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H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

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→ EUROPE AIMS TO LEAD PUSH FOR HYDROGEN ECONOMY

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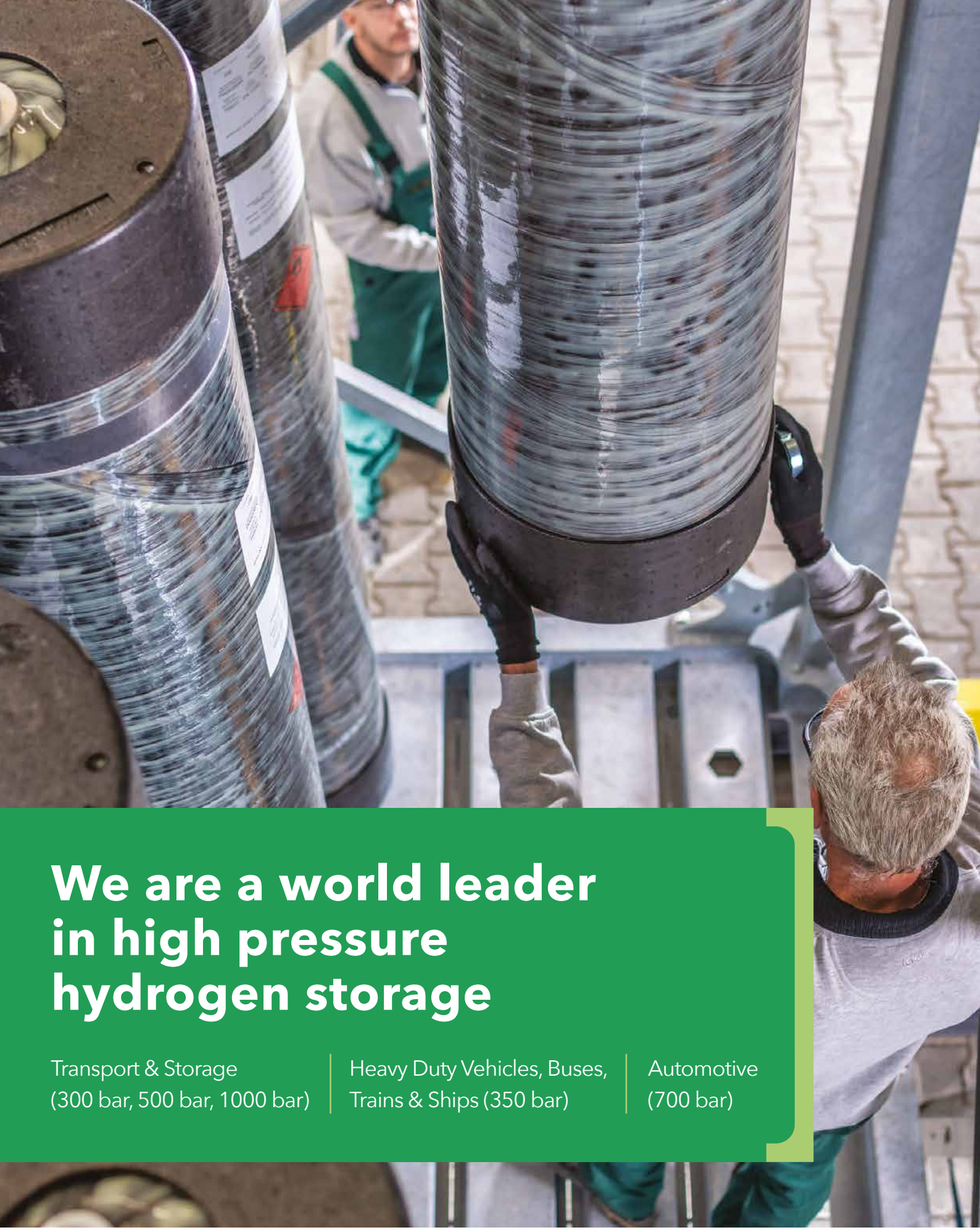

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Cover image Trash truck runs on hydrogen [Source: Faun]

WHERE TO GO FROM HERE

Dear readers

These days, hydrogen has become a focal point of discussion in Germany and at the highest echelons of the European Union. Gradually, the energy carrier is getting the attention it deserves. At last, despite the roadblocks, a breakthrough is imminent.

You can almost hear the sigh of relief currently going through the hydrogen community. Although there was no big bang moment, there are telltale signs that something, actually a lot, will be happening soon.

And yet, that progress also acts like a magnet, attracting those who showed barely any interest in the gas for years but now want to take the lead in setting up a market. To the chagrin of quite a few, some of the people that were appointed to the National Hydrogen Council (see p. 10) will be involved in high-level decisions on matters they know rather little about.

However, the council is only one example of how some who could be seen delaying and slowing down advances in the hydrogen and fuel cell sector suddenly want to influence decision-making and benefit from current enthusiasm.

We have reached the point at which a growing number of visionaries are being replaced with business managers. It is a scenario all too familiar to anyone who has ever worked in the solar or wind energy industry. There, it took idealists years to build up something that was later taken over by those aiming to generate as much profit as they can.

You need to look no further than the German hydrogen and fuel cell association DWV (see p. 8) to feel a sense of déjà vu. A handful of seasoned volunteers, who, decade after decade, put every effort into making the association what it is today, said they would not run for their seats again. Others announced that their candidacy would depend on the direction of the new board. When you read these lines, the organization's annual general meeting in Hamburg will likely already have taken place, and you may know which path the DWV has decided to take and who will be in charge.

The above is not to say that paying management and welcoming people with know-how is something that needs to be opposed. Drawing on their expertise, industrial representatives can provide valuable input to the council and the DWV, and any association that wants to succeed these days needs a host of full-time employees. Still, you may wonder how many long-held beliefs will need to be sacrificed in an effort to shape the future. Is working for the betterment of society a goal that all, in particular non-profits, can hold on to? Or will the new objective be to maximize the returns a select few could reap?

Similarly, there is the question of which technology should take priority and why. A study by the German machinery and industrial equipment association VDMA noted that fuel cell systems require more parts than all-electric equipment (see p. 42). As a result, they would add more value than batteries, most of which are imported from Asia anyway. The economy, the study said, would thus get a bigger boost if the auto industry, the machinery sector's largest customer domestically, focused on FCEVs, not BEVs, for the simple reason that Germany could create more value and revenues this way.

This goes to show that businesses, as well as their representatives, seem to think protecting us and our surroundings, or, more specifically, all of humanity and nature, is of secondary importance and that their main aim is to continue business as usual while pursuing ever-higher living standards and earnings.

The outbreak of Covid-19 around the globe has proved how such an approach quickly reaches its limits. In a globalized world, in which just-in-time production is the norm and processes run at peak efficiency, little attention is being given to a growing world population and the natural environment surrounding us. This makes it now more important than ever to think sustainably.

Anyone who believes the only thing that matters is the German machinery industry's competitiveness should think about what we will be in for if we stall the advance of new, disruptive technology only to keep the current system going for a few more years. If the main argument in favor of fuel cells is that they have more in common with ICEs than BEV motors – in other words, that they are more complex than batteries – then we should say goodbye to fuel cell stacks right here, right now.

Whoever supports fuel cells in order to keep selling conventional technology has not understood how crucial a complete and immediate transformation of the energy market really is.

Fortunately, there are those whose aim is not to maximize profits at every turn, who seek harmony and a clean, sustainable economy that will be a boon to humanity and our environment. And sure enough, fuel cells also offer real advantages, making them a suitable choice in many markets, such as the truck sector (see p. 30).

To make a long story short: Let us seize current opportunities but avoid past mistakes. It would really be a pity if we missed this unique chance for transformative change. Both Germany and Europe could show the world that a fully renewable energy system is no longer just a work in progress.

PS
The advert on the last page of this issue gives you the opportunity to download and read an excerpt from River Publishers' book "Hydrogen in an International Context." We encourage you to use the chance to learn more about International Success Stories. ||

Best wishes

Sven Geitmann
Editor of H2-international

MATHIAS BODE LEAVES HORIBA


Image: Andreas Lander

Mathias Bode, FuelCon and Sensotech's longtime chief executive, has decided to change careers. An automation technician by trade, he is now working for Aquin & Cie., a privately owned consultancy that specializes in mergers and acquisitions, mainly in the industrial automation, automotive testing and electric vehicle markets.

Bode founded Sensotech in 1990 and FuelCon in 2001, developing the latter into a major supplier of fuel cell and battery test equipment. He also supported FuelCon's acquisition by the Japanese Horiba Group in 2018. He told H2-international that "Horiba asked me to stay with the company. But after 30 years in the market, I wanted to try out something new. Day-to-day business is now in the hands of Horiba Europe's Markus Bode [no relation]." ||

AND WHAT ABOUT E-FUELS?

How important synthetic fuels, also known as e-fuels, will be in a future energy system is a question many are hotly debating these days. The answer, of course, depends on whom you ask and whom they represent. To bring some facts to the table, energy institute ifeu recently conducted a study for German environment agency UBA to determine the amounts of carbon dioxide and other pollutants emitted by fuels produced through power-to-X.

Titled "Comparing clean energy carriers," the study was written jointly by ifeu staff and researchers working at the German Aerospace Center – DLR and the Joanneum Research Forschungsgesellschaft. The authors found that many pathways for producing synthetic fuels release between 85 percent and 90 percent fewer emissions than those relying on fossil energy sources.

Even when using lower heating values as a basis, hydrogen continues to have the lowest environmental impact, followed by synfuels, Fischer-Tropsch fuels and methanol. Additionally, biomass production pathways are, on average, more sustainable than pathways sourcing electricity. Overall, ifeu said that while e-fuels can contribute to climate protection, there is likewise a risk that they could lower air, water or soil quality.

E-fuels are produced from clean energy and can be used in conventional ICEs. Their manufacture (aka synthesis) requires carbon dioxide, which will later be emitted during combustion. In contrast to fossil fuels, e-fuels do not emit additional carbon dioxide but bind it temporarily. They are said to extend the useful life of gasoline and diesel engines without offering advantages similar to those of electric motors running on clean electricity. ||

"E-fuels are not the answer. They should only be used as a bridging technology."

Werner Diwald, DWV chairman

"E-fuels are one option to give automakers a bit more time to adapt."

Christoph Bender, chief executive of oil association MWV

IFW LAMENTS 'ONE-SIDED INCENTIVES'

The IfW World Economy Institute Kiel has criticized the German government's Covid-19 stimulus package, saying some elements of it are "harmful." A mid-August IfW analysis titled "Incentive boom thanks to Covid-19?" found that the "one-sided, massive incentivization of all-electric vehicles" is pushing other car markets to the sidelines. Its authors suggest eliminating EUR 4.4 billion from the stimulus package approved on June 3 "without replacing the funds with other incentives."

The analysis specifically mentions the government's support for all-electric vehicles, including higher economic incentives, vehicle replacement programs and bonuses for automakers' and suppliers' investment plans. One of the study's authors, Claus-Friedrich Laaser, explained: "The government's one-sided, massive incentivization of all-electric vehicles disadvantages other engine designs, even though the alternatives might turn out to be more beneficial. The bonus program merely subsidizes automakers and their suppliers. Other important industries are left to fend for themselves."

The criticism was not meant as a broadside against the government's climate action targets but zeroes in on how to achieve them, the IfW researchers said. Incentivizing individual technologies or measures is not conducive to efficiency, they noted. "A standard carbon price across all sectors would be much cheaper and much more to the point," Laaser explained, adding that from an economist's point of view, incentives need to be disbursed entirely independent of the technology used. ||

NEW DLR INSTITUTES IN NORTHERN GERMANY

The German government's central research organization for aerospace technology, DLR, continues to expand its operations. It plans to build two new institutes, one to develop maritime energy systems and another to advance systems engineering in the transportation sector. On June 23, DLR's oversight board gave the green light for both. At that time, the German parliament had already approved the economy ministry's November 2019 request for EUR 22 million annually to build and run the new research facilities. Another EUR 2 million a year will come from the German states of Lower Saxony and Schleswig-Holstein.

The DLR Marine Energy Systems Institute will be in Geesthacht, with Alexander Dyck serving as its acting director. Dyck, who leads the urban and residential development department at DLR's Integrated Energy Systems Institute in Oldenburg, told H2-international that he is putting his current job on hold to take on the role. In the meantime, the new facility has been advertising for a director and a professor. Research work will focus on how to lower carbon emissions, improve sustainability and certify novel technology in maritime transportation. The institute will also investigate how to make the most of alternative fuels, integrate new equipment, such as fuel cells, and put up a fueling infrastructure on land. In all, 250 employees are to be employed on site.

By contrast, the Systems Engineering for Transportation Institute is a spin-off from OFFIS' transportation division, OFFIS being a private research organization on the campus of Carl von Ossietzky University. It will be headed by Professor Axel Hahn for the time being and is DLR's second facility in Oldenburg besides the above-mentioned Integrated Energy Systems Institute, where Professor K. Andreas Friedrich, who also leads the electrochemical energy department in Stuttgart, is now the leader of the fuel cell research group. ||

"Making Germany an attractive place to conduct business and research requires a wealth of scientific knowledge and investigations into the technological, social and economic issues of today. The new institutes will advance our expertise in key areas, such as maritime energy and future-proof transportation."

Professor Pascale Ehrenfreund, formerly DLR's executive chair

NEW RESEARCH CENTER IN MECKLENBURG-WEST POMERANIA

Germany's northeast is finally buzzing with activity. For a long time, Mecklenburg-West Pomerania's hydrogen community had rarely made the news. However, that was before the state's economy ministry announced at the hydrogen sector meeting in Güstrow on Aug. 21 that it plans to build a hydrogen research center.

Stefan Rudolph, who works at the economy ministry, said that Mecklenburg-West Pomerania will receive around

Fig. 1: Manuela Schwesig, governor of Mecklenburg-West Pomerania [Source: S. Schramm / Staatskanzlei MV]

EUR 50 million for shutting down the coal power station in Rostock because of Germany's exit from coal-fired energy production. "By far the biggest chunk of the money will be used to build a hydrogen research facility," he said, adding that "LIKAT Rostock, Fraunhofer IGP and Leibniz INP are conducting an initial study to determine the facility's exact technological focus."

Late August also saw the launch of the HY! Rostock initiative, while prior reports from Schwerin indicated that HIAT intends to grow its electrolyzer business. In March, HIAT's chief executive, Tino Freiheit, founded Hydrogen Innovation to separate the company's commercial and research activities. He told H2-international that HIAT is "operating in many markets around the world." which means the electrolyzer stacks developed by the non-profit institute will primarily be sold abroad. He added: "We are not taxpayer-funded per se so we have to generate revenue, mainly by selling PEM electrolyzer stacks, catalyst coated membranes and similar products. Still, as a recognized R&D institute, we do receive the full amount of incentives for our research."

A month earlier, in July, the public utility serving Schwerin announced that it will increase its share in HIAT from 18 to 25 percent. When Mecklenburg-West Pomerania's governor, Manuela Schwesig, visited Apex Energy in Rostock-Laage in the company of German labor minister Hubertus Heil, she remarked: "Hydrogen is of strategic importance to our business, climate and energy policies. All across Germany, people are starting to take note of the opportunities that the gas provides, opportunities that we in Mecklenburg-West Pomerania want to seize as well. […] Our goal is to keep and create well-paying jobs in clean hydrogen production to shore up Mecklenburg-West Pomerania's economy." ||

WEBINAR? CONFERENCE?

How I miss those face-to-face events. The hustle and bustle in the hallways, the in-person conversations, and, of course, the latest news coverage. And now? No networking, no rumors. All of this makes it quite difficult to gauge the mood in the industry, shifts in companies' market positions and the outlook for the year ahead.

In the past months, trade shows, congresses and workshops have been replaced with webinars, conference calls and online sessions. Many were not up to standard, not so much when it comes to content but rather because of dubious video and sound quality. Many providers ventured into the online world, moving their real-life events to internet chat rooms. For a while, NOW offered weekly webinars on a variety of topics, often with an audience of more than 200. Even smaller organizations reached quite a lot of people, many of whom might not have been able to attend in person.

And Silke Frank seems to have founded Mission Hydrogen at just the right time, that is, at the onset of the Covid-19 virus outbreak in Germany. Since March, she has been holding regular online conferences, with some pulling in more than 1,000 viewers from all over the world.

Meanwhile, others can do little more than wait for things to get back to normal. Tobias Renz, the organizer of the Hydrogen + Fuel Cells Europe in Hanover, was not the only one for whom 2020 was a total write-off. Quite a few announced that they were cancelling their carefully preplanned shows altogether.

Others hope that postponing their events will be enough. Peter Sauber is still planning on holding the f-cell, partly online, partly face-to-face, this year, with the shows in Canada and Germany taking place in the same month this fall. Cancelling them would have been greatly frustrating. Like our sister magazine HZwei, the Stuttgart-based f-cell symposium is celebrating its 20th anniversary this year.

Whatever happens, and regardless of whether some events will eventually be allowed to take place, one thing is certain: Covid-19 will leave a permanent mark.

Right now, one can only speculate which companies and event organizers will survive the pandemic's economic fallout. But the virus has and will continue to have clear social and economic repercussions.

Business trips have become exceedingly rare; the same has been true for live press conferences. Plus, congresses are partly held online, which provides few opportunities for networking. And what about trade shows? Will we even have any in 2021?

In all, companies are seeing a drastic reduction in travel expenses. The money they save by not having to process expense claims – an often cost-intensive, time-consuming task – can now be used to purchase new IT equipment, such as headsets and software tools.

The question that remains is what will happen to the energy market, climate action and the growing interest in hydrogen pre-Covid-19. When the dust has settled, will the hydrogen and fuel cell industry become a force to be reckoned with? So far, all signs point in that direction. Both in Germany and in Europe, it seems as if establishing a hydrogen economy has turned into a trend that everyone wants to get behind. And although hydrogen is not a panacea to all the world's troubles, the colorless gas is finally receiving the attention that some idealists have repeatedly said it deserves. ||

Category: Opinion | **Author:** Sven Geitmann

NEW MANAGEMENT, NEW DIRECTION

DWV to create executive committee

Fig. 1: DWV's board members at the annual general meeting in Leipzig in 2019: Wurster, Behrend, Schaloske, Scheppat, Diwald, Klees, Weinmann, Töpler, Schmidtchen, Lehmann (from left) and Martin (not in the picture)

The quiet life is over. That much is clear, even to the German hydrogen and fuel cell association DWV. Growing interest in hydrogen and fuel cells has some wanting to turn the organization into a powerful industrial body. Others remain focused on sustainable, distributed energy generation. The non-profit is facing a crucial test of its ability to adapt to changing circumstances. Should it keep developing into a lobbying organization and speak for only its industrial members? Or will it remain true to its founders' vision of a clean energy system running on hydrogen?

We have seen this all before, in the solar and wind power industries. Near the end of the 20th century, the few idealists promoting the nascent clean energy sector were often dismissed as eccentrics, that is, until a growing number of people followed their example when they saw that there was money to be made. Only a handful of visionaries held on to their jobs through every up and down in the market. Many did not. The economic pressure they were under was simply too great. They were replaced by managers who knew little about the technology but were experts in navigating the market and more experienced in selling to customers.

The same is currently happening in the hydrogen and fuel cell industry. More and more business graduates are taking over the jobs of inventors or company founders, aiming to commercialize the technology. This is not a bad thing per se, since inventors are very rarely good at marketing themselves and their products. And yet, there is a good chance these changes in management will upend long-held goals and values.

By now you may be wondering what all of this has to do with the DWV.

On Sept. 10, the association will hold its annual general meeting in Hamburg to vote on a new board. Members will also have to decide which organizational structure and executive team is the best fit for the DWV. Will there be a closer partnership with gas and water industries association DVGW? Will they perhaps join forces under one roof? Or will the DWV try to go it alone most of the time?

When you read these lines, you probably already know who was selected to lead the DWV, who is still on board and who is not. Did members choose idealists or market-oriented business leaders? Eberhard Behrend and Ulrich Schmidtchen, who co-founded the association and were central to its success, will definitively not be running for their seats again. Even younger members, such as Manuel Schaloske, once thought to be sitting on the board for a long time to come, will be backing out. Same with André Martin, who led the task force reorganizing the DWV.

Birgit Scheppat and Johannes Töpler did declare their candidacies but had to face off against Manfred Schuckert and DWV founding member Oliver Weinmann, who wanted, or, you could say, were expected, to become deputy chairs

instead. While Scheppat and Töpler represent the older generation with much scientific expertise under their belt, courtesy of long university careers, Schuckert and Weinmann are a bit younger and work for large industrial companies.

Weinmann, one of the board's associate members, is rumored to be ideologically and personally relatively close to the association's chairman, Werner Diwald, but has rarely been seen at board meetings. His candidacy is being interpreted as a sign that the association's members no longer have faith in either of the deputies. However, this is probably just another attempt at pushing Töpler out, which some already tried 15 years ago.

As for hiring paid staff, that is an issue which has been under discussion for several years. Past events have proved that the association cannot rely on only volunteers to meet the challenges ahead. Over the years, ENCON.Europe, led by Diwald, has taken on a growing number of tasks. Diwald said that in the last two years alone, the company contributed a great deal to increasing the DWV's visibility without putting itself front and center.

In fact, ENCON.Europe has been the sole driver behind making the DWV and the performing energy committee known among political leaders while always acting in the association's best interests, he added. Other people working for the firm are managing partner Gerd Harms and DWV members Dennitsa Nozharova and Benjamin Baur.

For a while now, there have also been repeated calls in some quarters for a more noticeable separation of the DWV's business and association activities. The same could be said about the performing energy committee headed by Diwald, as its role and function have not always been that clear. This explains the heated discussions surrounding one of the items on the agenda, the creation of new expert committees such as HySteel, HyLogistics and HyLaw. For compliance reasons alone, restructuring and disentanglement would seem to be long overdue.

The DVGW began helping the DWV professionalize in January 2019 and has since shared its longtime office with the hydrogen and fuel cell organization. Diwald said that the gas and water industries association had partnered with the much smaller DWV mainly because of the latter's "excellent political connections across Germany and the EU," which resulted in "successful lobbying work." In turn, the DWV benefits from the DVGW's wealth of gas sector expertise and its extensive portfolio of education and training programs.

