogen and fuel cell shares to their knees.

That's my suspicion, at least, after seeing multiple spikes in short interest lately. But the growing number of shorts could also be a boon to the market. As soon as good news comes from individual companies or the whole sector, driving up prices, short sellers may be forced to cover their positions. That would then likely boost demand for the shares being sold short.

One thing that's crystal clear these days is that the time has come for hydrogen and fuel cells to disrupt the energy world. They're not a dead end. The sector is simply trying to find its footing. A new megatrend is emerging. Growth may not happen in a straight line, but there will be tremendous gains over time.

What investors need to consider is that all these companies, all their technologies and business models, are only now – in 2021 – starting to generate notable revenues, which could translate into fast-growing earnings further down the line. That's not at all unusual for a nascent market. It's also why shareholders shouldn't look at hydrogen and fuel cell companies through the prism of yearly revenues and quarterly results. Of course, companies in the sector will keep posting high losses for now. R&D requires a lot of cash. But the stock market reflects views of the future, and much of that expectations game is rooted in psychology.

A few detours may be necessary. Technology adoption rates differ from country to country, continent to continent. Countries in East Asia, from Japan to South Korea to China, were the first to make the switch to batteries. Now, they seem to be again the prime movers, this time in the hydrogen and fuel cell market. What investors need is patience. I reckon that in one to three years, hydrogen and fuel cell stocks could earn them a lot of money. Though only if they spend funds not meant for more immediate needs. Taking out a loan to buy stock is a big no-no. What every investor needs to keep in mind is that a market crash is always a possibility. And it's not just price bubbles that those borrowing money for buying stock need to worry about; inflation and interest may be even bigger risks.

As for the stocks discussed in this magazine, I believe the worst is already behind us. Plus, the industry's technologies and business models are becoming viable enough to help the fight against climate change. That seems like good prospects for high revenues in the long term. >>

BALLARD POWER QUIETLY SHARPENS ITS EDGE

Ballard [Nasdaq: BLDP] is quietly moving forward with forging new alliances around the world. Or, more specifically, the company is building prototypes that are sure to lead to joint ventures and partnerships to commercialize stacks and modules and components for parts suppliers. I previously covered Ballard's business relationship with Mahle. Now, Ballard has teamed up with compressor manufacturer Chart Industries, as well as Linamar, a Canadian automotive supplier with sales of USD 7.5 billion and over 26,000 employees. The aim of Ballard's partnership with Linamar is to develop fuel cell powertrains for light commercial vehicles weighing up to 5 tons and for SUVs, and maybe other kinds of passenger cars in the future. Ballard might even consider forming a joint venture with a company such as Honeywell, to which the fuel cell maker sold its former subsidiary Protonex' fuel cell drone program – but not before indicating plans for some type of future collaboration.

As for rolling stock, Ballard has partnered with Siemens, Germany, CRRC, China, and Canadian Pacific Railway, the owner of 1,400 locomotives. Regarding boats and ships, it is working with German ABB on new fuel cell systems. One venture to keep on the radar is Ballard-Weichai's in China for the joint production of commercial vehicle stacks and modules. That deal could be a sign Ballard will eventually also join forces with Weichai subsidiary Kion to produce fuel cells for forklift trucks. In any case, all these partnerships lay a solid foundation for future orders, revenues and earnings.

It's why I think Ballard's current quarterly, or yearly, figures aren't as important or relevant as they might seem. Of course, there are those who beg to differ. They base their arguments on Ballard's financial results for the first quarter, when total revenue fell to USD 17.6 million, less than the USD 26.5 million analysts expected, and the net loss per share came to USD 0.06 instead of USD 0.05.

Ballard's market cap now stands at USD 5 billion. In February, the cap was nearly USD 10 billion, despite estimates that have the company's revenue for all of 2021 at a mere USD 80 million to USD 120 million. Some market pundits and analysts find that disparity hard to grasp, striking even.

Fig. 2: JCB excavator powered by a Ballard fuel cell [Source: JCB Group]

> "The development of the first hydrogen-fueled excavator is very exciting as we strive towards a zero-carbon world. In the coming months, JCB will continue to develop and refine this technology with advanced testing of our prototype machine, and we will continue to be at the forefront of technologies designed to build a zero-carbon future."
> *Lord Bamford, JCB chairman*

But Ballard has around USD 1.3 billion in the bank, money it can put to good use. The company could build new production facilities in Europe or make a large acquisition, or both.

As said, the stock market reflects views of the future, not the current situation. That is precisely what's happening in this case. There are huge, global opportunities opening up for Ballard, a leader and pioneer in fuel cell technology.

BOLD PLANS FOR CHINA In March, the Chinese government released its 14th Five-Year Plan. A source in China told me the plan makes special mention of renewable energy, hydrogen in particular. What's missing from the picture is the precise amount the country wants to spend on creating a hydrogen economy. Are we talking about USD 100 billion over five years? Or about USD 500 billion – or even USD 1 trillion – over a decade?

By its own account, Ballard and Weichai's joint venture is the People's Republic's largest stack producer by volume. A few months ago, Ballard CEO Randy MacEwen took a six-week trip across China, meeting with Communist Party big shots, mayors, business leaders and community representatives. As he noted, it's important to show up in person and pay homage to the local region. It's the kind of attitude that can go a long way in gaining new orders and business partners, for example.

Over the next two to three years, I expect Ballard to

1. make stacks at commercial scale in China and increase production capacity.
2. take the joint venture with Weichai public via an IPO.
3. build new manufacturing facilities in Europe, in partnership with a major auto supplier.
4. ramp up the production of modules and stacks for rolling stock.
5. set up or acquire a business unit that will make electrolyzers and, possibly, its own hydrogen.
6. enter the market for drones, or passenger cars even, using patents that will become available upon the end of the company's collaboration with Audi/VW.
7. grow long term starting in 2022 and push the market cap above USD 10 billion.

BLOOM ENERGY – 30 PERCENT STEADY ANNUAL GROWTH

Investment bank J. P. Morgan's analyst meeting with KR Sridhar, Bloom Energy's chief executive, on May 26 revealed bright prospects for the company. When one analyst asked by how much Bloom wants to grow in the near future – if it aims for a rate of 20 percent to 25 percent annually – Sridhar replied the target is rather 30 percent a year over a long period of time. He based his assessment on an analysis of the company's advanced technology, IP portfolio, markets and applications, as well as its competitive position, expertise and experience.

Bloom, he added, is well equipped to provide on-site electricity via its own fuel cell-based power systems. They are up and running nearly 99.9 percent of the time, are secure, even against hacking, inexpensive, reliable, and resilient to environmental hazards and disasters, e.g., wild fires, storms and cold weather. Plus, they supply clean electricity. They can also take a variety of input fuels, ranging from natural gas, LNG and biogas to hydrogen. Sridhar wants this list to be understood chronologically. That means hydrogen-fueled systems will come. But other gases will remain in use – at least, for the time being. Blends are possible too.

Bloom's customer base includes several big corporations, operators of huge server farms, hospitals and university campuses. All of them require electricity and energy supplies. That benefits Bloom while giving its customers more freedom from the public grid via new platform technology. Sridhar said the company is now able to generate electricity for USD 0.09 a kilowatt-hour. That's definitely much cheaper than a power outage caused by a failing grid.

Additional growth is said to come from sales in new markets. Sridhar noted Bloom is expanding rapidly as "grid costs are coming down." Step by step, oil is being displaced by hydrogen. Bloom's plans include constructing 20-megawatt fuel cell power systems with a daily production capacity of 20 tons of clean hydrogen. At some point in the future, it expects to build one such system a month. Projects that competitors are just sketching out Bloom already has in its pipeline, ready to implement, Sridhar added. He further expects the price of hydrogen to fall to USD 2 and create a global market worth USD 10 billion a day.

As for first-quarter results, Bloom's revenue grew to USD 194 million, up 24 percent year over year. The non-GAAP gross margin increased from 16.2 percent to around 30 percent in the same period, mainly driven by a product gross margin of 36.7 percent. That works out to a:net loss of USD 0.15 a share on a GAAP basis and USD 0.07 based on non-GAAP. Yearly revenues are expected to reach close to USD 1 billion. The question now is whether Bloom can increase annual production capacity to 400 megawatts of fuel cells and 1 gigawatt of electrolyzers. The company is on the right track, Sridhar said, ahead of the competition, thanks to "compelling competitive advantages that are unique to Bloom." Those advantages could also help Bloom finally get into the black this year.

COLLABORATION WITH BAKER HUGHES AS A BLUEPRINT
To increase deployment of its fuel cell and carbon capture equipment, Bloom set up a joint venture with Baker Hughes, an engineering firm specializing in the manufacture of pipelines, compressors and gas turbines. The aim of the collaboration is to exploit synergies in the design of off-grid fuel cell power systems and micro-grids for Baker Hughes' clients. Baker Hughes is said to have important technology that integrates perfectly with Bloom's to build systems for the petrochemical and fertilizer industries. This will include utilizing the gases found in sludge and wastewater and leveraging both companies' expertise in carbon capture technology.

GENERAL ELECTRIC Jeff Immelt, formerly CEO of General Electric, is a Bloom board member, while several ex-GE staffers hold high-level jobs at the company. Recently, they were joined by another ex-GE employee, Stephan Reimelt. Reimelt used to manage GE operations in Europe and is now overseeing the same at Bloom. Of note are his trades in 2020, when he bought USD 1 million worth of Bloom shares. He later purchased another batch for USD 750,000. I think his bonus package will have given him enough options to buy stock, so his personal trading activity can be seen as a positive sign. Meanwhile, GE has announced it will invest a massive amount of money in renewable technology, including hydrogen and fuel cells.

I think Bloom [NYSE: BE] is the most mature fuel cell-hydrogen venture in the market, one that can hope to rake in USD 1 billion in revenue this year and break even. The company needs comparatively little cash to fund large increases in capacity. The payback period for putting up new fuel cell power systems is said to be one year only. And the high participation rate of institutional investors means Bloom Energy is seen as a long-term position that promises strong growth. Bloom's global expansion of operations and its use of in-house technology to branch out into electrolyzers have the potential to fire up not only one's imagination but also the stock, currently trading at a very decent price. Why couldn't Bloom reach USD 100 or more in the next three years? I correctly predicted Ballard to go double digits when the stock was trading between USD 2 and USD 3. I'm inclined to believe Bloom will surpass the USD 100 mark.

NIKOLA MOTORS – COMPETITION IS GOOD FOR BUSINESS

It seems like Nikola Motors [Nasdaq: NKLA] was able to stop the bleeding of the past few months. The stock is rising again. Up to 30 million shares are now traded each day, a comparatively high volume for the company. The new-found optimism among investors seems to stem from reports about Nikola's recent progress in meeting its targets. Construction of the Arizona factory is well underway. Then there are new production facilities being built in Ulm, Germany. And another boost for the stock came when competitor Daimler Truck announced its intention to have 5,000 hydrogen-fueled heavy-duty vehicles on the road over the next few years, with business partner Shell providing the fueling infrastructure (see p. 26). Sounds a lot like Nikola's business model, the difference being that Nikola will produce its own hydrogen, and be able to keep the revenue, instead of outsourcing the task to another company.

NIKOLA, THE START-UP BUSINESS The most important thing for a start-up to have is a business idea. Or, better yet, its founders have already drawn up a business plan and built a prototype of their product. Some venture capitalists are even willing to invest in an idea only and offer capital or funding based on milestones or similar agreements specified in a start-up's financial plan. That's what's happening in Nikola's case. The company has recognized that the commercial vehicle market is, right now, the best opportunity for the broad adoption of fuel cells. That doesn't mean Nikola has abandoned battery-powered solutions. What technology is a better fit depends on a logistics firm's operations profile. Nikola has developed a software program to answer that question. It is now working together with Bosch and CNH Industrial's Iveco to construct prototypes and prepare for mass production. The stock market gave Nikola the capital to implement its business plan.

When people invest money like venture capitalists do, they purchase stock knowing full well that it will take time before a business has enough orders, production capacity and profits. It is said that this year, Nikola will be making 50 to 100 units. In 2022, that number may rise to 1,200 to 1,500. In 2023, we could be looking at a production capacity >>

of as many as 10,000 or more (though nothing is guaranteed). Nikola has also begun to put up a fueling infrastructure – a fuel cell truck will be a hard sale if no one offers hydrogen at decent prices. That's, in a nutshell, Nikola's business model and it's similar to Tesla's eight years ago.

Furthermore, Nikola has inked a sales and service agreement with RIG360, a company with 65 service centers located in key metropolitan areas and major intersections of the US interstate highway system. It also signed a deal for the supply of renewable electricity, in an effort to achieve price parity with diesel. And partner Iveco announced that it plans to market the fuel cell trucks that will be built in Ulm across Europe. Meanwhile, construction of Nikola's factory in Coolidge, Arizona, has been on schedule. The company's staff is said to grow from 530 to 1,000 by the end of this year.

Nikola's cash reserves came to USD 763.8 million for the quarter ended March 30. The net loss in that period was USD 120.2 million, which includes USD 50.3 million in stock-based compensation. All in line with business plan targets.

What's more, Nikola is currently in negotiations with 25 large fleet operators. Plus, a hydrogen infrastructure is being put up at key locations and near big prospective customers, with Nikola investing USD 30 million in five new fueling stations.

CONCLUSION I think with some patience, Nikola stock could be a rewarding buy. I speculate that the next larger capital raise, via the issue of new shares, will bring in the money Nikola needs to follow its business plan to the letter. New strategic partners could be on the horizon and those now working with Nikola may increase their ownership stake. The stock's price still reflects some of the negative expectations but none of the positive ones. I'm counting on the latter.