One section of their cooperation agreement also deals with whether to merge the two associations. Diwald said that while a review of all options has indicated a desire for closer collaboration with the DVGW, founding a limited liability company is no longer on the table. Alfred Klees, the head of DVGW's Gas Technology and Energy Systems division and a DWV board member since 2019, told H2-international that the DVGW performed a SWOT analysis, which found that reshaping the DWV has more advantages than setting up an LLC. Now, the aim has shifted to establishing an executive committee, which the DWV is slated to introduce at its 25th annual meeting.

This means that the organization will be led by full-time board staff as well as an executive committee made up of volunteers. The committee will set a strategy and formulate aims, while the board will reportedly take care of day-to-day business.

That leaves the question of where the association stands on renewable energy generation. Not long ago, Diwald said that the DWV wants only "green hydrogen. Everything else is merely a distraction." He believes that carbon capture and storage lacks widespread acceptance in Germany so promoting the blue version of the gas would be hardly a winning issue. The detour via CCS, he added, would also waste a lot of time. Instead, he called for direct investment in renewable hydrogen.

> "The analysis found that there are several reasons why founding a limited liability company under the auspices of the DWV would be a less-than-ideal solution at this time."
>
> *Werner Diwald, chairman of DWV*

According to the performing energy expert committee, that clean hydrogen could then be used to make synthetic fuel. It is unclear, however, if the synfuel pathway, favored especially by the auto and oil industries, is the method of choice for all DWV members or only for those sitting on the expert committee.

It is no surprise then that many believe this year's meeting in Hamburg to be one for the history books. In several respects, it will decide the fate of this hydrogen and fuel cell association founded in 1996.

Whatever the DWV members' decisions, the entire hydrogen and fuel cell community is at a similar crossroads. Today, we are laying the groundwork for where the large amount of funding provided by the German government and the EU will end up. And wherever this taxpayer money goes, corporate investment will follow, providing us with a great deal of leverage to move the market forward – in any direction. All of us should be aware of that unique opportunity for change.

The potential is enormous, making it even more important to act responsibly. I am looking forward to seeing how it will all play out. ||

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

NATIONAL HYDROGEN COUNCIL LAUNCHED

No decision yet on where to house coordination office

The National Hydrogen Council is a vital element of the German hydrogen strategy published in June and comprises 26 representatives for industry, academia and civil society. Although its members were appointed by the German cabinet, multiple organizations had previously contacted the federal ministries involved in drafting the strategy to submit their suggestions for who they want to see on the council.

Source: BMWi

Most council members hail from the business world. They work for energy providers, automakers or other industrial companies. Another four are researchers and three are from environmental organizations. In all, 17 hold high-level management positions, i.e., are chief executives or chairs, who certainly have much authority though not always a great deal of subject-matter expertise.

When H2-international asked the economy and energy ministry which criteria it used to decide on appointments to the council, it replied that "many elements factored into our decision. An important criterion was profound hydrogen expertise. In addition, because of the high number of applications, the government needed to restrict the number of those sitting on the council to ensure that all members are still able to work together. Other considerations included giving an equal voice to representatives for different parts of the supply chain and provide equal opportunities for men and women according to the Federal Equality Act on Committees."

Among those selected to sit on the council is Silke Wagener. A chemist by trade, she led the fuel cell R&D department at the Freudenberg Group more than two decades ago before becoming the chief executive of Freudenberg Fuel Cell Component Technologies. She served in that role up until 2013, when she also left NOW's advisory board, of which she had been a member for several years. Weinheim-based Freudenberg intentionally sent an experienced scientist who could offer advice by drawing on her extensive industry background.

Fig. 2: Katherina Reiche [Image: E.ON]

Others are taking up positions as well. Stefanie Peters, who co-leads the Neuman & Esser Group, is among those now sitting on the council. Her brother, Alexander Peters, the group's co-CEO, is a candidate for the post of DWV chairman this fall.

KATHERINA REICHE VOTED PRESIDENT The first meeting took place on July 9, not long after the strategy was published. German environment minister Svenja Schulze said at the time: "I am pleased to see the newly formed National Hydrogen Council taking shape. With this expert committee at our side, we want to quickly set up a green hydrogen economy, both at home and abroad. Green hydrogen can help us considerably in achieving our climate targets and making the economy fit for the future. More importantly, the hydrogen strategy that the European Commission published yesterday states exactly the same goal, that is, to create a sizable market for green hydrogen."

At the meeting, Reiche was voted in as president by the council's 25 members (Professor Heinz Jörg Fuhrmann, of Salzgitter, and Arnd Köfler, of ThyssenKrupp, share a seat, thus the 26 names mentioned in news reports). Reiche is E.ON subsidiary Westenergie's CEO and used to preside over the German association of municipal corporations, VKU. Her first encounter with the hydrogen industry came when she worked for the federal transportation ministry from 2013 to 2015 (see HZwei, January 2013).

> "The Hydrogen Council will offer the government significant support in pursuing and advancing its hydrogen agenda. Together with my co-members on the council, I will put in every effort to make Germany the world's leading hydrogen market."
>
> *Katherina Reiche, president of the National Hydrogen Council*

KNOW-HOW VERSUS PROPORTIONAL REPRESENTATION

Another key element of the national hydrogen strategy is the Hydrogen Coordination Office, tasked with coordinating activities nationwide. Its secretariat and project management staff will reportedly help negotiate as well as formulate recommendations for action and support departments in strategy implementation.

It is said that several of the departments that were involved in drafting the strategy are being considered for housing the office. Their names are:

- German Academy of Science and Engineering – acatech at the education ministry
- National Organization Hydrogen and Fuel Cell Technology – NOW at the transportation ministry
- German Energy Agency – dena at the economy ministry
- Future, Environment, Society – ZUG at the environment ministry

Sources with knowledge of the negotiations told the ZfK newspaper in mid-July that the economy ministry wants to create a consortium led by dena, an idea that is being rejected especially by the education ministry. Around a month later, the departments were still wrangling with each other. On Aug. 7, the education ministry told H2-international that "there has not yet been an internal agreement on where to set up the Hydrogen Coordination Office. With talks still ongoing, we are unable to provide further comment at this time."

Considering the German economy ministry has the authority in this case and the education ministry got its wish of an innovation commissioner, the decision may fall on dena, even if the NOW has obviously accumulated many more years of experience in the sector. ||

TJARKS LEAVES NOW

Geert Tjarks, director of the national hydrogen and fuel cell innovation program NIP, left NOW for Oldenburg-based EWE Gasspeicher on Sept. 30. Tjarks was instrumental in drafting the government's hydrogen road map. He told H2-international that "publishing the strategy was an important political signal to the industrial sector. Now, companies can start advancing the national agenda and it was my wish to join the private sector to help with its implementation."

Category: Policy | **Interview Partner:** Stefan Kaufmann

GOVERNMENT WANTS HYDROGEN ECONOMY

Interview with Innovation Commissioner Stefan Kaufmann

In summer, the German government published its national hydrogen strategy, drafted with input from several federal ministries. An example of this intergovernmental collaboration was education minister Anja Karliczek's idea for creating the post of Green Hydrogen Innovation Commissioner, to ensure that the strategy's ambitious aims lead to swift action, her ministry said. H2-international spoke with Stefan Kaufmann, who was appointed to the post, about his new job and his concrete plans for the industry. A lawyer by trade, and a member of the Christian Democrats, he has been in parliament since 2009, representing voters in Stuttgart South.

Fig. 1: Stefan Kaufmann [Source: BMBF/Hans-Joachim Rickel]

H2-international: Mr. Kaufmann, in June, the German government appointed you to the post of Green Hydrogen Innovation Commissioner. Could you tell us in a few words how you got the job?

Kaufmann: In its national hydrogen strategy, the government laid out ambitious targets that underline Germany's role as an engine of innovation. The aim is to become the leading supplier of green hydrogen and the key market for trading the gas. Germany has strong research capabilities that are sure to give the sector a boost and facilitate the development of future-proof green hydrogen solutions. This is why the strategy says we need that post. My many years of experience in crafting research and innovation policies will help bring together leaders from academia, industry and the government to create commercial products out of project findings as fast as possible. That is also one of the main objectives of the new strategy.

How did you come to be innovation commissioner? Nothing on your resume seems to suggest deep knowledge of the energy market, let alone hydrogen.

Research and innovation are, you could say, the lifeblood of my political career. I have always been curious about what the future holds for us. After I won my district in 2009, I joined the parliament's research committee. Since then, I have gained years of experience and many connections throughout the innovation community. So I was delighted when Ms. Karliczek offered me the job and, of course, I accepted. Hydrogen provides us with a unique chance to promote German ingenuity and grow our economy. The same is true all across Europe, which is why the gas has played a key role under Germany's EU presidency.

Three times in a row, you won your seat outright instead of being picked from a party list. As for Stuttgart, the city is heavily dependent on revenues from the auto industry. What would you say has changed in the past years? Were fuel cells a factor in deciding on the right strategy for the transportation sector?

Automotive and machinery manufacturing are major economic drivers in Baden-Württemberg. The state is also home to a whole host of excellent education and research facilities, four of Germany's 11 elite universities among them. In short, Baden-Württemberg offers the perfect environment for ensuring the success of a hydrogen economy. Right now, German automakers place little emphasis on manufacturing fuel cell models, while their competitors in Japan are several years ahead.

What do you believe German automakers should have done? Have they waited too long to come up with electric vehicle designs?

The auto industry is facing great challenges. As Germany's Green Hydrogen Innovation Commissioner, I want the country to have a lead on the fuel cell competition and I welcome support from anyone who shares that goal.

Are batteries or hydrogen the more sensible choice to power vehicles?

Green hydrogen is a valuable resource, with great short-term prospects in heavy-duty, maritime and railroad transportation.

But what do you say to those German automakers, including Stuttgart-based Daimler, which – for years – happily took the incentives offered for fuel cell RD&D but have yet to deliver market-ready FCEVs? Not to mention that although Daimler previously signed a jobs guarantee, management is reportedly thinking about using a loophole to let go thousands of employees in Stuttgart. When you won your seat, you said your aim for the next four years was to make sure the Stuttgart region would continue to provide employment opportunities and prosperity and that new industries would create jobs and innovative products. The exact opposite has happened.

Compared to the rest of Germany, very few people living in Stuttgart are unemployed, and we intend to keep it that way. As for fuel cells, German automakers, including companies based in the southwest, are indeed losing to the competition. As someone who was born in the Stuttgart region, I want to ensure that the state can provide the best possible solutions nationwide. It pains me to see that others have raced past us in the meantime. Unfortunately, over the last several years, both Stuttgart's mayor from the Greens and the state's Green Party government have missed opportunity after opportunity to fund innovation and develop proactive economic and industrial policies. As an example, Stuttgart's council did not

even submit a bid when Baden-Württemberg was looking for a site to test autonomous vehicles.

Let us talk about your new job. What were you asked to do exactly?

My responsibilities are set out in the national strategy. The main task is to bring together leaders from academia, industry and the government to make sure that clever ideas quickly grow into successful, innovative products. Plus, I am a member of the federal departments' joint hydrogen committee and the National Hydrogen Council, a group of researchers and industrial representatives advising the government.

Minister Karliczek said that we need "a positive outlook and send a clear message to innovators and investors." What did she mean by that?

The government wants Germany to be known as a "hydrogen republic." We want to demonstrate to the world that you can have a functioning hydrogen economy while showing others how to accomplish that goal. If Germany is to retain its image as a fountain of innovation, people need to experience the exciting opportunities that the energy carrier has to offer. It also goes without saying that green hydrogen could help us tremendously in meeting our COP21 climate targets. Whenever I talk to stakeholders in industry and academia about the technology, the thing that stands out the most is their positive outlook on the sector.

How do you intend to encourage positivity?

At the same time the German education ministry chose me to be their Green Hydrogen Innovation Commissioner, it launched an idea competition, which I have been following closely ever since. Clever people from all walks of life, be they researchers, business managers or social leaders, have been invited to send us their suggestions for a hydrogen economy buildup.

It was education minister Karliczek who urged the government to create your position in the first place. Your task as Germany's innovation commissioner, she said, will be to "improve the knowledge transfer between academia and industry." Does this make her your superior? Are you primarily working for the education ministry?

Mine is a management-level position in the education ministry, although I am not acting under her authority. Ms. Karliczek and I are in frequent contact to exchange ideas. We have a common objective, which is for Germany and Europe to become global leaders in clean hydrogen production. To achieve that aim, we need to out-innovate the competition. This is what I am here for.

How will you get the other federal ministries to support you? Reportedly, there are widely varying opinions on how to proceed.

From my time in parliament, I know how much of a struggle it can be to negotiate the best possible solution. The same happens in the executive branch. As Germany's Green Hydrogen Innovation Commissioner, I am fully committed to helping the government achieve the ambitious aims that it set out in the national hydrogen strategy. Other departments know they can rely on me and I am certain I can rely on them too.

Do you see yourself as a kind of mediator to improve cooperation between Germany's ministries, which have so far not been able to find much common ground when it comes to transforming the energy system?

Transforming the energy market requires collaboration and the federal government is indeed working as a team. I do not share your assessment of their efforts.

Exactly which steps are you planning to take initially?

We have already seen the launch of the Hydrogen Republic Germany idea competition. I am looking forward to reading the row of suggestions that applicants will be sending in. Furthermore, I travelled the country in the past weeks to gain further insights into the different aspects of hydrogen use in industrial and research settings. My next goal is to take a closer look at our international hydrogen partnerships. For example, we at the ministry have been working on a Hydrogen Potentials Map, backed by research findings, to get a green hydrogen economy off the ground in Africa. This will help shift the focus of cooperation to particularly promising partners and business models and strengthen our research partnerships in, for example, western and southern Africa. We also have many prospective partner countries in Europe. As mentioned earlier, hydrogen has been getting a great deal of attention under Germany's EU council presidency.

What do you want to achieve? What is your precise goal?

It should be possible for us to put up a large demonstration project in Germany prior to the next general election. I am hoping for an electrolyzer capacity of at least 100 megawatts. Beyond that, preferably by 2030, we want to have 5 gigawatts up and running. We also need to forge new alliances globally to increase our energy imports. Make no mistake, Germany will have to continue to import energy. But we want that energy to come in the form of green hydrogen.

In other words, you will have to work closely with the new national hydrogen office. Will that office be housed at the transportation ministry's NOW, the economy ministry's dena, the education ministry's acatech or the environment ministry's ZUG?

I cannot comment on ongoing negotiations.

Last question: What do you, as an advocate for clean gas, think of blue and turquoise hydrogen?

As Green Hydrogen Innovation Commissioner, my job is to make people aware of the many benefits of this zero-carbon alternative. Aside from that, I prefer white and red, the team colors of the VfB Stuttgart soccer club.

Mr. Kaufmann, thank you for our interview.

IDEA COMPETITION "HYDROGEN REPUBLIC GERMANY"

When education minister Anja Karliczek announced Kaufmann's appointment, she also said that her ministry will be inviting innovators from the worlds of academia, industry and civil society to submit their ideas for establishing a hydrogen economy. The competition's main objectives, the ministry said, will be to develop new ways to scale electrolyzers to commercial, allow for green hydrogen imports across greater distances, and integrate hydrogen equipment into Europe's energy system. Basic research will continue to be funded as well. Submissions are expected to provide innovative ideas for green hydrogen supply chain components, i.e., production, storage, transport, energy conversion or consumption, though funding is likewise available for materials research projects and studies investigating how to adapt the energy system to run on clean hydrogen. The budget set aside by the education ministry for this program is around EUR 600 million.

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

EUROPE'S GREEN HYDROGEN DEAL

European Alliance for Clean Hydrogen launched

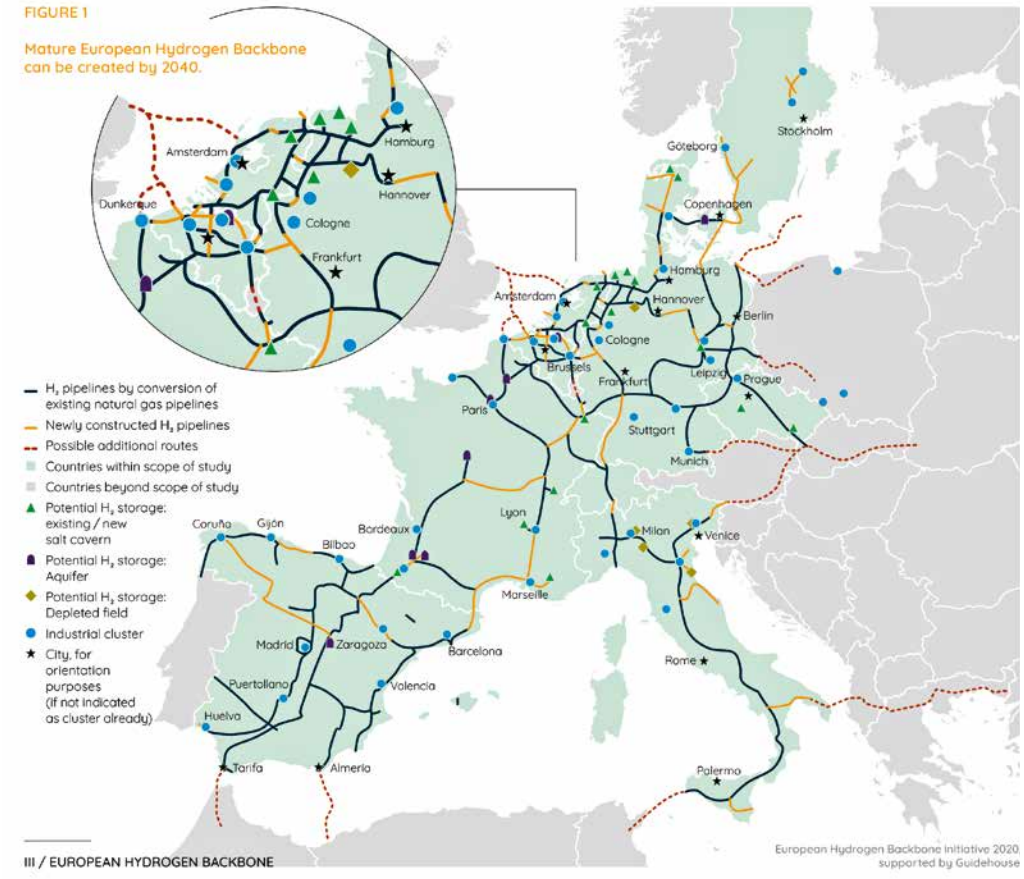


Fig. 1: By 2040, the hydrogen grid will reportedly be 23,000 kilometers long. [Source: European Hydrogen Backbone Initiative, Guidehouse]

On June 8, the EU followed Germany's example by announcing a hydrogen strategy. The European Commission even published two road maps, one for energy systems integration and another for clean hydrogen as part of the NextGenerationEU stimulus package and the European Green Deal. Aiming to help the economy recover after the Covid-19 lockdowns, both programs have certainly more than enough funds available.

The first strategy lays out a plan for how energy systems can work more efficiently on their own and with each other, stating that an integrated, demand-responsive system will be more effective and less costly to society. It also envisions a future in which vehicles run on power generated by solar panels. These panels will be sitting on the roof of buildings heated by waste energy, energy supplied by nearby industrial facilities that use renewable hydrogen produced by offshore wind farms.

Much will depend on consumers' growing direct use of electricity, made possible by an expansion of green power production in multiple areas, be it for residential heat pumps, electric vehicles or industrial ovens. Industries that are hard to decarbonize are to use more clean fuels, such as renewable hydrogen or biofuels. The commission set out 38 measures detailing how to achieve a green market. They include revised regulations, financial support, research ideas, software tools, guidelines, changes to taxation, and consumer leaflets.

GREEN, AND BLUE AS WELL Similar to the German government's hydrogen strategy, the European Union's focuses on

"The strategies adopted today will bolster the European Green Deal and a green recovery and put us firmly on the path to a decarbonized energy system by 2050. A hydrogen economy can bring about the growth needed to help ease the economic pain caused by Covid-19."
Frans Timmermans, executive vice president for the Green Deal

"The energy sector produces 75 percent of all GHG emissions across the EU so we need a paradigm shift to reach our 2030 and 2050 targets. [...] Hydrogen will play a key role in this, as falling clean energy prices and continuous innovation will turn the gas into a viable solution for a climate-neutral economy."
Kadri Simson, EU energy commissioner

"The European Clean Hydrogen Alliance we launched today will channel investments into hydrogen production. It will develop a pipeline of ready-to-go projects to support decarbonization efforts in Europe's energy-intensive industries such as steel and chemicals."
Thierry Breton, EU commissioner for the internal market

GREEN DEAL
The European Green Deal is the EU's growth strategy. It provides a road map to a greener economy by turning climate and environmental issues in all policy areas into opportunities for growth while ensuring a fair transition to sustainability.

clean hydrogen mainly produced from wind and solar energy. However, even EU politicians expect that blue or turquoise will serve as a bridge to green. The strategy states that in the short and medium term, "other forms of low-carbon hydrogen" will be required to lower emissions as quickly as possible and support the creation of a sustainable market.

By 2024, the EU wants to see 6 gigawatts of wind energy capacity put up for clean hydrogen production. By 2030, this capacity is to increase to 40 gigawatts across the Union and another 40 outside the EU. The cost of installing all those electrolyzers is estimated at EUR 5 billion to EUR 9 billion by 2024. By 2050, the total investment in this gigantic endeavor could reach up to EUR 470 billion.

While the German government put the National Hydrogen Council and the National Office (see p. 10) in charge of strategy implementation, the European Commission launched a European Clean Hydrogen Alliance, made up of representatives for manufacturers, the society as a whole, national and regional authorities and the European Investment Bank. The initiative's founders foresee around 500 industrial companies joining the alliance in its first year, a number that could double by 2024 and again by 2050.

EUROPE-WIDE HYDROGEN GRID Only nine days after the commission presented its hydrogen strategy, a consortium of 11 independent network operators from nine EU countries announced the founding of the Hydrogen Backbone initiative. Complementing the Union's efforts, the coalition will reportedly build a Europe-wide hydrogen pipeline system, with construction starting in the Netherlands in the middle of this decade. By 2030, the system will then be around 6,800 kilometers long and cover most of Europe.

Although it feels like German institutes have been conducting research into hydrogen for ages, someone recently said in a talk show that the Netherlands have been quicker in putting ideas into practice (see HEAVENN Hydrogen Valley in Groningen; H2-international, February 2020). Considering this, it may not be a bad idea for Germany to start looking to its small neighbor for guidance.

To this end, the grid operators want to adapt some natural gas pipes to deliver hydrogen and link them via new pipes specifically designed for hydrogen transport. In the future, it was said, two parallel cross-regional systems should independently supply hydrogen and (bio)methane.