I believe the stock will, as early as this year, be back above USD 20, or above USD 25 if there's another strategic partnership, and pass USD 30 by 2022. It all depends on how much of Nikola's plans will come to fruition, including how much money the company can raise issuing new stock. Estimates indicate that by 2024, Nikola will generate revenues of USD 1.4 billion and turn a profit from selling hydrogen. Those willing to take a gamble can buy the stock. But they need to be patient.

PLUG POWER – CASH INFUSION DRIVES UP PRICE

A few months ago, Plug Power [Nasdaq: PLUG] was forced to revise several of its previously published financial statements. While the accounting errors were not severe enough to have a material impact on the statements, they resulted in a USD 62.9 million decrease in R&D costs in the years 2018 to 2020 and a corresponding rise in cost revenue. Furthermore, non-cash charges, including charges associated with warrants Plug granted to Amazon and Walmart, exceeded USD 400 million. That's pretty notable. Do these charges have anything to do with Plug's relatively high amount of short interest, which comes to over 50 million shares? Could Amazon and Walmart have exercised warrants? Or have they now shorted stock to shore up their unrealized gains running into the billions of dollars?

Plug has done a very good job of maintaining investor relations and becoming a focal point of discussion on Reddit and WallStreetBets. In other words, Plug's stock will likely continue to rise. Still, questions have been raised about a few of the com-

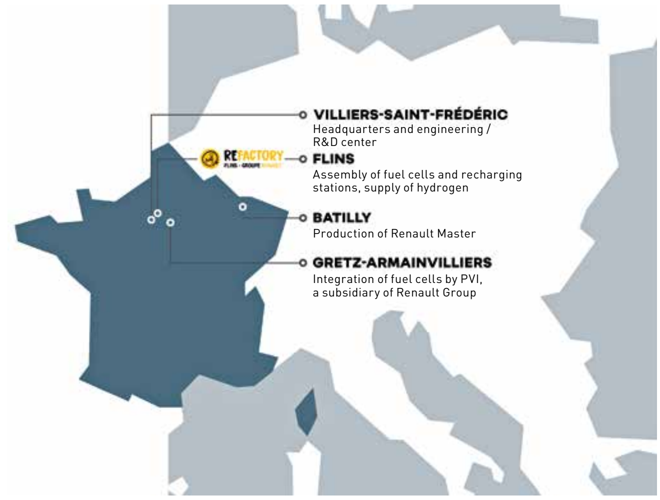

Fig. 3: Production facilities of HYVIA, Plug Power's new joint venture with Renault [Source: Renault]

pany's first-quarter acquisitions. Plug reportedly issued around 55 million shares worth USD 1.6 billion to acquire multiple companies previously owned by SK Holding: Grove Energy Capital, Plutus Capital NY and SK E & S Americas. At around the same time, SK Group South Korea purchased a 9.9-percent ownership stake in Plug. So, were Plug's acquisitions part of an asset exchange? Will they affect the USD 5 billion Plug has in cash? I'm only speculating here as to the company's motives. Though I have yet to find answers to both questions.

Plug's actual goal was to become less dependent on two big customers, Amazon and Walmart. It seems there's no money to be made from either. But there's good news as well, as Plug is forging multiple new alliances. Partners include Baker Hughes (see Bloom), which is in talks with Plug about setting up a hydrogen fund, metal trader Johnson Matthey and Chart Industries (see Ballard). You could rightly say Plug is all over the map these days; see also its collaboration with automaker Renault (see fig. 3 and p. 7). Now, the fuel cell business needs to demonstrate that it can produce hydrogen at reasonable costs and turn a profit selling the gas as fuel for forklift trucks. Analysts have set new price targets in the range of USD 40. I believe Plug should take a closer look at what Nikola Motors is doing. I can think of several reasons why Plug should be setting up a new joint venture or make another acquisition. As for the stock itself, I prefer Bloom's or Ballard's.

TESLA – PROFITABLE IN WHAT WAY?

Nowadays, Tesla [Nasdaq: TSLA] is largely making headlines not for of its financials but for the tweets of its charismatic chief executive, Elon Musk. His thoughts on cryptocurrencies such as bitcoin and doge coin, which, depending on the time of day, he says are a really good or a really bad deal, can dominate whole news cycles. Someone recently brought up the huge amounts of energy needed to mine them. As it turns out, the process uses non-renewable sources of energy, which could end up reflecting badly on the image of battery-electric cars as well. In response, Musk said he will rethink his position on bitcoin, which helped cause the cryptocurrency's price to plunge from over USD 60,000 to USD 30,000. One might wonder what his behavior did to Tesla's own USD 1.5 billion bitcoin investment.

Is that a proper way for a CEO to act in public? His more than 50 million followers, including his hardcore fan base, seem more than happy to play along. But why does the SEC stay silent? According to the commission's settlement agreement with Tesla and its chief executive, Musk has to seek approval for tweets that could affect the stock price or the market in general.

On to the numbers: 184,800 Tesla cars were delivered in the first quarter this year. Model X and S were the least popular offerings, with around 2,000 vehicles shipped. Most orders were for Tesla's less profitable models Y and 3. The electric carmaker posted non-GAAP earnings of USD 0.93 per share, USD 0.15 above estimates. On a more conservative GAAP basis, however, earnings came to USD 0.39 per share, USD 0.08 less than what analysts predicted. That hardly matters, though: Tesla fans, buy-side analysts and funds like ARK Invest are only ever interested in the more positive figure.

Regulatory credit and bitcoin sales brought in USD 518 million and USD 101 million, respectively. Minus those, Tesla would have most likely posted a loss this quarter. Impressive, on the other hand, the jump in revenue to USD 10.39 billion, a 73.5 percent increase year over year. And yet, compared to the fourth quarter of 2020, the first of 2021 wasn't a good look, as car sales were up by only 4,000 units. On top of this, Stellantis, formed via a merger of Fiat and Peugeot-Citroen, said it will no longer consider buying Tesla's zero-emission vehicle credits now that it can get enough on its own. But lucky for Tesla, there's still Volkswagen, which reportedly agreed to buy the electric carmaker's credits in China.

COMPENSATION PACKAGE FOR MUSK UNDER SCRUTINY

Musk's compensation plan is quite the deal, earning him millions of options if he reaches the targets set out in the agreement. Milestones include revenue, profitability and Tesla's market cap, which unlocks a new tranche of options each time it grows by another USD 50 billion. With the company's market value currently exceeding USD 600 billion, Musk has the right to purchase more than 50 million shares at USD 70.01 apiece. That works out to USD 30 billion in stock. A lawsuit has been filed over the compensation package and, in my opinion, the deal could come with tax pitfalls for Tesla, as well as its shareholders. Musk has now reached six of the 12 milestones and could gain another 40 million options if Tesla meets additional targets. But if all these options are exercised, won't that massively dilute the existing stock?

Fig. 4: Tesla's upcoming Gigafactory in the Grünheide community near Berlin [Source: Tesla]

GROWTH – IN EVERY CORNER OF THE GLOBE Construction on Tesla's Grünheide factory near Germany's capital Berlin has slowed down lately. Aside from some missing permits, there are unanswered questions about how much water can be taken out of the ground before putting the region's supply at risk (the factory is being built in a water conservation zone). At least, the Cybertruck production site in Austin, Texas, may soon be up and running. But the competition isn't asleep at the wheel. As an example, Ford is now offering an electrically powered F-150 and its eMustang is already enticing customers away from Tesla. Meanwhile, the electric carmaker has announced plans to expand to India and is exploring the idea of building a factory in Russia. Tesla does have over USD 17 billion in cash. But that could be a bit little, too little, to fund all its new ventures. Tesla may have to raise capital again. One option to do that would be an at-the-market program. The question is, will investors go for it?

Recent events then put the focus on quality and safety issues. Tesla has announced that it's no longer including a radar in some models, which will be equipped with onboard cameras instead. In response, Consumer Reports and the Insurance Institute for Highway Safety dropped Model 3 from their safety rankings. Additionally, Tesla is being plagued by the same problem as any other automaker. The current car chip shortage means some of the company's vehicles just can't be delivered. >>

Things don't seem to be going so well in China either. Government officials are no longer allowed to buy Tesla cars over fears the vehicles might record sensitive location information, reports say. Tesla is now building a data center in China to store and process information in the country and not, as I would guess, in Fremont.

CONCLUSION Tesla stock tends to decrease in value whenever it experiences big daily fluctuations. Short sellers and institutional investors betting on failing prices, such as Michael Burry ("The Big Short"), expect the stock to drop, as the company's market cap of more than USD 600 billion has no basis in reality. I fully concur. Not only is the competition getting more intense. Fuel cells could also put a big dent in Tesla's plans a few years from now. To justify a high stock price, the electric carmaker would need to turn a profit from selling vehicles and related software, not from trading bitcoins or regulatory credits.

WIKIFOLIO

Like the company stocks discussed in this issue, my Wiki portfolio, BZVision, has lost some ground. And yet, it's still up by over 60 percent year over year. My Tesla puts with a USD 600 strike price are seeing a great deal of movement, fluctuating between EUR 0.7 and EUR 1.3. This is because the stock is now trading at the set limit, so there's a constant back and forth between intrinsic value, i.e., a price under USD 600, and time value. But their December 2021 expiry isn't that far into the future. Should Tesla's second-quarter results be as disappointing as I think they will be, its stock could drop, possibly to as low as USD 400. That's a bet I'm willing to make, as the puts comprise only around 13 percent of my portfolio. I will need to wait, though, until the puts are sold before I increase my investment in the three hydrogen and fuel cell stocks previously discussed in this section. In the meantime, the price of those three should gradually be rising again, so we'll have new targets soon.

WEICHAI POWER – INTRIGUING PROSPECTS

Like all hydrogen and fuel cell stocks, Weichai Power's has come under pressure since February. That doesn't change the business's bright prospects. Weichai [2338:HK] is turning a profit and is expanding its operations through joint ventures and strategic acquisitions. One example of this is Weichai's recent purchase of a 45-percent ownership stake in Kion, the world's second-largest forklift truck manufacturer. The deal, valued at EUR 3.5 billion, might even lead to the deployment of hydrogen and fuel cell systems in Kion's next-generation forklift trucks. Like Bosch, Weichai owns part of CERUS. It also has an around 15-percent stake in Ballard Power, with which it runs a stack factory in China (a 51/49 partnership). The factory may become the center of attention once the Chinese government puts numbers to its hydrogen and fuel cell plans, which could benefit the entire sector. Chinese fuel cell stack producer Refire (see also p. 7) will then be used as the basis for assessing the performance of the joint venture, as an IPO seems likely. Analysts expect Weichai's stock to end up between EUR 2.7 and EUR 3.5 – which works out to, on average, 50-percent growth.

NEU: BURCKHARDT COMPRESSION – PERIPHERAL TECHNOLOGY

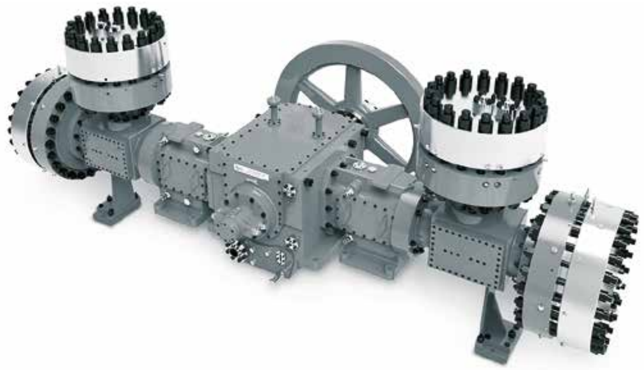

Fig. 5: Oil-free high-pressure membrane hydrogen compressors [Source: Burckhardt Compression]

Burckhardt Compression, formerly a subsidiary of Swiss engineering group Sulzer, could become the next stock to pique the interest of investors. The world's foremost manufacturer of piston compressors, Burckhardt [SIX: BCHN] is increasingly producing equipment that is later used in hydrogen production or transport, as in gas networks delivering hydrogen blends or in electrolyzers, providing the company with new and huge opportunities for growth. Burckhardt is expected to generate CHF 620 million to CHF 650 million in revenue this fiscal year. Its performance last year had already resulted in earnings of CHF 13 a share, including CHF 6.5 in dividend payouts. In its annual report, Burckhardt noted that 2020 saw a "substantial increase" in demand for hydrogen-related components in the transportation and energy sectors.

I'll put the stock on my watchlist for now. Investors are increasingly focusing not just on companies that produce hydrogen or convert the gas into electricity (via fuel cells). They're also taking a growing interest in technology suppliers and other companies supporting the sector, as the relevance of both groups is on the rise. I think that gives those businesses an opportunity to set up one or more joint ventures and increase demand for electrolysis. And many big corporations are looking for smaller market players to buy, in an effort to become one-stop hydrogen providers. Companies such as Burckhardt Compression could then, I imagine, be a target for acquisition. As the stock is traded in a narrow market, investors should set an order limit, as well as buy directly from the Swiss stock exchange if they want to acquire a large number of shares. I'm looking forward to reading the news coming out of Burckhardt's annual general meeting, set to take place on July 2. ||

RISK WARNING

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

Category: International | **Author:** Johanna Schilling

IS JAPAN HEADING FOR A HYDROGEN SOCIETY?