The venture is estimated to cost between EUR 27 billion and EUR 64 billion. Consulting firm Guidehouse, one of the partners in the project, calculated that the large upfront investment will ensure moderate prices of EUR 0.09 to EUR 0.17 for transporting one kilogram of hydrogen over 621 miles (1,000 kilometers). ||

"The new grid is essential to setting up a hydrogen market on the continent. This makes it all the more important for Hydrogen Backbone to become a truly European initiative that establishes strong ties with the Union's eastern member states."

Daniel Muthman, OGE

Category: Energy storage | **Author:** Michael Jensen

HYDROGEN BREAKTHROUGH IN STEELMAKING

Reduction of global emissions by 7 percent

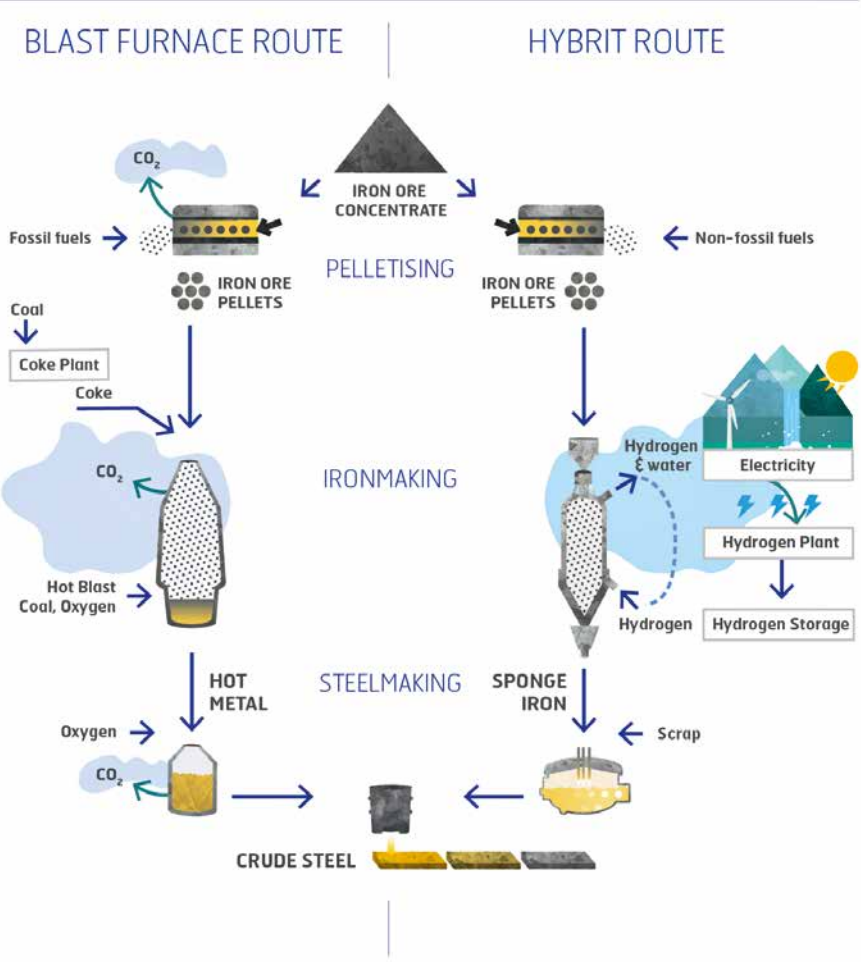


Fig. 1: Conventional steelmaking process versus the HYBRIT process
[Source of all images: HYBRIT]

New revolutionary process using hydrogen, developed by the Swedish steel industry, proves a viable and competitive way to replace coal and other fossil fuels traditionally used in steelmaking. It reduces the carbon footprint of 1 tonne of steel from 1.8 tonne of CO_2 to 25 kg.

The process called HYBRIT (Hydrogen Breakthrough Ironmaking Technology) is developed in collaboration between Swedish steel industry and Swedish government more specifically LKAB (iron ore mining), SSAB (steelmaking/-processing), Vattenfall (energy/power) and the Swedish Energy Agency (capital and scientific/technical support).

The HYBRIT process considers all steps from mining and processing the iron ore to the finished steel to ensure that fossil fuels are close to eliminated. Practically a slight amount of coal will remain necessary in the steelmaking process to adjust the steel's carbon content and thereby its physical as well as corrosive properties.

When fully implemented in Sweden HYBRIT is expected to cut national CO_2 emissions by as much as ten percent. Globally steelmaking accounts for around seven percent of all CO_2 compared to around eight percent for cement production.

Steel produced with the HYBRIT process is 20 to 30 percent more expensive than traditional steel, but this is based on current fossil fuel prices with current taxation schemes. When the HYBRIT method is more widely implemented and further developed it will become less expensive both in absolute terms and relative to conventional steelmaking. Considering the global market pull for CO_2 reduced products and the increasing rejection of polluting and climate impacting products the global markets will see an increasing demand for climate friendly steel. Even if the price initially is higher.

For the process to remain CO_2 neutral the hydrogen used must be made in a CO_2 neutral way preferably by electrolysis using renewable power. The HYBRIT consortium estimates that approximately an additional 15 TWh are needed annually if the new process fully replaces current methods of iron ore and steel production in Sweden. That is about one tenth of Sweden's current power production.

A pre-feasibility study, partly financed with 60 million SEK by the Swedish Energy Agency, and conducted from 2016 to 2017, proved that the HYBRIT process is in fact viable and commercially meaningful. On the back of the study's conclusions the industry partners and the agency in 2018 decided to commence with three pilot projects each representing different steps in the steel making process:

1. Direct Reduction of Iron (DRI): Hydrogen and steel production
   A pilot plant in Northern Sweden is under construction since summer 2019. The plant is situated at an existing SSAB steel plant in Luleå. This plant will be producing hydrogen made via electrolysis using renewable power from the energy company and project partner Vattenfall. An electric arc furnace in the pilot plant is also supplied by Vattenfall. The pilot is expected ready and operational sometime 2020.

2. Fossil free iron pellets
   In a pilot project also started in 2019 in Luleå as well as Malmberget in Northern Sweden, the mining and iron ore processing company LKAB works on developing and scaling a new pellet production design using renewable fuels and new heating technologies.

This project includes the conversion of one of LKAB's pelletizing plants from fossil fuel to 100-percent-renewable fuel (bio-oil). Thereby the fossil-generated carbon dioxide emissions from the existing Malmberget operation will be reduced by up to 40 percent during the test period, which corresponds to about 60,000 tonnes per year.

3. Hydrogen storage
   In 2021 the HYBRIT consortium plans for a hydrogen storage research facility at SSAB's site in Luleå. At this site a pilot storage facility will be erected to complement the DRI project mentioned above. Large scale efficient hydrogen storage will be a prerequisite to implementing the HYBRIT process on industrial scales. The pilot also investigates how hydrogen storage can play a role in balancing renewable power production by converting surplus renewable power to hydrogen when overall power demand is less than current production.
   Development and implementation to arrive at a technologically and commercially competitive stage replacing current fossil fuel based steel production, in Sweden and eventually globally, won't happen overnight. The consortium expects a commercially mature stage in 2035. The pilot phase runs from 2018 to 2024 and towards 2035 demonstration and plant trials will be conducted.
   Making Swedish steel production carbon neutral is an important part of Sweden's overall national goal of a carbon neutral society in 2045. Current carbon emissions from the Swedish steel industry are approximately 6.5 million tonnes annually or around ten percent of Sweden's total carbon emissions.

GLOBAL STEEL DEMAND IS GROWING A growing world population, increasing urbanisation as well as a globally growing economy all spur a growing demand for steel used in construction and industry. Global carbon emissions from steel production were around 2.9 gigatonnes CO_2 in 2017 or somewhere between seven and nine percent of total global carbon emissions (World Steel Association).

HOW CARBON INTENSIVE IS STEELMAKING? Conventional steelmaking is very carbon intensive as 1 tonne of finished steel results in 1.8 tonnes of CO_2 emissions stemming mainly from the energy intensive coking process and particularly from the melting and processing of iron to steel (World Steel Association). Below an illustration of the various emitting steps in a Swedish reference case. Note that the Swedish reference is lower than the global average due to better efficiency, energy reuse and optimised processes.

STOPPING GLOBAL WARMING WILL REQUIRE NEW METHODS IN STEELMAKING Representing almost one tenth of global carbon emissions, reducing the carbon footprint of steelmaking is a major factor in reducing the climate impact of human activity on the planet. The HYBRIT prospect seems a promising one in succeeding with our common global goals of halting global warming.

The Swedes are walking the talk and even Greta Thunberg can in this respect be proud on behalf of her home country. ||

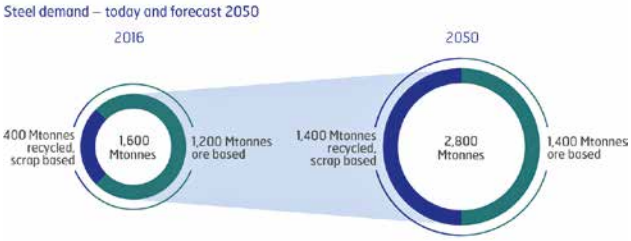
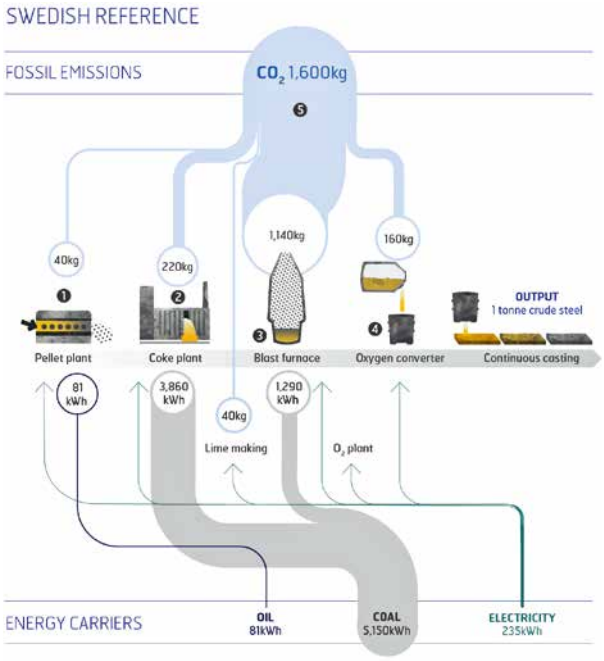
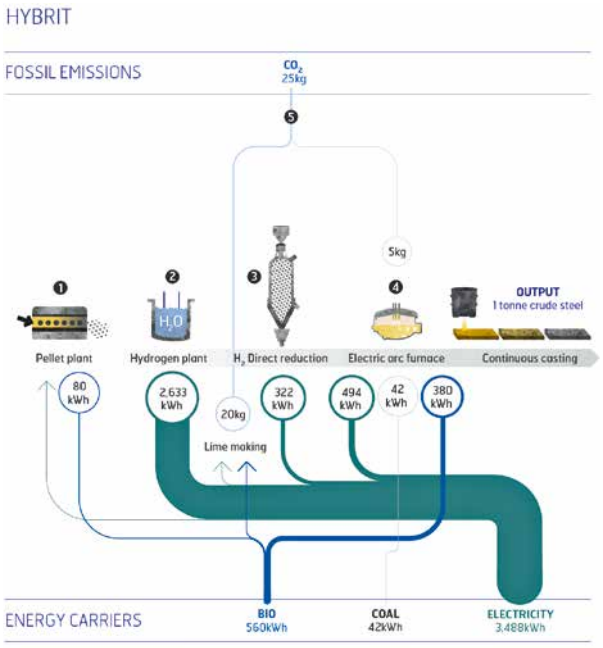


Fig. 2: Growth in world steel demand (Mtonnes = Megatonnes)



Principal system description. Numbers do not reflect a specific production site or time period.
All numbers per tonne of crude steel.

Fig. 3: CO_2 emissions in conventional steel production



All numbers per tonne of crude steel.

Fig. 4: The HYBRIT steel making process reduces fossil emissions to 25 kg of CO_2 per tonne of steel produced, provided that carbon neutral fuels such as hydrogen and certain biofuels are used. A slight amount of fossil coal is needed in the process to ensure the right carbon content and henceforth the requested physical, metallurgical and corrosive properties in the crude steel.

Category: Energy storage | **Interview Partner:** Peter Röttgen

HOW TO SPEED UP THE ENERGY MARKET TRANSFORMATION

Interview with energy expert Peter Röttgen

Peter Röttgen, a PhD geologist, was once the head of the E.ON Energy Storage Innovation Center in Düsseldorf. He then became president of the Brussels-based European Association for Storage of Energy and remained in that role for many years. From August 2017 to early 2019, he led German renewable energy federation BEE before he left to work at Finnish energy supplier Fortum's German office as vice president of public affairs. In March, Fortum became Uniper's majority shareholder.

Fig. 1: Peter Röttgen [Source: Fortum]

H2-international: Mr. Röttgen, when you left BEE a bit over a year ago, you said you will be keeping an eye on the industry. What is your current take on the sector now that you are an 'outsider'?

Röttgen: Sadly, in my view – and I am, of course, still advocating an increase in clean energy capacity – progress has been very slow. The wind energy industry in particular has experienced a painful drop in annual capacity additions. Growing divisions between clean energy supporters and opponents make it hard on policymakers to commit themselves to anything. Today, the issue is no longer if renewable electricity costs too much. Attention is currently shifting to how we can get people to accept clean technology. Spatial planning instruments give us an opportunity to address the concerns they might have and work out a compromise. And besides encouraging more interest in climate action, we need to support enthusiasm for renewables and the innovations they spawn.

That sounds optimistic. Covid-19 has presented us with new challenges. Do you somehow see the current crisis as a chance to advance the transformation of Germany's energy market?

The current pandemic is first of all a global human tragedy that fills me with great sadness. Nevertheless, it also highlights issues that are usually difficult to detect but which, if unchecked, could have dramatic consequences. Applying this train of thought to the global warming debate, we must acknowledge that climate change is real and that we need to act soon. What we could reasonably do to address the problem is to transform our energy system – in all sectors. Here is hoping that the Covid-19 experience will lead to a better understanding of climate issues and that we will be able to implement some projects earlier than planned. As an example, the German government's stimulus package provides financial incentives for investing in clean transportation and building a hydrogen infrastructure. This could very well speed up the transformation.

The government long wanted to eliminate the German clean energy law's solar cap, which stipulated the stop of incentives at 52 gigawatts of PV capacity. Why did it take the government so much time to remove that provision?

There are fault lines between and within political parties. PV opponents still remember how much money was spent on incentivizing the technology. That is no longer true, though – the prices for PV equipment have tumbled by 90 percent since then. To be frank, tying the solar cap to wind energy setback rules was certainly not a well thought-out move. But that is part of politics, negotiating a compromise. Regardless, the cap is now history thanks to the cabinet-approved stimulus package.

How high do you think the carbon price should go if it is to have a noticeable impact on emissions?

In its road map, the German government tried to find a middle ground between basically not introducing a price at all and setting one that should have been higher if we want to reverse course rapidly. The starting price seems acceptable in light of what was politically possible, not to mention that it has since been revised upward. We will soon get a first glimpse of its impact on the market – when we need to decide what technology we want to rely on to meet future energy needs. However, the government needs to monitor the market and adjust the amount should its clean energy targets be in jeopardy. On a positive note, the price will apply across all relevant economic sectors. The same now needs to happen across the EU. A Union-wide carbon price could help us tremendously in fighting climate change and guaranteeing fair competition. Besides, I hope that in the second half of this year, the German EU council presidency can give some fresh impetus to the sector and that the entire Green Deal will move ahead quickly.

Your company, Fortum, now owns nearly 70 percent of Uniper [an E.ON spin-off], making it the energy provider's majority shareholder. Just recently, Uniper started up a coal power station named Datteln 4 in the state of North Rhine-Westphalia despite the German government's planned exit from the coal industry. What future do you see for that kind of power generation in Germany?

Your question ties in with the debate about emissions from coal power plants. Coal-fired electricity generation, especially without carbon capture and storage, stands in stark contrast to climate targets and the transition to a cleaner energy market. However, it would be wrong to point the finger squarely at coal producers and denigrate entire groups of factory employees. The work they do was invaluable and to the benefit of all of society for many years. But the situation has changed. German coal power production no longer has a future, and that will lead to transformative change.

How will you achieve this transformation?

First of all, there is the European Emissions Trading System, which will limit emission allowances gradually. That system is not in dispute among EU members. Even before the Covid-19 outbreak, from 2018 to 2019, the amount of energy produced from coal had fallen significantly, according to Agora Energiewende, the main reason being the rising carbon price. The price boosted both low-emission natural gas and zero-emission renewable sources, leading to a 12 percent reduction in emissions.

Seems like clear statements and hard facts to me.

Indeed. The German Coal Commission has advocated exiting the coal sector by 2038 at the latest, and the government is seeing to that. Operators of coal power stations have now been tasked with transforming their business. This means they need to forget about using conventional equipment and start looking at alternative energy generation methods that are socially, legally, technologically and, last but not least, financially viable. Current coal power plants have to be shut down in a way that guarantees their replacement by inexpensive but reliable and eco-friendly production methods. Things may get difficult, though the goal remains achievable.

Finnish company Wärtsilä believes Covid-19 could speed up the energy market transformation by providing more opportunities for electrification. Do you think so as well?

I also believe we can accelerate the process. Earlier in our conversation, I mentioned Germany's recently passed stimulus package, which could drive growth. My opinion on electrification may differ a bit. Electricity has taken on a dominant role in the debate. But Germany's transformation strategy was built around a partnership between electricity and gas suppliers. Today, suppliers of natural gas have taken the lion's share of the gas market and efforts to transform natural gas into a zero-emission fuel are underway. This is why current discussions focus on the question of what type of fuel we want to use to power a future energy system. Will we only have hydrogen produced from green electricity or also natural gas in combination with carbon capture and storage? Based on my observations, many have realized that we will continue to require gas sources for a lot of applications. This is also a crucial point when designing future energy storage.

When you worked for E.ON Gas Storage, you devoted much of your time to developing energy storage solutions. What technologies do we need in this market?

In essence, we have all the electricity, gas and heat storage technology we need. Nowadays, many PV installations are equipped with small storage units or connected to energy clouds. This provides suppliers with a high degree of flexibility, allowing them to increase energy efficiency or put up big batteries in central locations. Expanding the electric transportation infrastructure will also get us large, distributed capacity if we can use the batteries of parked vehicles for storage. There are great opportunities to be had when switching energy sources in the industrial sector, and much of the electricity we produce could go into seasonal hydrogen storage facilities underground. Nowadays, however, storage is often distributed and relatively small. It will need to grow in line with renewable energy capacity and grid expansions.

And green hydrogen?

We will need large quantities of hydrogen to, for example, decarbonize the industrial sector. This will lead to two competing uses for clean power because you can either make green hydrogen from that electricity or sell the power on the exchange. The hydrogen industry, however, needs to see significant progress now and not in a few years if Germany is to become climate neutral by 2050, as stipulated in the federal renewable energy law. If we cannot produce enough hydrogen from clean power, we will have to accept that some of it will come from non-renewable sources, as in the case of blue hydrogen that is made from natural gas using CCS. And demand is huge so imports will play a crucial role as well. In that context, I believe we are about to witness the emergence of a new global market.

In summer, when the German government presented its new hydrogen strategy, the industry said it would have liked to see more than 5 gigawatts of electrolyzer capacity be put up by 2030. Do you agree?

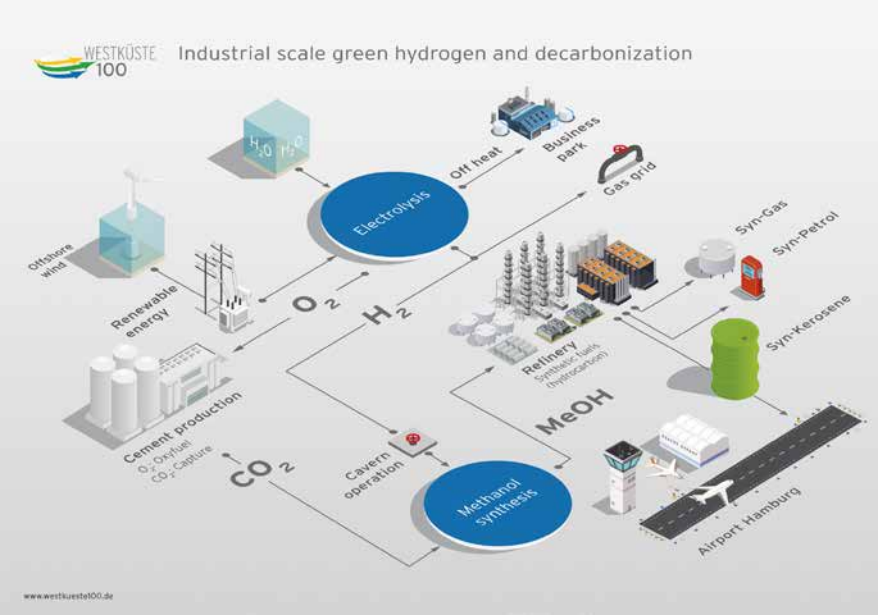
This capacity alone will not be enough, that much is clear, even today. Unfortunately, there is that clash again over who gets the renewable electricity we have. Criticizing blue hydrogen because of its natural gas source will carry the debate about fossil fuel use over to the hydrogen sector, where it serves no purpose. We should rather be consistent in our argument and price hydrogen production according to its carbon footprint.

During Germany's EU council presidency, the gas will certainly be part of the agenda and justifiably so. Hydrogen has long ceased to be a local niche market and could be a big help in reviving the economy post Covid-19. ||

Category: Energy storage | **Authors:** Michael Berger, Dirk Burmeister, Martin Eckhard

GREEN HYDROGEN FOR INDUSTRY

WESTKÜSTE100 launched in German Heide region



Sandwiched between the North and Baltic seas, Schleswig-Holstein is considered to have great potential for generating clean wind energy. Boasting an installed turbine capacity of around 6.7 gigawatts onshore and 1.8 gigawatts offshore, and a nearly 37 percent renewable energy share in total final consumption (122 percent in gross electricity use), Germany's northernmost state is well above the national average. Its 2025 aim is to have renewables contribute up to 65 percent to state-wide energy generation. And by 2050, the North Sea and its coastal areas could be home to Europe's largest clean energy system – ideal prospects for kicking off a real hydrogen economy.