Hydrogen set to play a vital part in green growth strategy

In 2017, Japan became the first industrialized nation to set out its national hydrogen plan. As part of the hydrogen society strategy, massive investments have been made in pioneering pilot projects, albeit with a clear focus on the importation of blue hydrogen. The Japanese hydrogen roadmap foresees expansion on the user side – through fuel cell vehicles, mini combined heat and power units in buildings, and the energy supply – as well as infrastructure build-out and, above all, the rapid establishment of supply chains abroad. And thanks to the Japanese government's new climate target and green growth strategy, hydrogen has now assumed an even greater significance.

Shortly after taking over the reins from his predecessor Shinzo Abe, newly elected Prime Minister Yoshihide Suga used the opportunity of his inaugural address on Oct. 26, 2020, to announce a new direction in Japanese climate policy: a commitment to achieving net-zero greenhouse gas emissions by 2050. Such a goal would be impossible to reach under the Basic Energy Plan, published in 2015, that envisages a 56 percent share of fossil fuels in the electricity mix for 2030 and an unrealistic 20 percent to 22 percent contribution from nuclear power. A new strategic plan is due to be presented in spring 2021.

Against this backdrop, hydrogen is set to play a much more important role in Japan's overall energy supply strategy in the future. The Japanese economy ministry's "Energy Outlook of Carbon Neutrality in 2050" plan sees hydrogen as an important pillar in its bid for a carbon-neutral energy supply by 2050. In addition to its direct use in transport and buildings, hydrogen is also expected to provide a "decarbonized power source" alongside ammonia, which will act as a transitional fuel as the country shifts to a "hydrogen-powered society." With Japan's demand for electricity predicted to rise by 30 percent to 50 percent, the intention is for these energy carriers to cover 10 percent of the power requirement. Japan's remaining electricity needs would then be met by renewables (50 percent to 60 percent) and nuclear and gas power plants with carbon capture use and storage (30 percent to 40 percent).

The country's New Energy and Industrial Technology Development Organization, NEDO, has already funneled more than JPY 200 billion, roughly equivalent to EUR 1.5 billion, into the development of hydrogen technologies. What's more, the Japanese government has set aside a pot of JPY 70 billion, or around EUR 0.53 billion, for hydrogen schemes for the new financial year which started in April. JPY 30 billion alone is being released in the form of subsidies for the purchase of fuel cell vehicles and the construction of hydrogen refueling stations. Hydrogen is also among the 14 priority areas outlined in the green growth strategy that was made public in December 2020; the initiative's green innovation fund will invest a total of JPY 2 trillion, approximately EUR 15.2 billion, in future technologies over the next 10 years.

800,000 FUEL CELL VEHICLES, 900 HYDROGEN STATIONS BY 2030 When it comes to end-user applications, Japan is clearly placing much weight on the mobility sector. Two Asian automakers in the guise of Toyota and Honda succeeded in launching mass-produced fuel cell cars onto the market early on. Both corporations, together with Nissan, are also founder members of Japan H2 Mobility. The consortium, which also counts Iwatani, Tokyo Gas and Toyota Tsusho among its partners, is undertaking an enormous expansion program of the hydrogen refueling network, helped by government grants. The aim of the economy ministry to reach 160 hydrogen refilling stations by March 2021, however, came up short: As of April 1, 2021, there were 146 stations in operation. Nevertheless, the country still boasts the world's largest hydrogen refueling network, according to Japan's Next Generation Vehicle Promotion Center. By the year 2025, this total should have doubled to 320 hydrogen stations, a figure that is projected to increase further to 900 stations by 2040. By that time, 800,000 fuel cell vehicles are anticipated to be on the road, with 200,000 hydrogen-powered vehicles expected by 2025 – an ambitious target given the around 4,000 fuel cell vehicles currently in use in 2020.

Another area of focus is the building sector. By 2030, 5.3 million fuel cell-based micro-CHP units are slated for installation. Current figures indicate that 1.4 million of these Ene-Farm systems are already supplying Japanese buildings with power and heat. Predecessor models for residential buildings, most commonly polymer electrolyte fuel cells, have run on natural gas. However, concrete plans are yet to emerge as to how these units might operate on low-carbon or zero-carbon hydrogen in the future. A switchover would entail more than just a technical upgrade of the Ene-Farm units, with the construction of new supply infrastructure also becoming a necessity. The lack of gas infrastructure is one reason why autonomous systems for the production of hydrogen, such as H2One by Toshiba, are a Japanese specialty.

FIRST COMMERCIAL SUPPLY CHAIN FOR BLUE HYDROGEN As well as growth in terms of user applications, Japan is also pursuing strategic expansion on the supply side. In order to accelerate mass production, import chains are due to be established for blue hydrogen as an initial step. This should allow the price of imported hydrogen to reach the USD 3 per kilogram mark by the mid-2020s and in the future attain parity with liquefied natural gas which currently resides at around USD 1.6 per kilogram. According to proposals, the intention is also for these supply chains to become carbon neutral by 2050, a target set to be achieved primarily through the use of carbon capture and storage technology. From 2040 onward, increasing amounts of green hydrogen are forecast to be produced domestically or imported from abroad.

The first international commercial supply chain for hydrogen, as organized as part of the HySTRA project backed by NEDO, went operational in Japan in the spring. In Australia's Latrobe Valley, hydrogen is being separated from brown coal, liquefied and shipped in the world's first >>

Thanks to generous subsidies, Japanese buyers get a discount worth JYP 1 million, around EUR 7,600, on the current starting price for a Toyota Mirai 2. The normal price tag is JYP 7.1 million.

Fig. 1: Fukushima Hydrogen Research Field [Source: Toshiba]

hydrogen tanker. The vessel, a Suiso Frontier carrier from Kawasaki Heavy Industries, will transport hydrogen in a storage tank measuring 42,400 cubic feet (1,200 cubic meters) to the Japanese city of Kobe. The resulting carbon dioxide, once captured, is to be sequestered underground off the Australian coast. At Kobe's port, the hydrogen will then drive a gas turbine and provide heat and power to a sport's center and a nearby hospital.

AHEAD is the name of another flagship project: A consortium including the plant construction company Chiyoda Chemical Engineering is responsible for arranging the extraction of hydrogen from LNG in Brunei and shipping it in liquid form, bound in methylcyclohexane or MCH, to Kawasaki. There, the hydrogen is separated again and used to power gas turbines. The toluene that is formed during dehydrogenation is then pumped back into the tanker and transported to Brunei where it is combined with hydrogen for the next MCH load.

GREEN HYDROGEN FOR THE OLYMPIC VILLAGE While the importation of blue hydrogen may be taking center stage, the commercialization and installation of power-to-gas systems for storing the excess power generated from renewables are, according to the hydrogen roadmap, at least a medium-term goal. Between 2030 and 2050, Japan is due to build electrolyzer capacity of between 15 gigawatts and 30 gigawatts. The system costs for hydrogen production from renewable energy are predicted to fall to JYP 50,000, or EUR 380, by 2030 – something that could be aided by the proposed large-scale expansion of wind power generating capacity in Japan's offshore and inshore areas.

DIFFERENCES IN HYDROGEN STRATEGIES:

- In Germany, there is a clear emphasis on green hydrogen. At least a proportion of this hydrogen is due to be produced in Germany itself. Japan, on the other hand, sees little potential for indigenous production of green hydrogen at scale.
- Japan's political strategy initially envisages the production and deployment of large quantities of hydrogen that is also derived from fossil fuels. Due to the limited coverage of the nation's natural gas grid, the main focus rests on infrastructure and technology for mobile distribution coupled with decentralized production and use, while Germany's extensive natural gas network offers great potential for methanation or direct injection.
- On the user side, Japan clearly centers its attention on mobility, buildings and reinforcement of the electricity supply, and to a lesser extent on industrial applications such as the use of hydrogen in direct reduction processes within steelworks. Germany, meanwhile, places industry and transportation at the forefront. Power generation and the building sector, by contrast, rank lower down on the list of priorities.

The Fukushima Hydrogen Research Field (see fig. 1) in the coastal town of Namie, located just 20 minutes north of the Fukushima Daiichi power plant that was damaged in 2011, is a test site for green hydrogen production that received NEDO funding for its construction to the tune of JYP 250 billion, i.e., EUR 1.9 billion. Here, a 10-megawatt electrolyzer manufactured by Asahi Kasei is connected to a 20-megawatt photovoltaic plant and is expected to produce 1,200 standard cubic meters per hour or 900 tons of hydrogen a year in future. Situated within the vicinity is also a further PV array, rated at 100 megawatts, which has entered service just recently.

The hydrogen is compressed and conveyed by truck to three stationary fuel cell systems. The H2Rex units from Toshiba then supply power, heat and hot water to sports facilities and a train station. As part of the Fukushima Hydro Supply project, the green hydrogen produced in Namie will be trucked to hydrogen filling stations in the prefecture – and also as far as Tokyo for the purposes of supplying the Olympic Village. The dedicated city quarter has been designed to be a model for hydrogen deployment, with 22 buildings, a school, supermarkets and 100 fuel cell buses connected to a hydrogen distribution network.

The Olympics and the G-20 summit have also breathed new life into another project: the Hydrogen Town in Kitakyushu. Found in the northern part of Kyushu island, it is Japan's fourth-strongest economic region. It was here that the first community hydrogen project in Japan was launched as early as 2011. Hydrogen, which accrues as a byproduct in a steelworks operated by Nippon Steel, is carried along a 0.75-mile (1.2-kilometer) hydrogen pipeline to a residential and commercial area where it feeds a fuel cell CHP plant that serves public buildings and private households. Further trials exploring the safe and cost-effective supply of hydrogen via pipeline are due to start here soon.

There are also further green power-to-gas projects in the prefecture of Yamanashi, in Hokkaido, and in northern Honshu where electrolysis will harness the power of the wind.

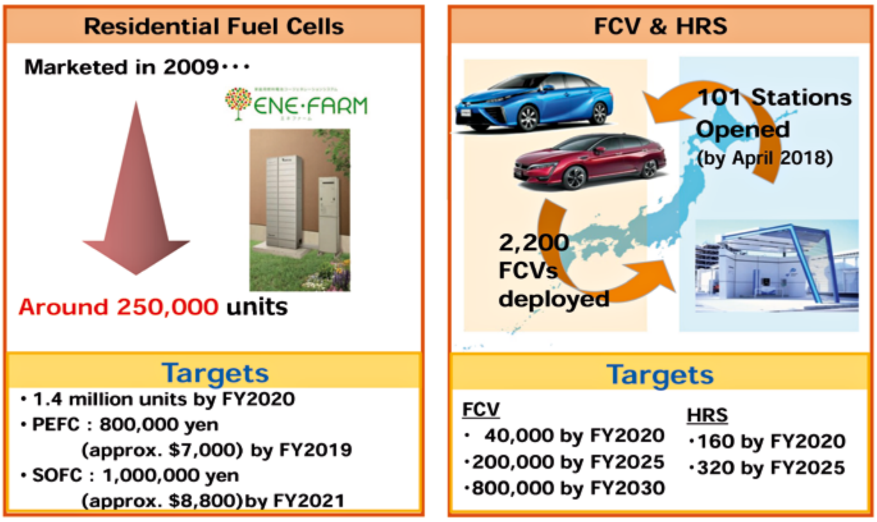

Fig. 2: Growth targets [Source: NEDO]

INTERNATIONAL COOPERATION SOUGHT At the annual Hydrogen Energy Ministerial Meeting in October 2020, organized by the Japanese government, the nation's economy minister Hiroshi Kajiyama made the following pledge: "Japan is determined to contribute to establish the low-cost H2 production technology from Renewable Energy resources. [...] It is important to promote further international collaboration in order to create one global hydrogen-based society in the future."

In recent times, hydrogen has represented a key area for discussion between Germany and Japan: As a case in point, Germany's National Organisation Hydrogen and Fuel Cell Technology, NOW, and NEDO have been collaborating for some time now. In addition, the German-Japanese Energy Partnership and the German-Japanese Energy Transition Council have instigated working groups for investigating the subject, plus the German-Japanese environmental and energy dialog forum UEDF frequently addresses the role of hydrogen in the energy system. While some differences may exist between Germany and Japan's strategic plans and technological preferences, it's plain to see that much effort is being made behind the scenes to enhance international cooperation. ||

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LARGE-SCALE HYDROGEN PROJECTS ON THE ARABIAN PENINSULA

Oman and Saudi Arabia's plans to export solar energy

Sun-soaked countries around the world are inevitably destined for solar-powered hydrogen production. Yet while many look to Australia, Chile or Morocco as prime locations, the Middle East is also gaining attention. Nations such as Saudi Arabia, Kuwait and the Sultanate of Oman, well known for their bountiful oil resources, have now recognized another useful asset – their copious sunshine – and one which is ideally suited to making hydrogen.

Many Arab states have grown rich on their large oil deposits. As supplies dwindle, these times of plenty will at some point come to an end – something that Oman is currently experiencing. The country's reserves will last only a few more years, with natural gas already being imported. Other Arab nations, too, have now become aware that it will only be economical to lift oil for a limited number of years and that natural gas extraction is also becoming more laborious. The exportation of solar energy could therefore be a suitable alternative to oil shipments, even though hydrogen was practically unheard of in these regions until just a few years ago.

OMAN UNDER PRESSURE TO ACT With a view to opening up these new markets, Bernd Wiemann founded the Hydrogen Rise AG start-up in 2018. Wiemann, who for many years held management positions at Mannesmann and Vodafone and had previously established the fuel cell company P21 in 2001, is well connected in the Middle East. Therefore his aim, he told H2-international, is to forge sustainable value creation on the Arabian Peninsula.