The Heide region's natural features, strong winds and underground caverns, and an innovative business alliance form the basis for the production and use of green hydrogen as part of WESTKÜSTE100 and its follow-on projects. The key aims of WESTKÜSTE100 are to install and operate a 30-megawatt electrolyzer to produce green hydrogen from renewables, prepare an underground storage cavern, and put up a grid for delivering the gas.

The project takes a holistic approach to energy generation. This means that it will use the oxygen released by electrolysis to generate, via combustion processes at a cement factory in Lägerdorf, highly pure carbon dioxide, a raw material for basic chemicals and synthetic fuels. To this end, the project members will investigate how to synthesize green methanol from green hydrogen and the cement works' green carbon dioxide.

The goal of WESTKÜSTE100 is to link three electrolysis products – hydrogen, oxygen and waste heat – via several side pathways and branches with the end of the production chain at e-fuels. As a result, stakeholders will need to find the most suitable methods for handling the technical and business aspects of these material flows while factoring in local conditions. The project consortium thus decided that it will also develop sustainable operating systems and business models for value chain components in order to address the chicken-and-egg dilemma faced by those introducing new technologies to the market.

A separate work package will cover socio-economic questions related to transformative changes in society and give recommendations on regulatory improvements. This is necessary because the success of green hydrogen production in Germany will depend on whether the technology grows into a social mainstay and can be operated under a sensible legal framework. Another key research task will be to draw on the results of plant operation for drafting a plan that can be used to scale the 30-megawatt system to 700 megawatts to make all of the cement works' processes more eco-friendly.

On Aug. 1, the German economy and energy ministry approved the grant request by the project partners after a thorough yet speedy consultation process. WESTKÜSTE100 is scheduled to run for five years. In addition to EUR 30 million in public incentives, the partners will provide approximately EUR 53 million in funds. Work has already started following the rapid creation of an organizational structure.

FEATURES WESTKÜSTE100 is part of ENTREE100, which envisions an area powered entirely by renewables. The northern German Heide region's development agency has spent 10 years to get this venture off the ground. It will now gradually implement several measures to bring Heide closer to its zero-carbon goals. Key objectives are to have an entire city block run on clean energy, through QUARREE100, synthesize kerosene, via KEROSyN100, create a primary control center, as part of MESH100, and support these efforts by conducting research on power-to-x projects ranging from grid integration to building systems, during CAMPUS100. Other ideas, such as creating a power-to-x business park to establish a frequent technology and knowledge transfer between businesses and research institutes, are under development.

Besides local activities, the industrial partners in WESTKÜSTE100 are working on related ventures to prepare for the large-scale application of the project's findings.

The project's second distinctive characteristic is its overall purpose. The 12 consortia chosen to establish living labs for climate change are planning to put up 300 megawatts by 2025, a relatively low figure compared to the government's aim of up to 5 gigawatts of electrolyzer capacity by 2030. This makes it all the more important to lay the groundwork for activities past individual projects. The 30 megawatts could, and will be, only part of the learning curve from 1 megawatt to 1 gigawatt.

WESTKÜSTE100 is mainly focused on the industrial sector, which typically needs a great deal more hydrogen

than other sectors. Each year, the Lägerdorf cement factory emits 1 megaton of carbon dioxide, an amount that can only be processed with the help of a well-organized supply chain ranging from electricity production to storage and transport.

The third distinctive characteristic of WESTKÜSTE100 is its social component, which will require the involvement of especially policymakers, local administrators and association members. Most people living on the western coastline are already acutely aware of the need for more renewable energy thanks to a strong wind energy sector and will hardly view hydrogen as some alien technology. The general mood in the region remains mostly positive as well – despite grid congestion, difficult spatial planning and slowdowns in investment. The prospect for new local jobs continues to be front and center. In 2016, the region additionally drafted a comprehensive plan, or, more specifically, an innovation strategy focused on clean energy. As much of the local land mass is barely above sea level, there is heightened awareness of climate change too.

It is well known that research projects do not always have a positive impact on a region. Thought must be given to the end of funding. For this reason, WESTKÜSTE100 has clearly sketched out long-term scenarios that match the strategies devised at every level of political decision-making. It is all in the project name.

THE NEXT STEPS The launch of this project has given rise to the crucial question of whether politicians and residents really want a hydrogen economy in Germany (see box). In light of the recently published national hydrogen strategy, there is little doubt that the answer to that question has to and will be a resounding Yes. The Covid-19 virus outbreak may have temporarily shifted attention to other topics. However, the new normal is ripe with old issues: We are running out of time to meet our climate goals and we are lagging behind the competition. We need to come up with ingenious solutions to address our problems by the next general election. There is no need for solutions to be as elaborate as possible, but they need to be something that you can rely on.

Paperwork and funding are not the only areas of concern: The technological clock is ticking as well and there will be a great deal of material to move. Production capacity must be raised, people trained and products developed. Our colleague, Professor Volker Quaschning, once compared the task ahead with the moon landing. We need to want it, he said. That we can achieve the transformation is not in doubt. ||

LEGAL HURDLES

The consortium has also identified several legal issues that should be addressed and solved as soon as possible. They involve German laws on renewable energy, electricity taxes and CHP systems and the regulations on grid and concession fees, as well as RED II. The partners agree that it would be more sustainable to stay on the right path early on instead of cross-subsidizing clean hydrogen production. In essence, achieving the climate targets will require investments in the amount of tens of millions of euros.

The project consortium is made up of Raffinerie Heide, Orsted Wind Power Germany, EDF Deutschland, Open Grid Europe, Holcim Deutschland, thyssenkrupp Industrial Solutions, Thüga and Stadtwerke Heide, the Heide Region Development Agency and the Fachhochschule Westküste university of applied sciences.

Reference(s) and source(s)
- www.westkueste100.de/
- www.region-heide.de/
- Energiewende und Klimaschutz in Schleswig-Holstein 2019, Bericht der Landesregierung
- www.rk-westküste.de/themen/projekte/innovationsstrategie-westkueste/

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Category: Energy storage | **Author:** Adenike Bettinger

HYDROGEN ON WADDEN ISLANDS

H2Watt to create hydrogen economy on Ameland and Borkum

Hydrogen is considered crucial to transforming the energy market, especially in the northern parts of Germany and the Netherlands with their growing number of clean energy systems. On two North Sea islands, INTERREG project H2Watt is now investigating the opportunities that a hydrogen infrastructure can provide before it will put ideas into practice. Where will it be eco-friendly to switch to hydrogen? What is the best way to accomplish this? Representing a microcosm of a supply chain, both islands offer the perfect chance to study the real-world use of hydrogen. In late April, H2Watt was kicked off by a week-long virtual event showing video clips created by the project's partners.

In the middle of the Wadden Sea, off the coast of Germany and the Netherlands, lies an archipelago collectively known as the Frisian Islands. Two of these islands, German Borkum in the east and Dutch Ameland in the west, have been pioneering the fight against climate change in the region. Five years ago, Borkum's council presented a list of objectives and targets the island needs to achieve by 2030, including climate neutrality. Equally ambitious plans have been announced on Ameland. Besides pursuing the same 2035 target of net-zero emissions, its council wants Ameland to become a leading supplier of clean technology and stop importing energy from the mainland. Both island governments are partners in the 10-member H2Watt project consortium.

H2WATT The consortium have EUR 2.3 million and 26 months available to analyze the benefits and drawbacks of hydrogen use on the islands. Plans are to study, plan and set up multiple projects to simulate a hydrogen economy (see fig. 1). What kinds of projects will be carried out on which island depends on local conditions. One focus area is the transportation sector.

On both Borkum and Ameland, the consortium members plan to install an electrolyzer and a storage and delivery system. Borkum will also adapt its light rail to run on the gas. Several times a day, this train carries tourists from Borkum's ferry dock to the only town on the island. The schedule changes with the season and while the service is used more frequently in summer, heating the train in winter requires considerably more energy. Other factors that will be evaluated prior to vehicle conversion include typical velocity profiles and running resistance.

In Ameland's case, the focus will be on maritime transportation. The prototype to be designed and built on the is-

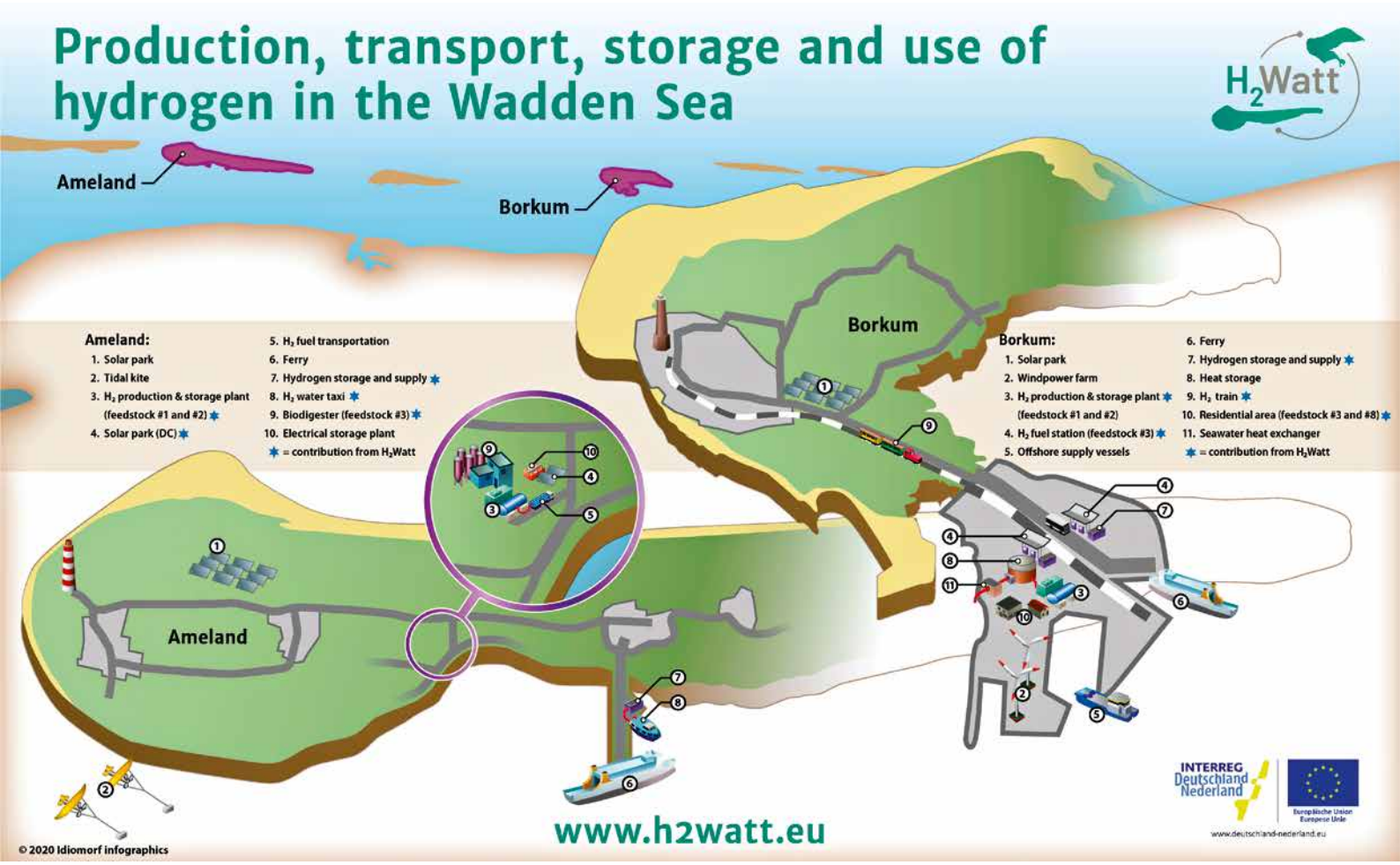

Fig. 1: H2Watt subprojects on the islands (marked with a blue asterisk)

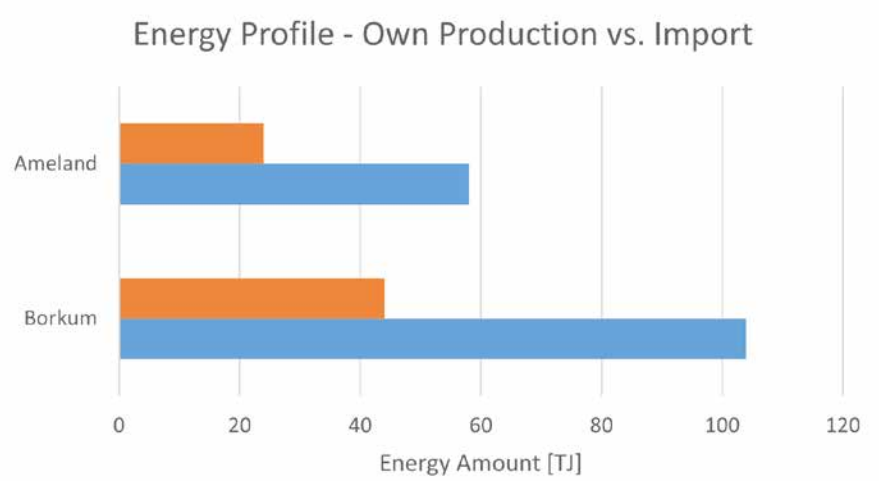

Fig. 2: This chart shows the total amount of energy available on the islands. While blue denotes energy imports, red represents clean energy generation capacity. [Source: H2Watt]

land is a catamaran-type vessel that will be powered by hydrogen or a hydrogen derivative, namely methanol. Eco-friendliness, economics, legal regulations and expenses for converting existing vessel stock will play a crucial role in determining the suitability of both energy carriers.

Borkum will also build an entire quarter for the employees of nearby offshore wind farms. The buildings will be heated using thermal energy from the North Sea and the upstream stage of hydrogen production. Ameland, by contrast, will put up a biogas plant for high-pressure anaerobic digestion and use hydrogen to improve operating efficiency.

ENERGY PROFILE The 2017 and 2018 figures on energy generation and imports indicate that there has been some progress on the clean energy front. But they also show that there is still a lot to do in the short term. This is particularly true for the Netherlands, where people have increasingly relied on natural gas to meet their energy needs. They will now have to rethink their strategy after the government announced that it plans to severely curtail natural gas production starting in 2022 and end it altogether by 2026. On both islands, hydrogen is used to further energy systems integration.

Ameland's council has decided to install a 3-megawatt solar farm in addition to the island's existing 6-megawatt farm as well as several smaller PV systems totaling 1 megawatt. To prevent another volatile energy source from testing the limits of energy management and grid capacity, the new farm will be linked directly to an electrolyzer. A battery pack will serve as temporary storage, eliminating the need for spontaneous start-ups and shutdowns.

Data gathered from monitoring the operation of the 6-megawatt system will be used to estimate the yield of the new farm and calculate optimum battery and electrolyzer capacity. Initial estimates put that capacity at up to 65 tons of hydrogen per year, provided the farm will power only the electrolyzer. The amount of energy produced would be sufficient for some of the planned projects. Nevertheless, meeting most of the island's energy demand would require additional clean energy and hydrogen production capacities.

The renewable energy plants that are up and running on Ameland today meet about 5 percent of total demand on the island, while natural gas provides around 45 percent of supply. Other important energy carriers are fossil fuels such as diesel and gasoline, which contribute 40 percent to the total. The high proportion of fossil fuel is mainly the result of ferry operation, even though there are already several measures in place to lower emissions.

By contrast, Borkum has two wind farms, each with 1.8 megawatts of capacity, and a PV plant with a peak output of 2.6 megawatts. Together, they produce 44 terajoules a year. This is around 25 percent of the electricity, or 5 percent of the energy, needed across the island. In addition, several CHP units inject thermal energy into a district heating system. Their average output is 14.5 terajoules a year. In all, 60 percent of the energy used on Borkum is provided by natural gas imports, while fuels and electricity contribute about 20 percent each. Vehicles require only one-fifth of the total, the biggest consumers being ferries and the vessels carrying crews to the wind farms off Borkum's coast.

CONCLUSION There are many benefits to establishing a hydrogen supply chain on these islands and implementing some supply chain components. First, the islands are (nearly) closed-loop environments, which makes it possible to fully track supply and demand and use the insights gained to construct larger systems elsewhere. Second, the components will create a great deal of value regionally, since local businesses and institutions are welcome to use the H2Watt living labs. Another notable advantage is that the regions discussed in this article are highly dependent on the tourism sector, which provides the perfect opportunity to increase the social acceptance of renewable energy. In essence, they are both showcases for wind, solar and hydrogen energy, highlighting the advantages of those sources in highly recreational and relaxing surroundings. In turn, increased acceptance can later facilitate the addition of clean energy capacity and ensure sustainable climate policy. ||

H2WATT

H2Watt, a German-Dutch collaboration, intends to prepare the economy on both sides of the border for the new challenges and opportunities arising from the integration of hydrogen into the energy system. Several innovative infrastructure, transportation and logistics subprojects on the islands of Ameland and Borkum will demonstrate technology advances and provide knowledge transfer. Daily video clips during the H2Watt Week, held from April 22 through 30, presented the project to the broader public.

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

LOHC – HYDROGEN TRANSPORT MADE EASY

How to use hydrogen, not oil, to power the economy

Fig. 1: Retrieving high-purity hydrogen from an LOHC system [Sources: Allgemeine Services KIT, Bramsiepe]

To achieve climate neutrality by 2050, Germany will need low-emission – if not zero-emission – solutions for transportation and industry. As part of a Kopernikus initiative called P2X, researchers are developing ways to safely store hydrogen in containers in atmospheric conditions. They use liquid organic hydrogen carriers, also known as LOHCs, which bind hydrogen reversibly and allow the subsequent separation of carrier material and gas through a special dehydrogenation unit. It is the only method for efficiently discharging this liquid storage. At the same time, however, the hydrogen needs to be upgraded to fuel cell quality.

Ellen Gapp, a young researcher working at Karlsruher Institut für Technologie, better known as KIT, turns on the faucet. Hydrogen starts immediately flowing from the LOHC pilot system into an aluminum-coated gas sampling bag (see fig. 1). She says both fuel cell buses and passenger cars need high-purity hydrogen. The LOHC color is what makes all the difference: One of the two bottles in front of her contains a clear and transparent liquid, still charged with over 97 percent hydrogen. The content of the other has turned slightly orange, as some of the gas has already been released and the state of charge is down to 80 percent (see fig. 2).

The aim of the Kopernikus' Power-to-X project is to investigate alternative approaches to storing clean power in chemical compounds. In the first project stage, which lasted for three years, the researchers analyzed a wide variety of storage options. This included ways to store electrolytic hydrogen in LOHCs and create synthetic fuels, such as synthetically produced kerosene, diesel, natural gas and gasoline and dimethyl ether, a diesel substitute. Now in its second stage, the project is focused on a more limited number of options, namely LOHCs and synthetic kerosene, diesel and gasoline.

HIGH STORAGE DENSITY The project seems to have been launched at just the right time. LOHCs are a perfect fit for Germany's recently published national hydrogen strategy, considering they make it possible to transport and distribute the gas with ease. Even the EU is starting to take note, having published a "hydrogen strategy for a climate-neutral Europe" in early July, explained Peter Pfeifer, group lead at KIT.

There are good arguments in favor of LOHCs. Not only can they be easily transported inside barrels and canisters but they also require a fueling infrastructure very similar to that of gasoline so they can be sold at gas stations as well. Moreover, taking the fuel system into account, LOHCs have greater volumetric and gravimetric densities than conventional options. The weight of ultra-cold or high-pressure hydrogen and its storage equipment is considerably higher than that of an LOHC stored in a plastic canister.

The above explains why the researchers at KIT are putting so much effort into finding new solutions. And they have help from a whole host of partner organizations, including FAU Erlangen-Nürnberg university, Areva H2Gen, Clariant Produkte, Forschungszentrum Jülich, Framatome, Fraunhofer ISE, Hydrogenious Technologies, Schott and Aachen's RWTH university.

"Thanks to the P2X project, we have already been able to demonstrate that delivering hydrogen stored in LOHCs is more economical than using other methods, even if you transport as little as 60 tons a day to remote locations," said Pfeifer. The findings will be especially helpful to fueling station operators and industrial users, such as glass manufacturers. The latter could use the energy stored in the gas for melting components. "LOHCs are therefore an excellent solution for transitioning from an oil to a hydrogen economy," he added.

HIGH PURITY GUARANTEED The KIT researchers are currently improving dehydrogenation efficiency and hydro-

Fig. 2: Draining LOHCs through two bottles (the differing colors indicate which LOHC is still charged)

gen purity so the gas can be delivered to fueling stations. "If LOHCs need to be discharged in a very short amount of time, you have to make sure that none of the byproducts from releasing hydrogen end up in the tank," explained Pfeifer. He and his team employ a combination of microreactors and membranes to avoid this scenario. "By improving the heat transfer into the microchambers and the mass transfer between the liquid carrier and the solid catalyst, we can speed up the precious metal catalyst reaction that releases the hydrogen."

At the same time, the hydrogen is separated with the help of ultrathin membranes, embedded by the researchers in the microstructures (see fig. 3). This gives an LOHC more time and improved contact with the catalyst, as the large quantity of hydrogen released in production is removed from the reaction channels. "These microreactors and separators have not been developed for demonstration purposes only. They can be scaled up," noted Pfeifer.

Ultimately, the researchers need to stay focused on creating economically viable and competitive products that are at a level with other reactor systems and purification methods. The factors to watch out for when designing new equipment, catalysts and membranes, Pfeifer said, are production costs and durability. "Our job is to come up with an inexpensive manufacturing process, optimally designed microstructures and improved membranes." While the use of palladium film in LOHC systems has been demonstrated, he and his team are still planning to test coated membranes on carriers and 3D-printed microstructures.

These approaches are still in their infancy, Pfeifer explained, but could lead to further improvements. Another aim of the project is thus to scale up and improve methods already in use. However, if there is to be a market for LOHCs, governments will need to keep promoting hydrogen in transportation and other sectors too.

ENERGY LOST DURING HYDROGEN RELEASE The project partners are using dibenzyl toluene, a commonly available heat transfer fluid, as a carrier material. After all, it is only used as a storage medium and can be charged and discharged as long as the associated process creates few or no byproducts. It is also hardly inflammable and classed only as mildly irritating, making it much less dangerous and toxic than gasoline, Pfeifer said.