Wiemann intends to supply the requisite technology and know-how to Oman so that money can be generated domestically. For this reason, the Munich-based entrepreneur set up the Oman subsidiary, Hydrogen Rise LLC, in the capital Muscat. In addition, he is already in talks with large German electrolyzer manufacturers about siting these plants in Oman, explained Frank Sreball, who deputized for Wiemann as director of Green Hydrogen Economics until August 2020. The water that would be needed by the electrolyzers would then be produced from seawater by means of desalination plants. "Hydrogen Rise offers this country of 5 million residents a strategy for developing a new energy economy," said Sreball.

One of the ensuing initiatives has included the setup of the Oman Hydrogen Center in Muscat on the campus of the German Technical University (see fig. 2). In January 2020, both Sheikh Abdullah bin Mohammed al-Salmi, minister for religious affairs, and Mohammed bin Hamad al-Rumhi, minister for oil and gas, took part in the opening ceremony.

Although the pandemic has made contact in the Arab world difficult in recent months, in May 2021 another consortium comprising companies from Hong Kong, Kuwait and Oman announced its intention to start a 25-gigawatt project to make green hydrogen and export it in the form of ammonia (see fig. 1). Preparations for this endeavor have been ongoing for more than three years. According to a >>

press release: "Renewable power generation will benefit from very high and stable levels of solar and wind energy, exhibiting the optimal diurnal profile of strong wind at night and reliable sun during the day. The project is also located near the coast for seawater intake and electrolysis."

NEOM – A BRAVE NEW FUTURE A much bigger undertaking is the Saudi mega-city Neom. Due to be designed and constructed from scratch, this metropolis is to be located in an area of Saudi Arabia close to the Suez Canal and is expected to give the world a glimpse of life in the future. Appropriately, it takes its name from the words for "new" and "future."

Neom is set to take shape on the northwestern tip of the Arabian Peninsula, directly on the Red Sea. The city, which is forecast to require an investment of over EUR 400 billion for its construction, could be as large as Mecklenburg-Western Pomerania and house several million people. According to the plans, Neom's energy needs will be met entirely by solar and wind power.

Fig. 2: Sealing the deal for German-Omani cooperation [Source: Hydrogen Rise]

A key part in the city's energy storage system is expected to be played by hydrogen. Consequently, potential electrolyzer manufacturers are busy jostling for position. For example, thyssenkrupp has succeeded in defeating other applicants in its bid for the Element One project, which focuses on the development and installation of a prototype for an alkaline electrolyzer in Neom with a 20-megawatt capacity. On Dec. 16., 2020, it was revealed that thyssenkrupp Uhde Chlorine Engineers would be receiving the allocated funding from the German economy ministry.

Martina Merz, chair of thyssenkrupp AG, accepted the EUR 1.525 million grant virtually and described the sum for such a project as "reasonable." The planned facility – as soon as it is finished – will be one of the largest green hydrogen plants in the world. Merz explained that hydrogen is very high up in the company's list of priorities which is why millions of euros are being invested in electrolysis. She continued saying that water electrolysis is an important area of focus at thyssenkrupp given that the global market is expected to be worth EUR 40 billion by 2030.

Also among the plans for the Saudi flagship region of Neom is the proposal to set up a hydrogen innovation and development center for testing and demonstrating the technologies and uses of green hydrogen. Following on from this, an industrial production facility is due to be built as part of the project's second phase. Dubbed the Helios Green Fuels Project and scheduled for completion in 2025, the plant is expected to produce up to 650 tons of hydrogen and 3,000 tons of ammonia per day, running on up to 4 gigawatts of power from solar and wind. Among the partners in this venture are the Saudi company ACWA Power and the U.S.-based Air Products & Chemicals corporation which jointly concluded a USD 5 billion deal with Neom in July 2020. The ammonia technology is being provided by Haldor Topsoe.

Neom CEO Nadhmi Al-Nasr referred to this "life's work" of Saudi Crown Prince Mohammed bin Salman "as the world's largest project for renewable hydrogen." ||

Category: International | Authors: Michael Matheson, Alexandra Stein

SCOTLAND'S HYDROGEN ECONOMY

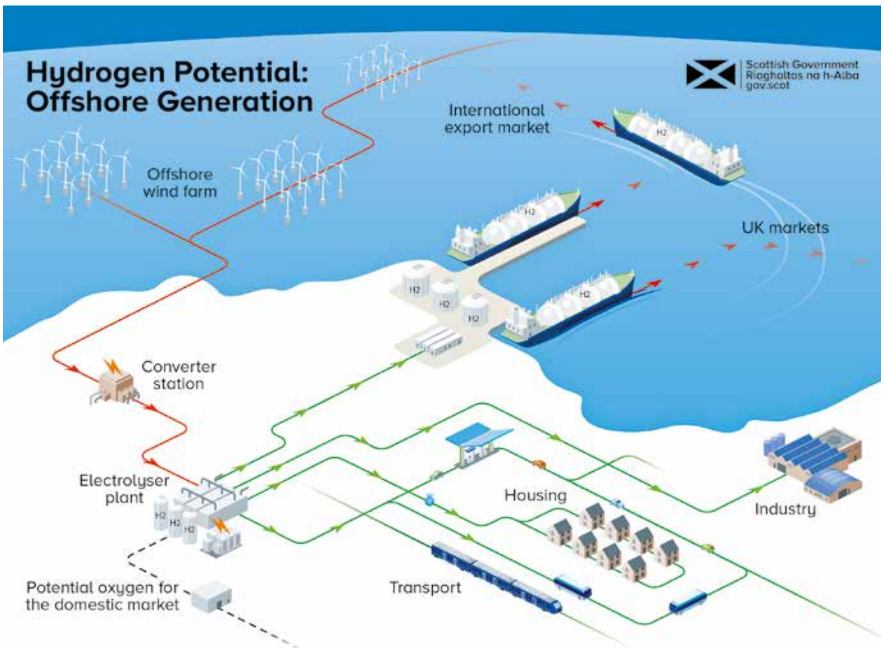
Delivering a bright future through collaboration and innovation

In December 2020 Scotland became the first country in the UK to publish a hydrogen policy statement, six months after publication of the German hydrogen strategy. This sets out Scotland's vision for hydrogen and how we can maximize our massive potential in the sector. Our accompanying Hydrogen Assessment Report appraised the potential for hydrogen to be deployed to help achieve our stretching decarbonization targets. Its economic impact scenarios concluded that Scotland has the potential to deliver up to 126 terawatt-hours of green hydrogen per year by 2045, up to 96 terawatt-hours of them for export. This would protect or create between 70,000 and over 300,000 jobs – in a population of 5.5 million – and deliver gross value-added impacts of between GBP 5 billion and GBP 25 billion.

It is clear that hydrogen will play an important role for all of us in our energy transition to net-zero and is a key component of the green recovery post-Covid 19. In 2019 Scotland tightened its legally binding climate change targets to achieve net-zero greenhouse gas emissions by 2045, with a 75 percent reduction by 2030 against the 1990 baseline. To achieve this, we need to move at an unprecedented pace across our whole economy to deliver the innovation, investment, regulation and market environment that will enable the required step change toward net-zero.

Hydrogen is rapidly emerging as a key sustainable solution for the decarbonization of the economy. We believe that Scotland's abundant resources – natural, human and physical – will support the establishment of a thriving hydrogen sector both in Scotland and in the emerging global hydrogen market. Producing clean hydrogen and demonstrating that it can be used to help meet the challenging energy demands of industry, transport and heat will be a key part in Scotland's energy journey.

Our ambition is for Scotland to become a leading hydrogen nation and a strong international partner in the production of sustainable hydrogen. The Scottish government will support the strategic growth of a strong hydrogen economy, focusing our efforts on the development of our hydrogen production capability to meet an ambition of at least 5 gigawatts of renewable and low-carbon hydrogen by 2030 and at least 25 gigawatts by 2045. The scale of our ambition will be familiar to German readers, with our hydrogen production plans for 2030 the equivalent of the target set by Germany. Naturally, we look forward to working closely with others such as Germany to advance this opportunity.



SCOTLAND'S RESOURCES AND EXPERTISE We have confidence in setting such high ambitions since Scotland has access to all the key components of a hydrogen economy. Scotland has the potential to produce industrial-scale quantities of firstly blue hydrogen and then – internationally more important – green hydrogen from our offshore and onshore wind resources and our potential wave and tidal power.

Scotland has an estimated 25 percent of all the wind resource in Europe, with an ambition for up to 11-gigawatt offshore wind capacity in Scottish waters by 2030. We have the largest seascape for future development, with 178,000 square miles (462,000 square kilometers) under management giving the best yield due to high load hours. Our potential production capacity far exceeds indigenous demand, giving us the opportunity for Scotland to produce and export low-cost clean hydrogen to Europe.

To set our hydrogen vision in context, it is worth reflecting on Scotland's hydrogen journey to date. The Scottish government has a strong track record of supporting world-leading hydrogen demonstration projects, with a broad portfolio of hydrogen projects that has grown over the years. For example, in the Orkney Islands, our initial funding of hydrogen projects at the European Marine Energy Centre EMEC has helped shepherd in an impressive GBP 65 million portfolio of projects that is still growing. In Aberdeen, our initial funding for 25 hydrogen double-decker buses has helped establish the infrastructure to support an ecosystem of over 60 hydrogen-fueled vehicles of many shapes and sizes. This has in turn been a catalyst for the much larger Aberdeen Hydrogen Hub initiative, which is now growing fast to become one of the key model hydrogen regions in Europe. Meanwhile, our flagship demonstration of hydrogen for domestic heat, the H100Fife project, is currently building a 100 percent green hydrogen production and distribution network and installing 300 homes with new hydrogen boilers to demonstrate hydrogen for domestic heating. >>

Fig. 2: Fuel cell container by Proton Motor, car, mobile storage unit and H_2 ferry of BIG HIT and Surf'n'Turf on Orkneys [Source: Colin Keldie]

These developments and others are supported by Scotland's company base and our valuable skills and assets in the oil and gas, offshore wind, and energy systems sectors, which will all play a critical role in the building of Scotland's hydrogen economy.

We are also clear on the need to support the demonstration, research and development and innovation required for hydrogen deployment. For example, we are funding a research project with partners in France to consider floating wind and hydrogen opportunities. We are also supporting a collaborative study into the potential for Liquid Organic Hydrogen Carriers or LOHC in the marine vessel transportation and storage of hydrogen. This forms part of our examination of the safe and cost-effective options for the marine transport of hydrogen between Scotland and UK and European ports.

In doing this, we want to explore how we can drive forward technological progress and advance innovation by unlocking public and private funds for development, and how we can support demonstration for key hydrogen technologies, such as fuel cells and electrolyzers.

INCREASING THE PACE If Scotland is to capture and maximize the economic value from hydrogen activities then we will need to act quickly and decisively. Just last month, planning applications were submitted for what will be the UK's largest electrolyzer, just outside Glasgow at Whitelee. The 20-megawatt electrolyzer, situated close to Europe's second largest onshore windfarm, will be able to produce up to 8 metric tons of green hydrogen per day.

Such pace is crucial. We need to grow the hydrogen sector quickly and develop an indigenous hydrogen economy that aligns with the needs of a growing global export market. To help achieve this, we will publish our national Hydrogen Action Plan later this year – building on the framework provided by our Hydrogen Policy Statement. This plan will provide further detail on our planned approach and the key actions necessary to implement our priorities. It will seek to provide strategic support for hydrogen research, innovation and demonstration, for the development of Scotland's existing supply chain and our green hydrogen export potential, and international collaboration.

WORKING TOGETHER IN INTERNATIONAL PARTNERSHIP

Although we may still be at the dawn of the hydrogen economy, we believe there is a bright day ahead, and that hydrogen will play a key role in realizing our climate change ambitions.

Scotland's vision for hydrogen is confident, ambitious and challenging. Our ambition, and indeed that of all nations looking to develop the hydrogen economy, can only be realized if we work together. None of us can go on this journey alone. Working with international partners will be critical to the successful development of the hydrogen economy. Scotland is committed to collaborating internationally so that we can all achieve our shared goals more quickly and efficiently. We know that international partnership will be key in developing the predictable, reliable and supportive business environments that are needed for future international hydrogen markets to grow and to flourish.

Whilst, regrettably, Scotland is no longer a member of the European Union, we are ready and committed to work with our EU partners and others to overcome the challenges of safe, rapid and cost-effective deployment as we build a hydrogen economy and develop international hydrogen markets.

COP26 can inspire all of us to move toward a net-zero future, with a Just Transition that is fair to all. It is clear hydrogen has an exciting and important role to play in this, and I look forward to working with our partners in Germany and elsewhere to achieve this. ||

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September 14th to 15th, digital & live in Stuttgart, Germany
www.f-cell.de

RENMAD Hydrogen
Design, Build and Operate Profitable Renewable Hydrogen Projects in Europe, September 14th to 15th, online
www.atainsights.com

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OCTOBER

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www.ees-europe.com, www.powertodrive.de

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www.hydrogen-online-conference.com

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www.greenhydrogenevents.com

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co-located with Carbon Capture Conference
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www.hydrogen-worldexpo.com

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www.hyvolution-event.com

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Hypothesis XVI
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November 8th to 10th, Muscat, Oman
www.hypothesis.ws

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www.zeroemissionbusconference.eu

EVENTS 2022

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March, 2022, in Porto, Portugal, *www.wplgroup.com*

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

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