Hydrogen is released using a solid catalyst that contains platinum. The reaction requires heat. Pfeifer said that in all, separating the hydrogen molecules consumes around 25 percent of the energy stored in the gas. Production will be more or less efficient depending on whether waste heat or even clean heat can be utilized as well.

So far, the KIT researchers have only created a lab-scale prototype that releases few liters of hydrogen per hour (see fig. 4). The unit consists of a single microstructure layer forcing the LOHC to move in a circular pattern from the center to the edge of the reactor. This approach increases the flow speed of the reaction mixture inside the microstructure to an insignificant degree, as it provides ever more space for the hydrogen split off in the process. The membrane is part of a separate component. "We have run this combination successfully for several hundred hours. We now want to scale up the system by adding several microstructure layers to a single component," said Pfeifer.

This concept is known in the microreactor industry as numbering-up. Lastly, the researchers will connect larger reactors and membranes in series to produce large amounts of hydrogen in little time and, if possible, allow the LOHC to be fully discharged.

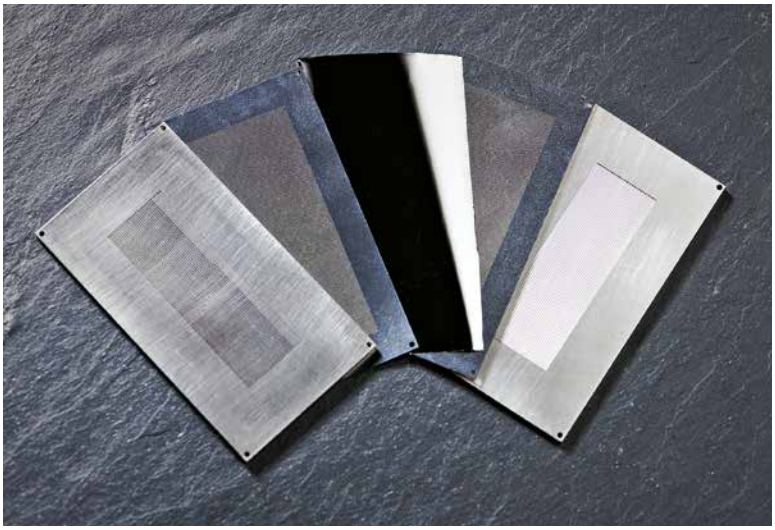

Fig. 3: Membrane structure for purifying hydrogen

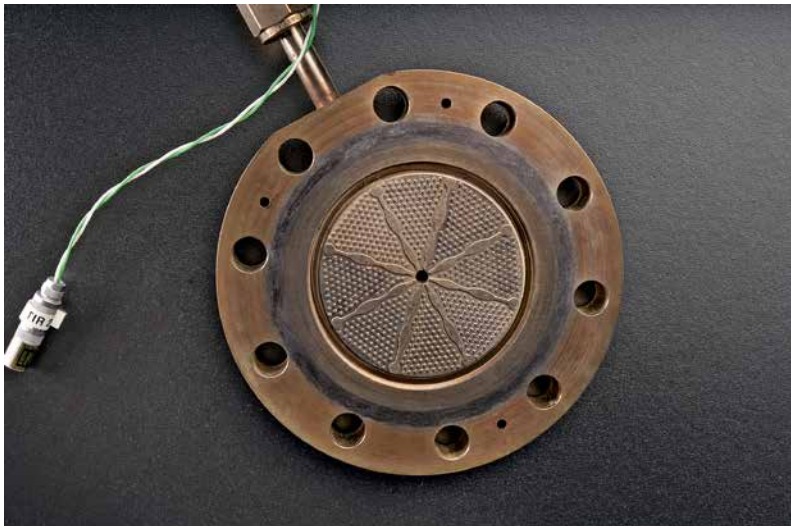

Fig. 4: Look inside a radial flow microreactor for releasing hydrogen from an LOHC

GUARANTEEING FUEL CELL QUALITY A German DIN standard states the level of quality needed to supply hydrogen to fuel cells downstream. But how can purity be guaranteed? "The gas separated by the membrane is first split into atomic hydrogen on the surface of the palladium before being transported through its lattice," explained Pfeifer. Unless, of course, the palladium has a defect, other atoms are too big to pass through that lattice, he added.

What is important, he said, is that there is a partial pressure difference between the supply, or retentate, side of the membrane and the permeate side where the pure hydrogen is located: "Otherwise, the material will not pass through the membrane." The substances separated by the lab-scale system are volatile compounds from LOHC production or from a side reaction of LOHC decomposition. This includes aromatic compounds, such as toluene and carbon monoxide. He added: "To achieve high hydrogen purity, we slightly increase the pressure by around 2 to 4 bars above ambient when producing the gas in the reactor before bringing the hydrogen into contact with the metallic palladium membrane." ||

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

WHAT MAKES US PROUD

eFarm project started in Bosbüll

Fig. 1: Schleswig-Holstein's environment minister J. P. Albrecht, GP Joule's H. Gärtner and O. Petersen, county commissioner F. Lorenzen, member of parliament A. Damerow and German transportation minister A. Scheuer (from left)

To get eFarm underway, German transportation minister Andreas Scheuer and many of the project's partners came to Bosbüll on July 7 despite dreary weather. "Germany's largest hydrogen transportation project," as GP Joule calls it, involves building two fueling stations, two fuel cell buses, seven tanks to deliver gas by truck, and five 225-kilowatt electrolyzers, each of which will be put up at a different site.

It was a gray and stormy day, typical of northern Germany. But that did little to dampen the mood among attendees as the prominent guests in their midst cut the ribbon on the eFarm project (see fig. 1). Surrounded by wind turbines, German transportation minister Andreas Scheuer said that "this project is the perfect example of how to implement Germany's hydrogen strategy, from using wind energy for clean energy generation to broadly expanding the needed infrastructure. This is how we will get clean, eco-friendly transportation. […] Some say we will do this with a bang; I say it is going to be a German turbo."

EUR 16 million will be poured into the project, covering half of its costs. Hopes are that the venture will become a beacon for all of Germany and show how excess wind energy can be used in zero-emission transportation while creating trust among those unsure of whether wind turbines and hydrogen power plants are a good idea.

FARMER TURNED HYDROGEN PRODUCER The developer's name is John-Heinrich "Jonny" Ingwersen, the chief executive of eFarming. Until 2018, his firm was known as GPJ Energiepark 103, set up in 2017 (see H2-international, January 2019). Ingwersen, a farmer by trade, was and still is the manager of several community wind and solar farms in Bosbüll. Throughout the region, he is seen as a pioneer, considering his first ventures into the renewable energy sector date to 1993. He told H2-international that the current project "is something we are pretty proud of."

Among GP Joule's partners are several wind farm operators. They hope that the project will allow them to keep on the turbines that will soon drop out of Germany's clean energy incentive program. There has been enormous interest in the new technology, with over a hundred people having stated their intention to buy an FCEV.

The production capacity of the H-Tec ME 100/350 PEM electrolyzer that will be run in Bosbüll is 100 kilograms of hydrogen a day. The waste energy generated by the system will be used to heat nearby buildings, which will raise efficiency to more than 95 percent. The hydrogen produced this way will be transported to two fueling stations, one in Niebüll and another in Husum. Their completion, originally scheduled for the second quarter, has been postponed. The two fuel cell buses will also be delivered later than expected, presumably in September. ||

Category: Energy storage | **Authors:** Marcus Vogt, Felix Heubner, Thomas Weißgärber, Lars Röntzsch

CLEAN HYDROGEN ON DEMAND

Controlled release of an all-in-one energy source

A few years ago, research at Dresden-based Fraunhofer IFAM's Hydrogen Technologies department led to the development of a paste-like substance that can provide on-demand energy under well-controllable conditions for multiple kinds of fuel cell applications. In partnership with businesses and other research institutes, IFAM has since launched several projects to demonstrate that this substance called PowerPaste, the main ingredient of which is magnesium hydride, is both safe and easy to handle. The institute is also currently building a system to produce multiple tons of PowerPaste a year for use in field tests.

There already are well-established methods for producing hydrogen via hydrolysis, for example, by having water react with either calcium hydride (CaH_2) or sodium borohydride ($NaBH_4$). Around four years ago, H2-international first reported on PowerPaste (see H2-international, January 2017), a storage compound IFAM created based on magnesium hydride (MgH_2). [Teg14]

The principle behind this kind of hydrolysis is always the same. When a metal hydride (MH_n) reacts with water (H_2O), it forms hydrogen and a metal hydride oxide:

$$MH_n + n\,H_2O \rightarrow n\,H_2 + M(OH)_n$$

In the case of magnesium hydride, the equation is as follows:

$$MgH_2 + 2\,H_2O \rightarrow 2\,H_2 + Mg(OH)_2$$

Since this technique makes use of the water available during the reaction, it generates twice as much hydrogen as thermal decomposition, with half of that amount coming from the hydride. As a result, the method gives off much less waste heat than other production techniques during which a metal or a metal alloy reacts with water (or an acid).

The reaction, which takes place inside a hydrogen generator, is exothermic, which removes the need for external heat sources. The thermal energy that it generates can be used to heat buildings, among other things. Hydrolysis produces about as much energy as PEMs give off in the form of waste heat, i.e., approximately 1 kilowatt of heat per kilowatt of electrical output, at a temperature of around 80 °C. The most sensible course of action would thus be to devise a plan for the shared thermal management of both the fuel cell and the hydrolysis reactor.

When it comes to hydrolysis, magnesium hydride has several advantages over other materials:

- Its specific energy is 6.1 kWh per kilogram, PowerPaste's being 3.8 kWh. Even when factoring in fuel cell losses, the material provides much more energy than today's batteries, the gravimetric energy density of which is around 0.2 kWh per kilogram.
- The magnesium to make magnesium hydride and PowerPaste is already available on the market in large quantities, at a raw material price of around EUR 1.70 a kilogram. Magnesium is also not a rare element but the third-most common in the earth's crust.
- According to IFAM estimates, even magnesium produced by conventional means will, over the longer term, lower the price of making PowerPaste to around EUR 2 to EUR 3 a kilogram. The levelized cost will be around EUR 20 to EUR 30 per kilogram at the point of use, including all expenditures for infrastructure and distribution. This reflects the full cost of production as opposed to artificial prices for hydrogen at fueling stations.

The above means that in many markets, including for UPS and light electric vehicles, the total cost of ownership will already be much lower than if the project involved putting up expensive hydrogen infrastructure or renting gas cylinders.

The growing use of magnesium in light vehicle construction (CAGR: around 5 percent) also makes it likely

Table 1: Material and energy needed to produce 1 kilogram of hydrogen via MgH_2

MATERIAL	QTY.	EDUCTS	PRODUCTION METHOD	ENERGY BALANCE	EFFICIENCY
Hydrogen (input)	0.5 kg	Water	Alkaline/PEM electrolysis	25 kWh	80%
Magnesium chloride (no water)	23.6 kg	Magnesium hydroxide, hydrogen chloride	Hydrochlorination (Dow process)	4 kWh	75%
Magnesium	6 kg	Magnesium chloride (no water)	Alcan process	63 kWh	59%
Chlorine	17.6 kg	Magnesium chloride (no water)	Alcan process versus membrane process	–42 kWh	n/a
Magnesium hydride	6.5 kg	Magnesium	Goldschmidt's technique [Kno90]	0 kWh	n/a
Hydrogen (output)	1 kg	Magnesium hydride	Hydrolysis	0 kWh	n/a
			Total	50 kWh (80%)	

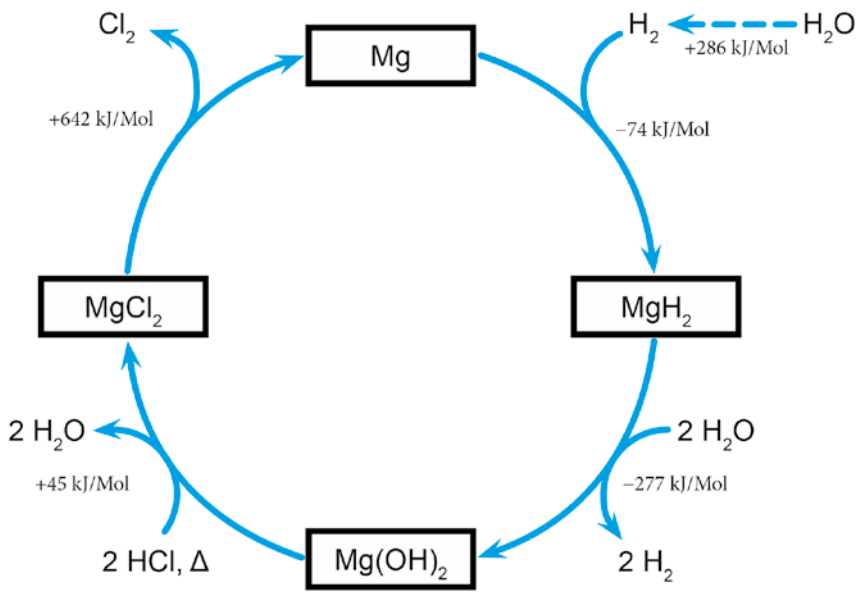

Fig. 1: Hydrogen production cycle based on magnesium, magnesium hydride and hydrolysis

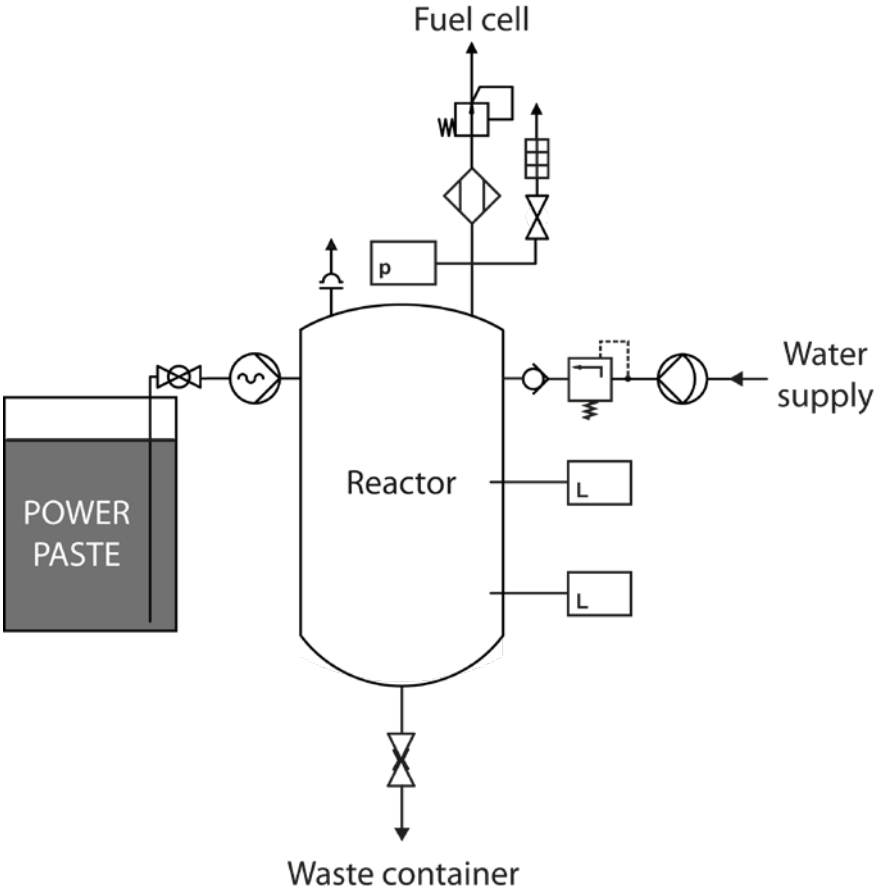

Fig. 2: Schematic diagram of a hydrogen generator running on PowerPaste. Left: PowerPaste cartridge or storage container. Middle: Reaction chamber equipped with fuel sensors and connected to (electronic and mechanical) relief valves, a pressure transmitter, a pre-drier and a pressure reducer. Right: Water pump including a pressurizer and a check valve. Bottom: Pinch valve and waste container

that magnesium extraction will undergo significant changes in the next 10 years and become more carbon-neutral, energy-efficient and inexpensive. [Ros20]

A technique based on the electrolysis of molten compounds could then be employed both to produce magnesium and to help set up a closed hydrogen production cycle based on magnesium and magnesium hydride.

Creating this kind of production cycle would be possible even today. Using conventional industrial manufacturing techniques, each subsequent cycle could realistically retain around 80 percent of the energy from the prior one. This holds true even if waste heat is not included in the calculation but the chlorine produced is (see fig. 1 and table 1). The latter would allow the replacement of older, less efficient chlorine factories that use the chloralkali process. An even higher amount of energy could be carried over from one cycle to the next if there is an increase in magnesium production efficiency as achieved in some laboratory experiments, where efficiency hit 89 percent.

PowerPaste, a mixture of magnesium hydride, a metal salt catalyst and an ester acting as a suspending agent [Teg14, Teg17], comes with multiple benefits:

From a chemical and process standpoint, the paste offers improved reaction speed, i.e., the reaction is neither too fast nor too slow (see also image on p. 3). Additionally, the solubility of the ester ensures that water covers as much of the magnesium hydride as possible. The ester can also serve as a wetting agent as early as the paste-making stage in, for example, a stirred media mill to provide greater process scalability while lowering costs and improving efficiency. This would also increase process safety by avoiding dust formation.

Additionally, a paste-like substance is much easier to feed into a hydrogen generator than a solid compound, particularly because the water entering the generator creates a humid atmosphere inside the reaction chamber. For example, in contrast to solid magnesium hydride, PowerPaste can be fed into the device by applying pressure to a piston, a tube or a vacuum bag or by pumping it into the generator.

Likewise, compared to other hydrolysis solutions, PowerPaste is easier to handle in conjunction with key process components such as shutoff and check valves. The reaction chamber contains only as much paste, and thus magnesium hydride, as is required to produce hydrogen in a fuel cell. In contrast to hydrolysis methods that can only be controlled by adding water and/or removing heat, PowerPaste allows for fast start-ups and complete shutdowns while providing inherently safe hydrogen generation. In principle, every device that uses PowerPaste for hydrolysis is made up of the same components.

By applying pressure or employing a suitable pump unit, PowerPaste is transferred from a storage container to the reaction chamber, where it comes

Fig. 3: Compact and portable 100-watt power generator that uses hydrolysis to generate electricity [Source of all images: IFAM]

into contact with a prespecified amount of water let into the chamber. Reacted material then gathers at the bottom of the device, from where it is removed in intervals through, for example, a pinch valve. The reaction is controlled by varying paste and water input.

In partnership with industrial companies and other research organizations, IFAM is currently developing several demonstrators to produce hydrogen for stationary, portable and vehicle applications. The systems' power output ranges from 50 watts to 1,000 watts. In all cases, the hydrogen generators were or are connected to PEM fuel cells of matching capacity. Research now focuses on ways to improve hydrolysis output and optimize generator weight for vehicle use, to achieve the highest possible specific energy output across an entire system.

Furthermore, IFAM is overseeing the construction of the world's first PowerPaste production plant at Fraunhofer ZESS in Braunschweig to ensure that enough paste will be available for current and future projects and field tests.

The system will consist of the following components:

1. A reactor that hydrates magnesium powder to make magnesium hydride. Includes stirrer.
2. Stirred media mill to mix and disperse magnesium hydride powder, metal salt and ester in a non-humid environment.
3. Semi-automated filling machine to fill containers, such as cartridges or canisters, with PowerPaste.

Running at full capacity, the system will be able to produce up to four tons of the substance in 2021 (corresponds to 4,300 normal cubic meters of hydrogen through hydrolysis). From a technical and business standpoint, it will allow IFAM to analyze economies of scale and provide reliable estimates that could be of use in follow-on projects aimed at commercializing the product.

As far as funding goes, some of the research on PowerPaste is being financially supported by the German state of North Rhine-Westphalia and the federal education ministry BMBF's H2PROGRESS (03ZZ0754A) project. ||

Reference(s)

[Kno90] Knott, W., Klein, K.-D., & Koerner, G. (1990). *Verfahren zur Herstellung aktiver, reversibel H2 aufnehmender Magnesiumhydrid-Magnesium-Wasserstoff-Speichersysteme.* Patent no. EP0490156B1.

[Ros20] Roskill. (2020). *Magnesium Metal. Outlook to 2030, 13th Edition.* ISBN 978 1 910922 14 9.

[Teg14] Tegel, M., Röntzsch, L., & Kieback, B. (2014). *Composite material for hydrolytically generating hydrogen, device for hydrolytically generating hydrogen, method for generating hydrogen, device for generating electric energy, and possible applications.* Patent nos. EP3154900B1 and US10239753B2.

[Teg17] Tegel, M., Schöne, S., Kieback, B., & Röntzsch, L. (2017). An efficient hydrolysis of MgH_2-based materials. *International Journal of Hydrogen Energy,* 42. 2167–2176.

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COMPETING FOR CUSTOMERS IN THE COMMERCIAL VEHICLE MARKET

Fuel cells to lower emissions from trucks

Fig. 1: Scania's fuel cell truck running at Asko [Source: Scania]

The debate about climate change and energy carriers is putting an ever-brighter spotlight on the commercial vehicle industry. A widely accepted fact these days is that we need to lower emissions from buses and trucks, and hydrogen offers us a great chance to bring about these reductions. A good example is Switzerland, where some weeks ago, Hyundai started building the world's first fleet of fuel cell HDVs. Other automakers intend to follow suit, though they have yet to deliver any trucks to customers. Still, the race for market share is on.

So far, Hyundai has been the uncontested leader in the market. In July, the South Korean automaker shipped its first 10 XCIENT Fuel Cell trucks (see H2-internationa, February 2020), which will reportedly be put in service this September. By year's end, the fleet is set to grow to 50 units. In 2019, Hyundai and H2 Energy formed a joint venture called Hyundai Hydrogen Mobility, with the aim of building 1,600 XCIENTs by 2025.

In February, the automaker then placed an order with French equipment supplier Faurecia. The 10,000 hydrogen fuel tanks requested by Hyundai are currently being assembled at the supplier's center of excellence in Bavans, France.

The fuel is coming from the Gösgen hydropower plant. In June, half a year behind schedule, Hydrospider, a joint venture created by electricity producer Alpiq and H2 Energy and supported by Linde, started up a 2-megawatt electrolyzer at the plant to produce clean hydrogen. This hydrogen is subsequently transported in swap bodies, each with a capacity of 350 kilograms, to a recently opened Avia fueling station in St. Gallen. The gas is to displace around 300 tons of diesel fuel, enough to power 40 to 50 trucks or 1,700 cars for an entire year. It took around four years before the station could be brought online, said Martin Osterwalder, business development manager at Osterwalder St. Gallen.

It is Switzerland's second fueling station, Coop's in Hunzenschwil being the first. In all, six publicly accessible sites will be put up in the country by the end of this year. Plans are to install the remaining four in Rümlang, Zofingen, Bern and Crissier. Hydrospider said that the Avia station, built by compressor maker Maximator, will provide only fully renewable gas.

At present, the second target market for Hyundai's heavy-duty FCEVs is Gwangyang in South Korea. Reportedly, Hyundai will deliver two fuel cell trucks to Yeosu Gwangyang Port Corporation by 2023 and possibly another 10 thereafter.

"When it comes to establishing a fuel cell market, Switzerland's private sector is truly in a class of its own. Some believed a successful hydrogen industry was nothing more than wishful thinking. And yet, Switzerland is proving to the naysayers that you can fuel both commercial vehicles and passenger cars with clean gas and push carbon dioxide emissions down to zero. The country is witnessing the emergence of an economically viable sector that will help prevent a great deal of further environmental damage. And customers can expect a solution that will not disappoint."

Bertrand Piccard, adventurer

VIABILITY THANKS TO TOLL ROAD SYSTEM Switzerland's toll road system is what makes operating fuel cell HDVs and hydrogen stations economically viable. The toll depends on a vehicle's emission class, i.e., Euro 1 through Euro 6, and ranges from EUR 2.15 to EUR 2.92 per ton and kilometer. For example, driving about 310 miles (500 kilometers) in a Euro 3 truck costs EUR 157. If the drive through the Alpine country is not a one-off but occurs regularly, the amount truck owners will have to fork over can easily run up to thousands of euros. But there is no toll on zero-emission vehicles, and the amount saved is enough to offset the higher price tag of FCEVs in a reasonable amount of time.

Early this year, Austria took a similar approach, tightening regulations about what HDVs can and cannot drive on the country's A12 expressway in northern Tyrol. The only trucks exempt from these rules are Euro 6 or electric, i.e., are powered by batteries or fuel cells.

By contrast, Germany's toll collection system provides little incentive for change. Still, more and more people are calling for either higher carbon prices or a toll system that would have a similar impact on emissions reduction as the one that Switzerland implemented nearly 20 years ago. But in Germany, low taxes continue to favor diesel. So far, the government's only action has been to extend the toll exemption for heavy-duty vehicles running on CNG, LNG (liquefied natural gas stored at -160 °C) and electricity (batteries and fuel cells) until 2023. Introduced in 2019, the exemption was originally set to expire at the end of this year. Regardless, compared to Switzerland, the money it saves truck owners is a lot less.

The dilemma numerous fleet operators and forwarders are faced with right now is that they do not know which truck engine to pick. There are 300 LNG fueling stations in Europe. In Germany, their number will reportedly grow from 38 to 50 by year's end. The following months will show if the toll exemption that the gas industry had been calling for and that has since been approved by the government will lead to an increase in natural gas HDVs and fueling stations or if truck operators will ditch their diesel vehicles and go electric. Timm Kehler, chairman of the German Zukunft Erdgas industry association, said that "following decades of stagnation," the exemption will "boost sales of practical, climate-friendly solutions in the HDV market. This will also benefit residents, as natural gas-powered trucks are much quieter."

Reinhard Zirpel, the president of international motor vehicle organization VDIK, said: "The German government's decision to extend the tax exemption will be reassuring to transportation companies that use eco-friendly gas-powered trucks. Natural gas and biomethane are low-emission alternatives to diesel, and gas-driven commercial vehicles are both technologically advanced enough and ready for the mass market." He added that compared to diesel, natural gas emits around 20 percent fewer carbon dioxide emissions, while using pure biomethane could reduce them by up to 90 percent.

Since July 2018, a government incentive program for energy-efficient or low-carbon heavy-duty trucks, or both, has helped get 2,363 LNG, 498 CNG and 71 electric trucks on the road. "The flood of applications shows that a growing number of logistics companies are acutely aware of their responsibility and want to do more to protect the environment," said Kehler.

TRUCK MAKERS UNDER PRESSURE What is happening in Switzerland has set a high bar for other countries around the world. It is also a major reason why businesses such as Nikola (see p. 36) and Hyzon (see p. 33) are attracting as much interest as never before. At the same time, the trend toward electric vehicles is putting pressure on conventional automakers like Daimler. And on top of that, the European Union has set strict targets for emissions from several parts of the economy, the truck sector included.

Its most recent piece of legislation requires that automakers reduce the emissions from new vehicles sold in the Union by on average 15 percent starting in 2025 and 30 percent in 2030. "Anyone missing those targets will have to pay hundreds of millions in fines," noted Bernd Heid, senior partner at McKinsey. The only benefit automakers have at the moment is that they can credit zero-emission vehicles sold since this July against those targets and count each vehicle twice. Manfred Kuchlmayr, of Iveco, said during a DVGW association event in March: "In light of the hefty fines, reaching the HDV targets is not optional."

Tobias Block, clean fuels coordinator at German auto industry association VDA, said that in contrast to the car market, HDV manufacturers will have time until 2025 before fines are imposed. This also means that they may not see a financial incentive in changing business models prior to the late 2020s . His observations are in line with statements by >>

several European automakers that they will not be able to produce enough zero-emission units before the end of this decade.

Nevertheless, some are already preparing to compete in a changing market. In spring, Daimler not only entered into a partnership with Volvo to develop fuel cell systems for the truck market, but it also founded Daimler Truck Fuel Cell (see H2-international, August 2020). In July, the automaker then announced plans for building a fuel cell factory in Esslingen's Pliensauvorstadt district.

Toyota has responded to the changing winds in the industry by partnering with Chinese firms FAW, Dongfeng, GAC, BAIC and SinoHytec to set up a joint venture called United Fuel Cell System R&D, with the aim of making fuel cell systems for commercial vehicles. The Japanese manufacturer will initially invest EUR 42 million in the venture, of which it owns 65 percent.

In collaboration with its subsidiary Hino Motors, the automaker has also moved forward with the development of the Hino Profia. The companies' joint efforts to optimize this heavy-duty vehicle for fuel cell use have resulted in a considerably lighter truck. It is powered by two next-generation Mirai fuel cell stacks, which give the truck a range of 373 miles (600 kilometers). Last but not least, Toyota set up a partnership with US truck maker Kenworth to bring the third generation of a heavy-duty FCEV to the North American market.

Furthermore, Honda announced that it struck a two-year deal with Isuzu to investigate possible uses for fuel cell technology in commercial vehicles. Like Toyota, it already has an FCEV on offer.

Scania's fuel cell endeavor is starting to take shape as well. Since the beginning of this year, four of its FCEVs have been tested in a pilot project at Norwegian food chain Asko in Trondheim (see fig. 1). Among these prototypes is a 27-ton HDV consisting of a triple-axle 6x2 chassis and a box body. The truck's internal combustion engine was replaced with a 290-kilowatt electric motor driven by a 90-kilowatt fuel cell and a 56-kilowatt-hour lithium-ion battery. Its tank can hold 33 kilograms of 350-bar hydrogen, providing the truck with a range of 249 to 311 miles (400 to 500 kilometers).

A relatively new market entrant is Lightning Systems, a US powertrain manufacturer based in Loveland, Colorado. In February, the company announced that it will offer a fuel cell truck system designed in collaboration with Plug Power. Plug previously said it was planning to add a 125-kilowatt fuel cell to its product portfolio for exactly that use case. Plug's chief executive, Andy Marsh, said the business is "thrilled to be partnering with Lightning Systems to expand our ProGen offerings with a new Class 6 trucking solution." General Motors 6500XD trucks outfitted with the new technology will reportedly come to market this fall. Their 20-kilogram hydrogen tanks will provide a range of around 200 miles (320 kilometers). An upgrade could push that number to almost 400 miles (640 kilometers) on a single tank.

A HYDROGEN CORRIDOR FOR LOGISTICS COMPANIES In July, essentially in response to the latest developments, several European companies joined forces to launch a business initiative that will support the establishment of a fueling infrastructure for commercial vehicles along main traffic routes. The idea came from Rotterdam's port operator. Together with industrial gas producer Air Liquide, it intends to put up a fueling station network in the Netherlands, Belgium and Germany with the capacity to fill up around 1,000 hydrogen-powered trucks regularly by 2025. Other project partners include multiple HDV manufacturers, such as VDL Group, Iveco and Nikola, and logistics companies.

Allard Castelein, the port operator's chief executive, noted that "each coalition partner brings different strengths to the table. Pooling those strengths can give fresh impetus to the market for zero-emission road vehicles and help local, national and EU authorities meet their ambitious aims. It is our responsibility as Europe's biggest port operator to make that happen."

As early as the beginning of this year, H2 Mobility's chief executive, Nikolas Iwan, said that his company will start to turn its focus on installing or upgrading fueling stations for commercial vehicles. He explained that small fueling sites are not viable enough and will have trouble dispensing 8 kilograms in one go, the usual quantity needed for a heavy-duty truck. However, medium-size locations that have been designed to refuel commercial vehicles could be profitable, he said, as long as there is a steady revenue flow from a sufficient number of customers.

Asked by H2-international how long he thinks H2 Mobility could continue, he replied that current plans include fueling station additions until 2027. Germany's national competition authority, he added, merely stated that H2 Mobility must remain a non-profit but had not set a deadline for the company's infrastructure expansions. ||

HYUNDAI INVESTS IN LOHC

In early June, Hyundai said it had invested in Hydrogenious LOHC Technologies the previous month, with the aim of setting up a far-reaching collaboration that will advance the development of liquid organic hydrogen carriers (see p. 24) and create business models for LOHC storage and distribution at fueling stations. Yunseong Hwang, vice president of Hyundai's Open Innovation Investment Group, explained that "we entered into this partnership to demonstrate the benefits of LOHC to both the government and consumers. We intend to establish LOHC as an integral energy vector of South Korea's plans to build a national hydrogen infrastructure." In the longer term, the automaker also wants to implement its vision in Europe.

Fig. 2: Even though this HDC-6 Neptune concept study netted Hyundai an award for best design, it will probably never be brought to market. [Source: Hyundai]

In late July, Hyundai then received the Future Mobility of the Year Award for its HDC-6 Neptune. The award, which the KAIST university presented to the automaker in Daejeon, South Korea, honors groundbreaking concept vehicles that could meet future transportation needs.

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

HYZON PARTNERS WITH HOLTHAUSEN

A mass market for fuel cell trucks by 2025

Fig. 1: Hyzon wants to be among the first to bring a large number of heavy-duty FCEVs to market. [Source: Hyzon]

Hyzon Motors attracted a great deal of coverage when it announced its intention to build 1,000 fuel cell buses, a move that could revolutionize the transportation industry (see H2-international, August 2020). But the start-up business is also eager to see both heavy-duty and pickup trucks run on hydrogen. To promote its fuel cell vehicles, it recently published several images depicting futuristic truck designs (see fig. 1).

n early 2020, the New York-based company said that it will reopen General Motors' former fuel cell facility in Rochester to produce systems for both buses and trucks. The 100-kilowatt VL III-100 PEMFCs (comprising 372 individual cells) that it wants to integrate into the systems will reportedly be shipped from Singapore by Horizon, its major shareholder. Initially, the focus will be on making fuel cell buses and heavy-duty trucks, Hyzon said, with the first trucks to be delivered before the end of this year. In 2021, the company then wants to expand its product portfolio by offering delivery vans and small buses that can carry up to 15 passengers. A 4WD pickup model could follow in 2022 or 2023. Other plans include manufacturing a regular four-seat passenger vehicle for ride-sharing. Each of these vehicles will have a range of around 373 miles (600 kilometers).

Hyzon said that it is already accepting preorders, at a EUR 10,000 discount, though the company has yet to state how much the vehicles will cost. It only remarked that it will offer all-inclusive leases and expects to deliver 2,000 units in the first three years after launch, aiming for a mass market for fuel cell trucks by 2025.

HOLTHAUSEN TO SERVE HYZON CUSTOMERS IN EUROPE

In July, news broke that Hyzon will set up its European office in the Dutch city of Groningen, where it founded a subsidiary, Hyzon Motors Europe, in partnership with Holthausen Clean Technology. The subsidiary will convert heavy-duty trucks, presumably DAF XF Space Cab tractor units, to run on fuel cells.

Holthausen Clean Technology had already made headlines two years ago when it changed a Tesla into an FCEV, renaming it H2esla (see H2-international, May 2018). Driven by Max Holthausen, the vehicle later participated in f-cell's Hydrogen Rallye in September 2019 (see H2-international, February 2020). Hyzon has since invested in the Dutch fuel cell pioneer.

One thing is for sure: Hyzon is confident of success. Its announcements are studded with superlatives, like best-in-class, and promises of a sharp competitive edge, among other things. In a recent press release, the company wrote that its "aggressive commercialization plans will support growing investment in hydrogen infrastructure in the USA, Australia, the EU and other jurisdictions." ||

"A European pioneer in the fuel cell truck market, we have years of experience in making FCEVs. We are honored to be joining forces with Hyzon to bring customers the most advanced technology."

Max and Carl Holthausen, managing directors of Holthausen

"We have seen incredible growth in Asia in recent years at Horizon, and now with the experience gained from hundreds of trucks in commercial service, we aim to bring our technology to the roads of the world.

"Our fuel cell systems have already proven themselves, and we see an opportunity to help the world decarbonize transportation much faster than people currently believe is possible."

George Gu, chairman of Horizon Fuel Cell Technologies and executive chair of Hyzon Motors

"We have developed fuel cells which have a significant advantage in whole-of-life cost and combining this with the imminent availability of very competitive large-scale green (renewable or sustainable) hydrogen in a number of countries, we are rapidly closing in on a total cost of ownership lower than diesel-based fleets."

Craig Knight, executive director of Horizon Fuel Cell Technologies and CEO of Hyzon Motors

"Having a product which has such great benefits for the environment, we take it as our responsibility to maximize its impact, and the operating experience already gained gives us great confidence in deploying vehicles in many countries and to support infrastructure investments in hydrogen availability.

"We need to work hard to deliver meaningful quantities of vehicles right now, to facilitate the inevitable cost-down curve for hydrogen as a fuel in commercial vehicles and to continue improving the economics around FCEV trucks, buses and other high-utilization vehicles."

Brendan Norman, Hyzon's former chief commercial officer

Fig. 1: Clean energy-powered waste collection [Image: Faun]

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

A QUIET, CLEAN WAY TO WASTE COLLECTION

Electric trash trucks in high demand

Trash trucks are a bit of a standout among specialized vehicles, since they require energy for both powertrains and hydraulic systems. Fuel cells have long been known to be a very good fit for these trucks, allowing efficient, low-noise operation in residential areas. In 2011, Faun Umwelttechnik delivered a trash truck outfitted with a fuel cell-powered loader to Berlin's waste management company BSR (see HZwei, October 2011). This August, the company announced that after putting a second prototype to the test, it was now ready to bring the vehicle to market.

Faun is not a conventional automaker but an owner-managed midsize business making a variety of truck bodies. To ensure quiet, electric vehicle operation, the firm installs a storage tank, fuel cells, an electric motor, a battery and control equipment onto a Mercedes-Benz chassis. The company's head of development, Georg Sandkühler, explained to the Weser-Kurier newspaper that "if you first need to remove the internal combustion engine, the transmission as well as some other components from the truck, a retrofit is essentially a waste of time."

Faun's system package includes up to three 30-kilowatt fuel cell modules. While their output seems a bit on the low side, they are still useful in extending the vehicle's range, with peak power being provided by an 85-kilowatt-hour lithium-iron-phosphate battery. Post-retrofit, the trucks, which also feature regenerative braking, can make two runs a day to collect 10 tons of garbage on each run.

Through its hydrogen and fuel cell innovation program, the German transportation ministry spent EUR 0.5 million to support the development of Faun's Bluepower retrofit kit. Bluepower originates with the Dualpower option the company created in 2006 and has improved upon ever since. The Faun prototype truck that BSR had in regular service from 2011 to 2013 was equipped with a Heliocentris fuel cell system providing energy for the loader body (see HZwei, October 2011).

Faun drew on the expertise gained from that first project to create a fuel cell hybrid powertrain that can be used in trash trucks and street sweepers. In 2018, it showcased a concept study at Munich's IFAT show, where German environment minister Svenja Schulze seemed quite taken with the idea. This January, the firm unveiled another prototype design, developed in collaboration with Mercedes.

Initially, Faun will reportedly manufacture only a limited of Bluepower hybrid kits. In August, it shipped one newly outfitted truck to ALB – Abfalllogistik Bremen, which will monitor fuel consumption, stability and durability during a 14-week test period. The monitoring data and driver feedback will then be used to make improvements to the vehicle. "The truck needs to be put through its paces and partnering with a waste management firm is the only way to make sure it will," Faun said.

By the end of this year, Faun will then deliver around 20 units to its regular customers. BSR alone ordered six of them. In 2021, production capacity could increase to around 100 units.

The fuel cell hybrid truck is around three times as expensive as its diesel counterpart but consumes only half as much energy. Its service life is higher too, Faun noted. Government funds could also help a great deal in reducing its price tag of EUR 0.75 million. McKinsey consultant Bernd Heid said that "2027 could be the first year in which we see hydrogen trucks getting cheaper than diesel versions."

In early August, the head of Lower Saxony's government, Stephan Weil, toured Faun's manufacturing facilities in Os-

> "The aim is to establish an innovation cluster for clean hydrogen in Bremen. We have two municipal companies, Abfalllogistik Bremen and Bremer Straßenbahn, to test the technology, which will open up a lot of opportunities."
>
> *Maike Schaefer, senator for climate action, transportation and housing*

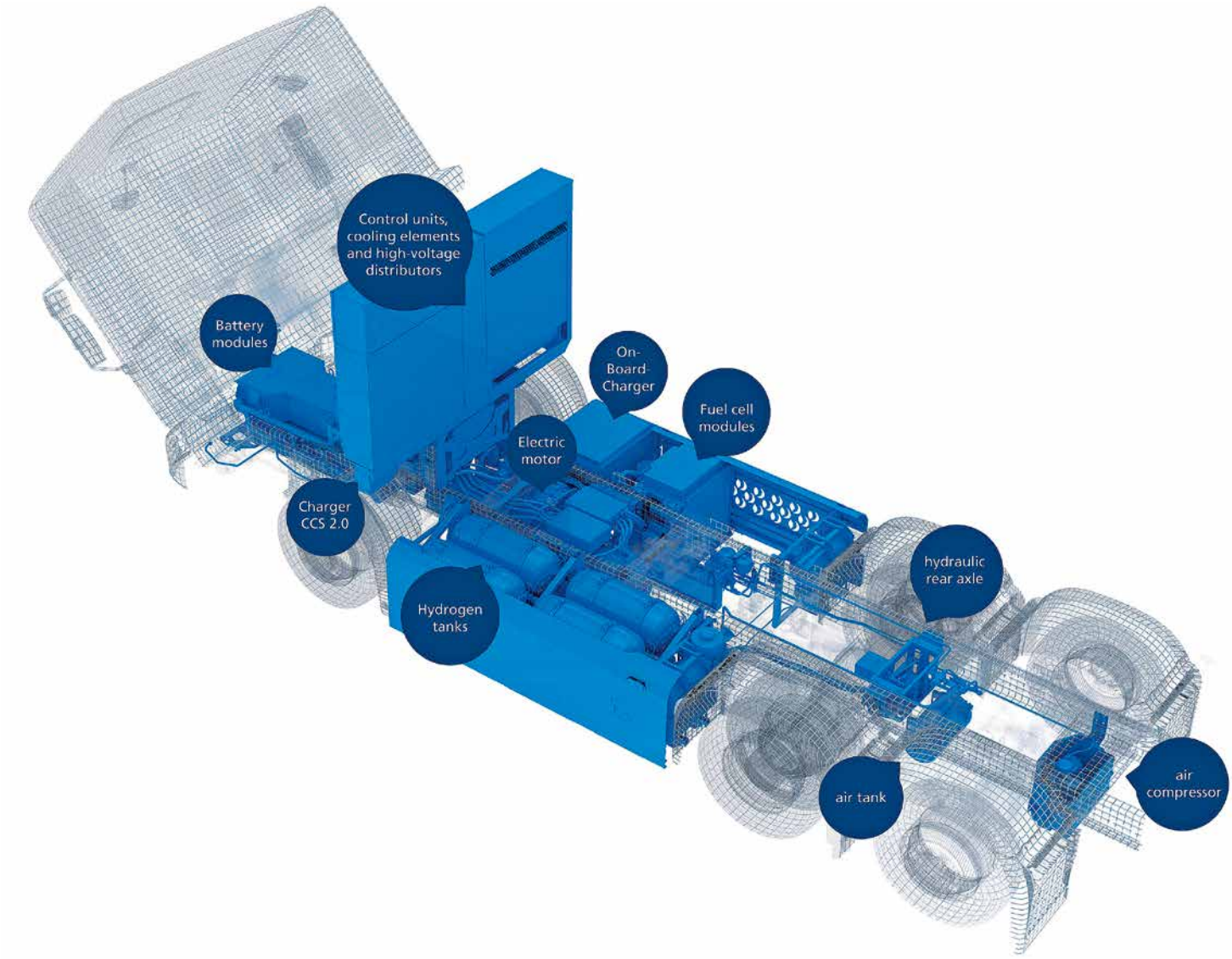


Fig. 2: Bluepower kit [Image: Faun]

terholz-Scharmbeck, a town in the north of the state. He was accompanied by a delegation of several regional and state politicians as well as business representatives, all of whom were eager to see firsthand how far Faun had come. In the presence of Faun CEO Patrick Hermanspann and the Kirchhoff Group's chief executive, Johannes F. Kirchhoff, Weil gave the green light for commercial production. Kirchhoff leads a group that employs around 13,500 people in 21 countries around the world. He said that half the trash trucks Faun is expected to deliver in the middle of this decade could run on hydrogen. ||

LARGE ORDER PLACED WITH NIKOLA

An example of the waste management industry's importance is Nikola's mid-August announcement (see p. 36) that it struck a deal with Republic Services, the second-largest waste disposal company in the United States, to deliver 2,500 electric trash trucks, called Nikola Refuse, with the option to add another 2,500 later (see image on p. 36). Subsequently, Nikola's stock rose by more than 22 percent, going as high as USD 44.81 at one point.

Nearly at the same time, Fuso, Daimler Truck's Japanese commercial vehicle subsidiary, showcased the eCanter SensorCollect, a battery-run concept study with a loader body, on a test ride at its headquarters in Kawasaki. So far, 160 zero-emission, light-duty Fuso eCanter base models have been delivered to customers in Japan, Europe and the United States.

Fig. 3: The Fuso eCanter SensorCollect concept truck parked in front of the business's headquarters in Kawasaki, Japan. [Source: Fuso]

Fig. 1: Refuse – Besides battery and fuel cell trucks, Nikola wants to sell chassis that can be used to, for example, construct trash trucks (see p. 34). [Source: Nikola]

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

NIKOLA – A HYDROGEN-POWERED TESLA

Making fuel cell trucks in Ulm

US manufacturer Nikola is the company currently making the most waves in the nascent hydrogen market, emerging as another success story similar to Tesla's. Its critics, however, consider the Phoenix-based would-be truck maker to be just as overrated as its competitor from Fremont, as it has yet to deliver on most of its promises.

The fundamental difference between Nikola and Tesla is probably that Trevor Milton, Nikola Motor Company's founder, seems not as dogmatic as Tesla's chief executive Elon Musk. While Musk is fully committed to advancing all-electric vehicles and regularly makes fun of fuel cells, Milton takes a much more pragmatic stance, aiming to offer battery as well as fuel cell trucks.

But aside from that, the resemblance is hard to overlook. Not only are both companies named after physicist and inventor Nikola Tesla, who died on Jan. 7, 1943, they also pursue similar marketing strategies. Not unlike Tesla, which began building an infrastructure at the same time that it introduced its first electric cars, Nikola is planning to install numerous hydrogen fueling stations.

Its USD 30 million agreement with Nel about the delivery of electrolyzers is a first step toward that goal. At first, five different sites will get one alkaline electrolyzer each, to produce 8 tons of hydrogen per day. Jon André Løkke, Nel's chief executive, said that since launching the partnership in 2017, Nikola and Nel "have been working together to develop a massive large-scale hydrogen fueling station." He added that the "framework agreement was one of the key triggers for deciding to develop our alkaline electrolyzer mega-factory in Norway," from where Nikola will get its stationary units.

The stations envisioned by Nikola would need to be a lot larger than typical car fueling sites, which have a price tag of 'only' EUR 1 million. The company has estimated that bigger stations to fill up over 200 hydrogen trucks would cost USD 16.6 million, an investment that it intends to write off over 21 years.

IPO STARTS OFF WITH A BANG Another similarity between Nikola and Tesla is their stock price, which many analysts regard as not matching up to reality. But while Tesla has been stirring up Wall Street for some time, Nikola just recently had its IPO, which saw the start-up business becoming a public company by purchasing control of Nasdaq-listed VectoIQ Acquisition Corporation (VTIQ; see H2-international, August 2020) in a move known as a reverse merger. On June 4, the stock then began trading under the NKLA symbol. At the time, Mark Russell replaced Milton as chief executive, whereas Milton, who founded Nikola Corporation in Arizona in 2015, became its executive chairman, intending to see the company grow in his new role.

> "This has been an incredible journey for Nikola Corporation. We started in our basement six years ago and now we are kicking off this 1 million-square-foot [93,000 m2] manufacturing facility."
>
> *Trevor Milton, Nikola's founder*

In 2019, the Swiss Neue Zürcher Zeitung newspaper reported about plans for breaking up CNH Industrial in 2021 and taking commercial vehicle brand Iveco, including Iveco's bus division and CNH's powertrain business, public as a separate entity. Each CNH stockholder will receive the same number of shares in the new business as in CNH. Hubertus Mühlhäuser, CNH's then chief executive, said that the move was designed to create more value for shareholders, especially the corporation's majority owners, the 100 or so members of the Agnelli-Elkann family.

MANUFACTURING IN COOLIDGE AND ULM Reportedly, the company's Tre will be made by Iveco, which formed a joint venture with Nikola for exactly this purpose. Iveco's parent company, CNH Industrial, is investing around EUR 40 million in an entirely new assembly line in Ulm, where until 2012, it had put together Iveco Magirus Stralis vans. Gerrit Marx, chief executive of Iveco, explained that in the first stage, the joint venture will "focus on 6x2 tractors [editor's note: tractors with six tires, two of which are powered], especially for the US market, and the popular 4x2 version for Europe, with batteries that allow the trucks to go between 186 miles (300 kilometers) and 249 miles (400 kilometers) on a single charge and provide them with nearly 350 kilowatts of output via one electric axle. A fuel cell truck will be available later on, as a long-distance option, giving vehicles twice the range." Initially, Nikola expected to roll out the Tre in 2021 to generate the revenue that has been missing so far. But because of Covid-19, delays may be inevitable.

In 2022, Nikola also plans to bring online a manufacturing plant at its headquarters in Coolidge, south of Phoenix. The groundbreaking ceremony for this 1.7 square-kilometer site took place on July 23. The plant will reportedly produce around 35,000 vehicles a year, with the Nikola Two Class 8 FCEV coming to market in 2023. The company is expected to turn a profit no earlier than 2024. Since 2014, more than USD 4 billion have been invested in the start-up.

One of Nikola's first customers in Europe was South Tyrol-based transportation company Gruber Logistics, which placed an order for fuel cell trucks in March 2019. Thomas Klauser, of Bolzano's Hydrogen Center, said that the "center, funded by the South Tyrol government and the EU, is the result of a successful collaboration between the operators of the Brenner A22 expressway and the Institute for Innovative Technologies – IIT. Gruber Logistics' recent request for a partnership ties in perfectly with our plan to expand, together with the A22's operators, the number of hydrogen fueling stations along the Brenner route." Previously, US brewing company Anheuser-Busch preordered 800 of Nikola's fuel cell-powered semitrucks, announcing that it wants to have all its vehicles run on clean energy by 2025.

It should be noted, however, that instead of selling hydrogen trucks, Nikola offers full leases for 7 years or 1.13 million kilometers, whichever comes first. Its ride package covers maintenance, repair and fuel costs so users will save around USD 0.02 per mile compared to a diesel model, the company said.

FIRST POWERCELL, NOW BOSCH Initially, Nikola partnered up with Swedish fuel cell manufacturer PowerCell, whose truck stack comprises around 400 individual cells, providing an output of 120 kilowatts, according to specifications. The plan was to use these stacks in Nikola-Iveco trucks and Chinese-made passenger cars. But last year, the collaboration came to an abrupt end. In April 2019, Per Wassén, PowerCell's chief executive, said that "tests have been going well. But since we viewed Nikola's proposed business terms as totally unacceptable and turned them down, Nikola has decided to discontinue our cooperation for serial production." Not long before the partnership ended, in March 2019, Nikola had announced plans to invest USD 16 million in its own fuel cell research lab.

PowerCell told H2-international that "a mere 4 weeks later, we announced our joint development and licensing agreement with Bosch about sales of PowerCell S3 in the auto market. Because of this agreement, we could not continue selling S3 units to automotive companies, including Nikola. Any further talks about the use of the S3 in Nikola trucks will have to be conducted between Nikola and Bosch. It is difficult to say whether Bosch and Nikola will strike up a commercial partnership and whether Nikola will source S3 units from them. In addition, Bosch purchased a stake in Nikola last year. We will have to wait and see if that increases S3 unit sales."

Stuttgart-based auto supplier Bosch, a very committed stakeholder in the fuel cell market, said its fuel cells will be ready for the market by 2022. It expects to reach full production by 2023, having already built a manufacturing facility at its Bamberg site. The company expects every eighth heavy-duty truck registered in 2030 to run on fuel cells.

Meanwhile, Milton was back to making headlines, saying in mid-August he had approached Hyundai twice so far with a proposal for a truck market partnership. He said that both times, the South Korean carmaker rejected his offer. ||

BADGER

The Nikola Badger is neither a passenger car nor an HDV but an electric pickup truck (see H2-international, August 2020). It competes in a category that includes Tesla's Cybertruck as well as Ford's F-150, the "most important vehicle in the United States," according to the auto motor & sport magazine (though Ford's is a fossil fuel model). Nikola said the Badger will provide a range of 600 miles (965 kilometers), with half the energy coming from the battery. At the push of a button, drivers will be able to choose, like in current LPG cars, whether the five-seater heavyweight (peak output: 666 kilowatts; continuous power: 335 kilowatts) will be powered by the battery only or the fuel cell too. Despite its mass, the truck can reportedly go from 0 to 62 miles (0 to 100 kilometers) in just 2.9 seconds. Since late June, Nikola has been accepting preorders for the pickup, which will not be manufactured by the company but a contractor. Delivery is scheduled for this year, though only to a select few customers. The company does not expect the Badger to ever enter mass production in the amount of hundreds of thousands of units.

Fig. 1: Iveco's Strator shares a platform with the Stralis, sold on the Australian market under the name Powerstar. [Source: Quantron]

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

WHERE CONVERSION IS KING

Quantron wants complete transformation

Like Clean Logistics in northern Germany, Quantron, headquartered in Gersthofen near Augsburg in the south of the country, is planning to convert diesel trucks to run on fuel cells. Founded by Andreas Haller last summer, the business presented a fuel cell truck concept this June before revealing more details about the vehicle at a press conference and during a workshop in Frankfurt in early August. Haller not only managed to get multiple partners on board, but his new company has also been endorsed by climate change advocate Hannes Jaenicke (see fig. 2).

Although people might easily associate Quantron, an abbreviation originating with the phrase "quantum leap in electronics," with a Californian start-up business, it is the name of a family-owned southern German firm with a long history in the industry. In 1882, Quantron began operating horse carriages under the name Haller. After five generations as a supplier of motorized taxi cabs as well as agricultural and other specialized equipment, it shifted its focus to electrically powered commercial vehicles in 2011.

STRONG PARTNERSHIPS At first, the company focused exclusively on batteries, especially by outfitting newer generations of used trucks with electric motors. To this end, Quantron partnered with companies such as electric powertrain manufacturer Voith and Frankfurt-based waste disposal service FES, which added Quantron vehicles to its fleet of trash trucks. In the meantime, the firm has grown to 40 staff, with 120 being employed by the Haller Group in total.

Mid-June saw Quantron unveil its latest model, Energon, a 44-ton FCEV for transporting goods. Quantron stated a range of around 435 miles (700 kilometers), made possible by a 130-kilowatt fuel cell and a 110-kilowatt-hour CATL battery powering a 340-kilowatt two-speed motor. The fuel cells are manufactured by Freudenberg, which supplies the vehicle conversion company with complete systems instead of individual components.

Manfred Stefener, vice president of Freudenberg's fuel cell division, told H2-international that his firm has come to see itself as a system provider intent on creating immense value across the transportation sector, and not just in the vehicle market. Another example of the supplier's fuel cell focus is its plan to build powerful methanol systems for the maritime industry.

Quantron has so far been converting Iveco Strator tractor-trailers to run on fuel cells. Unlike most trucks sold in Europe, they have long hoods, making them easier to convert than cab-overs, according to Quantron's marketing manager, Thomas Thiel. Still, other models will be offered eventually. Two pilot trucks will presumably be tested in the second quarter of 2021 and initial shipments to customers are scheduled for late 2022.

In mid-July, it became clear that Quantron is additionally targeting the medium-duty truck market. It announced that, together with AE Driven Solutions (see box), it plans to offer converted Iveco Daily pickup and box trucks. The companies presented a concept named Quantron Q-LIH2 (see im-

> "Thanks to our long history, we have deep experience in the industry, know its customers and their requirements, and can respond quickly to changes in the market."
>
> *Andreas Haller, founder and chief executive of Quantron and CEO of Haller*

Fig. 2: Andreas Haller and Hannes Jaenicke (right) at the press conference

age on p. 3), which will reportedly have a maximum range of 249 miles (400 kilometers) and be able to carry up to 1.2 tons.

In this market, Quantron's systems of choice are range extenders. These devices will allow the company to offer 4.2-ton models with 100 kilowatts of output or 7.2-ton HDVs with 147 kilowatts, regardless of whether the trucks are new, secondhand or currently in use.

Haller also intends to build a hydrogen fueling infrastructure, though not by installing publicly accessible stations like Tesla has done and Nikola is planning to do. Instead, he told H2-international that his company is already in talks with several businesses about putting up stations on fleet vehicle operators' premises.

According to Nikolas Iwan, H2 Mobility's chief executive, Germany had 84 hydrogen stations in August. However, not even 10 percent of those could fuel HDVs. Only in the coming years will we see more stations for filling up vehicles that consume large amounts of 350-bar hydrogen, he said. But before that can happen, the equipment will need to be standardized.

During the session on Aug. 4 in Frankfurt's Höchst district, German actor Hannes Jaenicke explained his support of Quantron, stating that the company's approach will "end the discussion about carbon emissions and fine dust once and for all." He conceded that "Hydrogen + Fuel Cells = Unlimited Energy," a marketing campaign for which he teamed up with NOW and the German transportation ministry in early 2016, "quickly lost steam" before criticizing traditional automakers for commercializing few of their innovative ideas despite them being efficient and sustainable. ||

AE DRIVEN SOLUTIONS

AEDS is led by people well known throughout the electric vehicle industry. They include Professor Achim Kampker and the chief executive of the Neuman & Esser Group, Stefanie Peters, who has recently been appointed to the National Hydrogen Council (see p. 10). AEDS (AE stands for alternative energy) was spun off from RWTH Aachen university, where Kampker chairs the E-Mobility Components Engineering department.

Kampker also founded StreetScooter, which was instrumental in moving the electric vehicle market forward. He told H2-international that AEDS is mainly focused on the link between hydrogen fueling infrastructure and vehicle use cases. He said he has always believed fuel cells to be a serious alternative to battery-electric motors but finds it unhelpful when advocates for both technologies start drawing contrasts or compete with each other. He also founded PEM Motion, an agency providing consultancy and engineering services. It has indirect ties to AEDS, supporting the organization's goals through contributing ideas.

Kampker added that the commercial vehicle sector is now faced with issues that resemble those in the passenger car market around 10 years ago. In 2010 and 2011, it was not unusual for electric vehicles to make the headlines. However, apart from the quite ambitious target of 1 million electric cars by 2020, there was little progress. Right now, it feels like we could see the same thing happening again, he told H2-international. Still, hope dies last, he said, stating his intention to make people aware of past mistakes so they can learn from them and set up a market in a shorter amount of time.

Fig. 1: Filling up a hydrogen fuel tank is not always an easy task.

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

FEELING LIKE A PIONEER

A comfortable (yet still exciting) ride

So far, Hyundai has shipped a total of 10,000 Nexo cars. Since launching a fuel cell model in March 2018, the South Korean automaker has delivered more FCEVs than any other vehicle manufacturer in the world. This July alone, an additional 700 Nexo vehicles went to customers in South Korea and 89 were exported to countries around the world. H2-international was given the opportunity to test a Nexo car this summer. The conclusion: If it had a lower price tag and there was a fueling station nearby, the Nexo would be the perfect ride.

There is still an ongoing debate about whether it makes sense to install fuel cells in privately owned vehicles. Still, it is becoming clear that the technology works best in large, heavy vehicles, since FCEVs are more difficult to build and maintain than their all-electric counterparts. A small city car will most likely be better off with a battery. But an SUV, or anything larger than that, could benefit from a fuel cell engine.

The Nexo is that kind of car: big and spacious, with good handling despite a weight of almost 2 tons. Hyundai Germany even delivered the SUV, which, like so many Nexo cars, had been painted in a copper tone, right to my doorstep. That was the beginning of my several-day road test.

A TRIP TO THE DANISH BORDER I took the car on a business trip to the Danish border, where I was to attend a press conference. But first, I mapped out the route. Planning was key, as there were few stations to fill up FCEVs along the way. Not that the extra time spent on this bothered me much. I faced similar issues with LPG years ago, as well as with testing other battery and fuel cell electric vehicles in the meantime.

When I checked H2 Mobility's website h2.live, I saw that despite being a relatively recent addition, the fueling station in Flensburg-Handewitt was closed around the time I was planning to drive there. As I was told later, it was getting a new roof. So I picked a route that would, hopefully, see me get home without having to fill up the car.

After starting in Oberkrämer, northwest of Berlin, I headed west to test out the fueling pump in Hagenow. The Nexo's fuel gauge showed that I had just 126 miles (202 kilometers) left. The prior evening, my adult son had taken the new vehicle out for a spin, giving him something to boast about to his friends. I was not in a hurry, however, so I limited my speed to 78 miles (120 kilometers) an hour and was well on my way. Both H2 Mobility's website and app provide a user-friendly experience. Connected to a route planner, they not only list the addresses and the distance to nearby fueling sites but also show the kilometers travelled.

One thing that confused me a bit was that the Nexo's navigation system failed to find the fueling station I had chosen. But after making the last turn and seeing the station in front of me, I was relieved to know that my trust in the H2-Live app was not misplaced. While hydrogen had yet to be added to the site's price sign, the white-and-blue pump was clearly visible from afar. However, following my first unsuccessful attempt at refueling, I was getting somewhat worried. I knew that if the car did not fill up, I would not make it to Hamburg.

I looked over to the gas station attendant for help. However, she only pointed me to the manual and the hotline. My second try got another 0.3 kilogram into the tank, at least. The third saw me add 0.2 kilogram, the subsequent attempt only 0.15 kilogram. During my last attempt, when I had all

Fig. 2: Fueling station in an industrial park, next to chemical company Yara Brunsbüttel

but given up, the compressors finally responded like they should have all along and 700-bar hydrogen was pumped into the tank. Phew, I thought to myself, what a stroke of luck. Else, I would have been in serious trouble. Hamburg's fueling station in the HafenCity district had been my fallback option to fill up the car. But as I found out later, that station was out of order at the time. As the one on Schnackenburgallee had also been shut down, there would have been only two other options I could have tried. But making it to one of them would have hardly been possible, considering how much fuel that would have used up.

None of this mattered now. The tank was full. With the car showing a range of 353 miles (568 kilometers), I finally stepped on the gas. After leaving Hamburg, I headed toward my old home, taking a small detour to the Elbe, and to Brunsbüttel to fill up the tank again. The navigation system did not display this station either, even though the on-site pump worked like a charm. From there, I drove north to Bosbüll, where German transportation minister Andreas Scheuer was about to inaugurate the eFarm project (see p. 26)

YOU ARE NOT ALONE Following the press conference, I went for a short drive to Tønder on the Danish side of the border before heading back to Hamburg via Schleswig and Eckernförde. Meanwhile, the HafenCity's station in Hamburg had been fixed. But I decided to fill up at another one of the city's fueling sites, the one on Bramfelder Chaussee, as I had never used it before. To my surprise, a second Nexo driver was already waiting impatiently for me to come back after I went to the bathroom. Even when I need to fill up LPG, for which there is also no more than one pump per site, I very rarely see someone else standing in line.

When I was back in Berlin, the same thing happened again. There, too, another Nexo was suddenly coming up next to me. When I told the driver that my car's tank was only up to 90 percent full, he promptly replied that he just came from Magdeburg, where the hydrogen station was inoperative so he will gladly take every kilogram he can get.

There is not a lot left to say about the Nexo (see H2-international, January 2019). It is quiet, very comfortable and easy to control. The only thing that may raise some eyebrows during an otherwise laid-back ride is that the hood begins to "flutter" noticeably when going more than 90 miles (around 150 kilometers) per hour.

Sae Hoon Kim, head of Hyundai's fuel cell division, told the Welt newspaper: "This year, we are planning to produce 13,000 Nexo vehicles, and we will keep increasing annual production capacity in the coming years." He added that in 2025, the SUV – which currently has a price tag of EUR 77,000 – should cost around as much as an all-electric vehicle (see box). ||

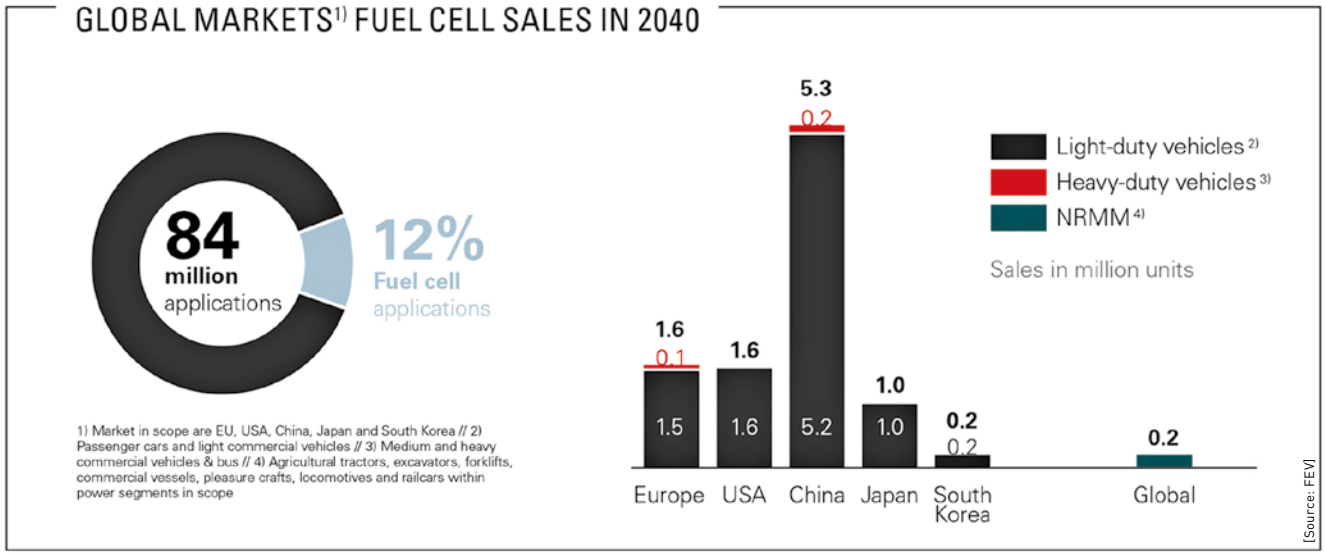
HYUNDAI KONA ELECTRIC

Hyundai's all-electric model, the Kona Elektro, is priced at EUR 41,850 and is a bit smaller, which leads to improved handling. While the Nexo seems pretty massive, driving the 64-kilowatt-hour Kona feels more like being in a sports car. Its 300-mile or 484-kilometer range is also quite impressive for a battery-powered vehicle.

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

A BIG OPPORTUNITY FOR MANUFACTURERS

VDMA study analyzes fuel cell vehicle market



Starting in 2030, fuel cells will be making significant inroads in the passenger car, commercial vehicle and heavy equipment markets. Their importance, as well as the required hydrogen infrastructure, will grow steadily in the coming years, mainly thanks to heavy-duty applications. By 2040, the technology will power 12 percent of all vehicles sold in those markets, creating 68,000 new jobs in Europe in the process. These are the key takeaways from "Engine of change – Fuel cells' impact on the machinery and industrial equipment industry and its suppliers," a study conducted by FEV Consulting for Germany's national engineering federation VDMA. Unlike battery-electric motors, fuel cells have quite a lot in common with internal combustion engines when it comes to production and supply chains, a boon to traditional automakers and machinery manufacturers.

Nevertheless, the regions and sectors analyzed in the study are moving at a very different pace. Japan and South Korea will continue to lead the market for passenger vehicles. By 2030, 6 percent of all cars sold in Japan will run on fuel cells, a share that will rise to over 20 percent by 2040. Besides setting strict well-to-wheel emissions limits, the Japanese government is pushing for social and political change in order to establish a hydrogen economy.

Fuel cell demand will not grow quite as fast in South Korea, where FCEVs will make up an estimated 3 percent of the market by 2030 and 14 percent by 2040. They will also contribute 2 percent to total sales in China by 2030 and 14 percent by 2040. In the United States and Europe, however, their share will remain below 1 percent in 2030 but rise to 10 percent by 2040.

The Zero Emission Vehicle Index developed by FEV Consulting indicates that China, Europe and the United States will have a chance to catch up to the first-mover markets later this decade. The index uses a variety of factors to determine the competitiveness of new engine designs compared to traditional ICEs. It shows that currently, battery-electric vehicles, also known as BEVs, are gaining traction in Europe and China and will, in the next two years, achieve a level of popularity that will allow them to easily compete with ICE cars. Fuel cells, FEV said, will reach 100 on the index in the 2030s, putting them on an equal footing with conventional powertrains.

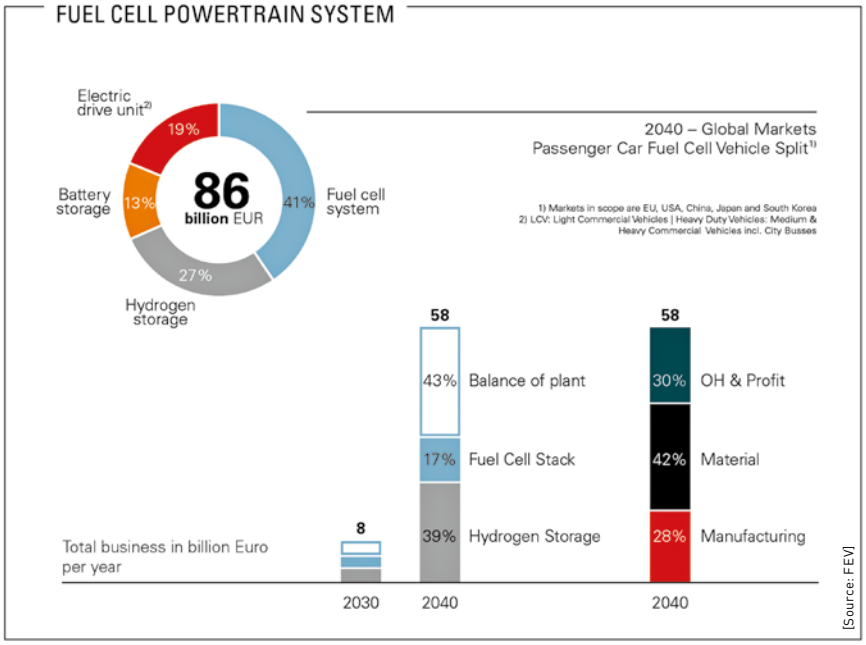
"Our study shows that the FCEV and BEV markets are about 10 years apart," said Michael Wittler, FEV's principal consultant. Overall, the consultancy expects FCEV sales to grow from one to 10 million between 2030 and 2040. This translates into a 12 percent market share and an around 25 percent growth rate per year.

STRICT EMISSIONS REGULATIONS Heavy-duty equipment will play a key role in bringing fuel cells to market, mainly because of the strict emissions limits that are to be introduced in Europe, Japan and South Korea. The new rules will force automakers to sell a certain number of zero-emission vehicles each year. "In long-distance and heavy-duty transportation, it makes no sense at all to haul around a battery that weighs multiple tons. We simply need to come up with another approach," Wittler said. He considers both fuel cells and hydrogen ICEs viable contenders for solving the weight issue.

It is still unclear which option will come out on top. In any case, what is more important than the choice between fuel cells and hydrogen-powered ICEs is that those who provide the refueling infrastructure can count on regular customers. "This is why heavy-duty vehicles are so crucial," Wittler said. Their energy-hungry engines will most likely more than make up for their comparatively low sales figures.

Additionally, fuel cells could very well take a notable chunk of the pie in non-road transportation, specifically in the forklift, railroad and maritime markets. Promising high daily operating hours, the technology is already in use in some forklift trucks. By 2030, FEV predicts that fuel cells will also power materials handling equipment with an output of 19 kilowatts or more.

From an industrial policy perspective, there are other benefits to producing fuel cell engines, as they have much more in common with ICEs than electric motors. "Fuel cell manufacturers rely on roughly the same supply chain components as companies making ICEs. Sometimes, the value



added during production even slightly exceeds that of conventional engines," said Wittler. In the BEV market, the value-add is considerably lower.

Total revenue potential in the passenger car market across the regions analyzed is expected to increase to nearly EUR 86 billion annually by 2040. FEV said that 68 percent of the estimated revenue will come from fuel cell stacks, balance-of-plant components and hydrogen tanks, while the other 32 percent will be generated by selling electric powertrains, including batteries and electric motors.

The manufacturing process itself will contribute 28 percent, that is, EUR 16 billion a year, to the fuel cell value chain, the study says. Crucial value-adding processes in the sector are forming, coating and methods that change material properties. This is especially true in stack component manufacture, which will add EUR 2.6 billion to the total by 2040. Work on these components, mainly on compressor/expander modules for fuel cell air systems, hydrogen control equipment, valves and gaskets, will come to EUR 5 billion a year. Another notable value-add is the production of composites used to make hydrogen tanks, a process estimated to contribute EUR 1 billion a year by 2040.

SIMILARITIES TO COMBUSTION ENGINES Today's automakers stand to benefit from the similarities between some fuel cell and ICE components, including turbochargers, instruments, valves and cooling systems or channels. For example, a vehicle's fuel cell air system also contains a compressor/expander assembly. "This assembly could be delivered by companies manufacturing turbochargers. Both components serve similar functions and have similar designs," said Wittler. In his view, the necessary changes to vehicle fleets will not be as dramatic as expected.

The same cannot be said about stacks. Mainly made up of bipolar plates and membrane electrode assemblies, they will need new production lines. Wittler said that bipolar plate manufacture is a challenging task because the plates have to be flat, among other things. In addition, suppliers will require large amounts of carbon-reinforced polymer to make hydrogen tanks. He expects the industry to use highly or fully automated systems to line tanks and stack bipolar plates.

To determine the economic impact that fuel cell use will have on the European market, the authors of the study analyzed and evaluated two supply chains in an OEM Make and an OEM Buy scenario. The first presupposes a higher rate of in-house manufacturing and concentrates on integrating parts into fuel cell stacks. It also assumes that besides hydrogen tanks, most OEMs will take it upon themselves to make some of the stack subcomponents, such as bipolar plates, as well as key balance-of-plant components, e.g., the compressor/expander unit. In this scenario, the OEMs are likewise in charge of assembling the fuel cell system. OEM Buy, on the other hand, focuses on ready-made components, for example, stacks and balance-of-plant subsystems.

EUROPE TO BENEFIT FROM VALUE-ADDED MANUFACTURING The market researchers working for FEV estimate that making fuel cell engines for cars sold in Europe will add EUR 4.3 billion in value a year by 2040. They stress that in both supply chain scenarios, the associated value-adds in Europe will be higher, possibly up to EUR 4.8 billion annually. "This underlines Europe's role as an exporter of auto products," the study notes.

Although OEMs will create less value in a Buy scenario, the gap will be partly filled by higher value-adds among local suppliers. Europe will also benefit from an increase in auto part exports to the tune of EUR 50 million a year. In both scenarios, supplier exports will contribute between 21 percent and 24 percent to total value creation along the supply chain.

FEV further estimates that by 2040, the value added during production will create over 60,000 jobs, with over 15,000 being provided by the manufacturing sector. Furthermore, also by 2040, the industrial sector will need to invest around EUR 8 billion (excluding depreciation) in machinery and manufacturing facilities. What is missing from FEV's analysis is a comparison of jobs newly created in the fuel cell market and those lost in the ICE industry. There are, however, plans to conduct a follow-on study to investigate whether on net balance, there will be more or fewer people employed in the auto industry.

"When it comes to adding value and creating jobs, fuel cells are a big opportunity for the machinery industry," said VDMA co-CEO Hartmut Rauen. Despite the relatively optimistic forecasts, he also made clear that the engine of change will not ignite itself. "The transformation is a huge challenge for businesses," he said and pointed to the results of another study, which found that in the coming years, around EUR 5 billion will need to be invested annually in research and development worldwide to make change happen. ||

Fig. 3: Hartmut Rauen, VDMA's co-chief executive [Source: VDMA]

Category: Research and development | **Author:** Viktoriya Tremareva

SPECIALTY METALS FOR WATER ELECTROLYSIS

Are iridium and platinum critical materials?

Hydrogen will have a crucial role to play in transforming the energy market. The first element of the periodic table has great potential to decarbonize much of the steel, cement and chemical industries as well as aviation, heavy-duty road haulage and maritime transportation. As a result, politicians across the EU are mapping out plans to support electrolyzer capacity increases and hydrogen production methods.

In December 2019, the European Commission presented its Green Deal, offering to fund climate action measures in the energy, transportation, trade, industrial and agricultural sectors to meet the EU's aim of becoming climate neutral by 2050. When Covid-19 hit the world economy, doubts grew about whether the measures could move ahead as planned. But the commission is sticking to its guns, viewing the deal as Europe's new path to growth.

On July 8, it published a hydrogen strategy as part of the Green Deal, focusing on green gas produced from clean electricity. With the help of carbon capture and storage, the commission also aims to have existing natural gas reformers converted to zero-carbon plants in the coming years so the carbon dioxide released during production can be stored underground. The Union's 2024 target is a minimum of 6 gigawatts of electrolyzer capacity that can generate one million tons of hydrogen a year. By 2030, this capacity is set to grow to 40 gigawatts producing 10 million. Estimates show that putting up the electrolyzers will require between EUR 24 billion and EUR 42 billion by 2030. In the same period, between EUR 220 billion and EUR 340 billion will need to be invested in solar and wind farms for green hydrogen production.

The German hydrogen strategy, approved by the federal cabinet on June 10, is similar to Europe's. Both have green hydrogen as their long-term goal. The budget for implementing Germany's national plan has already been earmarked as part of the country's second stimulus package, which is designed to lessen the impact of Covid-19. In all, the government will allocate EUR 9 billion for advancing the technology. The strategy determines how fast production will be ramped up and how much capacity will be added at every stage. The 2030 target is up to 5 gigawatts, including required offshore and onshore energy.

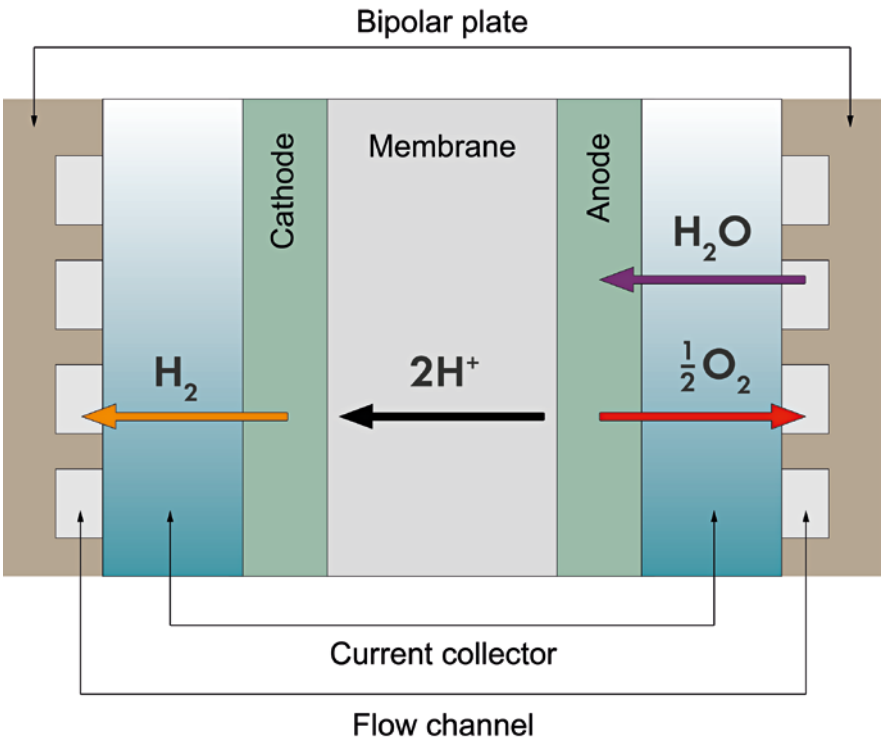


Fig. 1: PEMEL cell structure [Source: BGR]

Another 5 gigawatts will possibly be added by 2035, at the latest by 2040. The strategy will also support research and development as well as the transfer of innovative hydrogen technologies. It will be a great boon to all those that have so far not been able to find other options for decarbonizing their business, such as steel manufacturers and aviation companies.

WATER ELECTROLYSIS Even though the plans drawn up by both the EU and Germany state that there will be a short window to sell blue hydrogen in order to grow the market, the gas will eventually be produced by electrolyzers running mostly on clean power. These devices can use solar or wind energy to split water into hydrogen and oxygen. The key water-splitting technologies these days are polymer electrolyte membrane, alkaline and high-temperature electrolysis, known as PEMEL, AEL and HTEL, respectively.

Two of them, namely AEL and – for the most part – PEMEL, are already technologically advanced enough. By contrast, HTEL manufacturers are few and far between, and plant size and lifetime are not yet where they should be. At least in the short term, the main technologies used to establish a mass market will therefore be AEL and PEMEL. Slight differences in their technological makeup make them suitable for different sets of applications.

AEL has the big advantage that it does not require possibly critical raw materials. The electrolyte is a potassium hydroxide solution. The anode in commonly available electrolyzers is made of nickel, and the cathode consists of either nickel, steel or stainless steel. While AEL systems are relatively inexpensive, they are quite large, making them unsuitable for locations requiring compact solutions.

PEMEL is the technology of choice if space is limited or alkaline solutions are not an option, for example, in the proximity of offshore wind farms. The electrolyte of a PEMEL system consists of a proton-conducting polymer membrane and the catalyst is made of a precious metal, either iridium or platinum. Both of these components, however, increase system costs considerably.

SPECIALTY METALS FOR PEM ELECTROLYSIS A study called "Commercializing water electrolysis in Germany: Clean hydrogen opportunities and challenges in the transportation, power and heat markets (IndWEDe)," coordinated by hydrogen and fuel cell organization NOW, takes a closer look at, among other things, the criticality of several metals used in water electrolysis. In the case of PEMEL, the study's authors focus on iridium and platinum as possibly hard-to-get materials.

One PEMEL catalyst material is iridium, which is added in thin layers to fuel cell anodes. Thanks to high corrosion resistance, iridium is a sensible choice for the oxidative and thus highly corrosive environment surrounding these anodes. Another catalyst for coating PEMEL electrodes is platinum. Often, a thin layer made from platinum also covers fuel cells' bipolar plates to lower their surface contact resistance. These plates separate individual cells in a stack. They not only provide electrical conduction between cells but also supply water used for electrolysis and remove heat as well as reaction products (see fig. 1).

The IndWEDe study offers both a conservative and an advanced technology innovation scenario, estimating the iridium and platinum quantities needed to run electrolyzers in Germany by 2050. Calculations were based on the number of components presumably needed in 2030 and 2050. While the conservative scenario assumes demand for specialty metals to remain at previous levels, technological progress in the innovation scenario will lead to reductions in the amount of metals required.

In the conservative scenario, demand for iridium will be 2,650 kilograms in 2050. This corresponds to around 38 percent of estimated global iridium production in 2016, when it was around 7.1 tons. In the advanced scenario, electrolyzers will need around 200 kilograms, or 2.8 percent of the iridium produced in 2016. Regarding platinum, the conservative estimate puts demand at 1,300 kilograms in 2050, while technological breakthroughs would see the total drop to 150 kilograms that year. In 2016, global platinum production was around 190 tons.

When looking at these figures, it is important to remember that they show demand for only one technology and one country, that is, Germany. PEMEL may still have to compete with other technologies that also need iridium or platinum.

One benefit of both is that they can be recycled to keep the amount of newly mined metals to a minimum. This, however, has little impact on how much time is spent on researching ways to reduce or replace precious metal content in PEMEL systems.

A new version of the "Raw materials for technologies of the future" study, conducted on behalf of the German DERA platform on mineral raw materials, will estimate global mineral demand from water-splitting up to 2040 as well as examine all three technologies discussed in this article. Publication is scheduled for 2021.

PGM MARKET Platinum and iridium, and rhodium, osmium, ruthenium and palladium, are also known as platinum group metals, as they are often found together in the same geological formations. The world's largest producer of iridium and platinum is South Africa. According to Johnson Matthey (2020), South Africa contributed 136.8 tons of platinum, that is, 73 percent, to total global production in 2019. >>

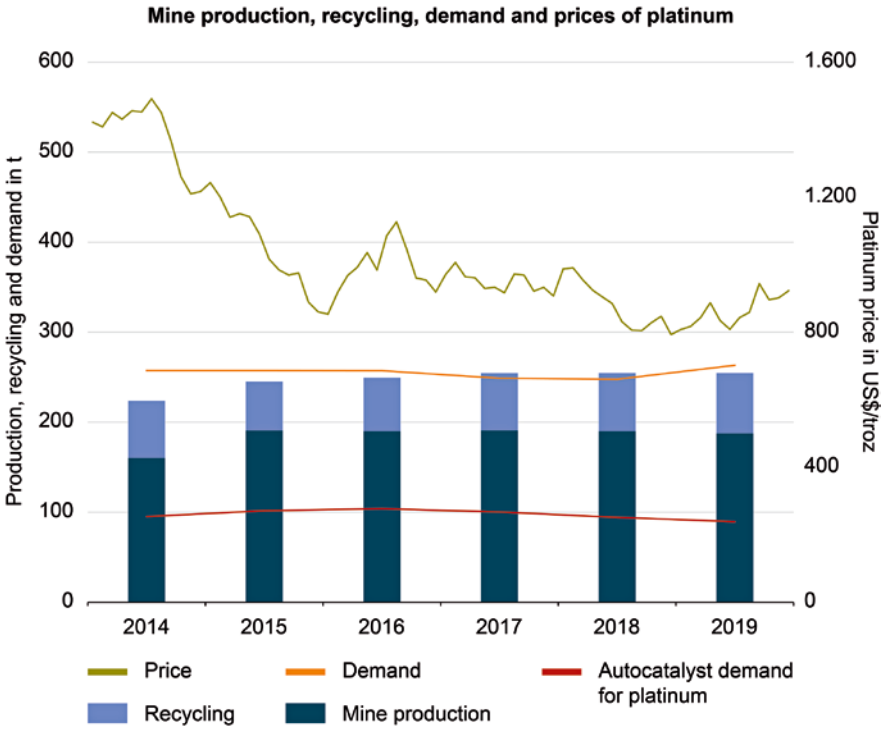


Fig. 2: Platinum mining, recycling, demand and price changes between 2014 and 2019 [Sources: Johnson Matthey 2020a, BGR 2020]

Other mportant mining sites are in Russia, North America and Zimbabwe. Platinum is often mined as a primary raw material, iridium being one of the byproducts, which makes supply of the latter wholly dependent on extracting the former.

The market for iridium is very small. Global annual demand ranges between 6 tons and 7 tons a year. Thus, even a slight increase in demand can lead to price hikes and supply risks. The global availability of PGMs, especially of platinum, palladium and rhodium, mainly hinges on primary and secondary production. The latter sometimes makes up 30 percent of the total, or around 26 percent in the case of platinum (see fig. 2). Producers, traders and banks also store PGMs. Physically backed exchange traded funds, known as ETFs, in particular are potential sources of platin and palladium. In short, current prices may not necessarily reflect actual supply and demand.

Since PGMs tend to occur in the same mineral deposits, mining only one of them is a nigh impossible task. This, of course, complicates pricing as well as balancing supply and demand. Producing more of one PGM is certain to lead to increases in other platinum group metals extracted from the ground. The most recent example of this strong relationship in PGM mining could be observed during the diesel emissions scandal. After the revelations about manipulated emissions tests came to light, the number of diesel vehicles manufactured around the globe began to fall and demand for the main precious metal used in their engines' catalysts, platinum, started dropping as well. At the same time, sales shifted to gasoline cars and demand for their main catalyst material, palladium, was on the rise. To produce more palladium, however, mining operators also had to extract more platinum. But prices for platinum had already dropped and a good portion of the newly mined metal was no longer needed. As a result, prices fell even further.

In general, we are not at risk of running out of PGMs. From a geological perspective, there are more than enough deposits available in the world. Still, the market could face temporary shortages, the Covid-19 outbreak being the latest cause of this. The economic slump triggered by the virus significantly lowered PGM supply and demand in the first half of this year. On March 27, South Africa then imposed lockdown measures, which were originally supposed to last for 21 days but were later extended by another 14. Mines and steel and iron works subsequently halted production. Since the country typically provides 73 percent of all platinum mined worldwide, the national measures had far-reaching consequences for the PGM market globally.

Both primary and secondary PGM production output will drop following the temporary shutdown of many mining businesses and the gaps in the supply chain. Johnson Matthey (2020a) estimates that PGM output in South Africa will decrease by at least 20 percent compared to 2019. Demand will shrink as well, as worldwide auto sales are predicted to fall by more than 20 percent this year (Johnson Matthey 2020a). Prices for platinum (99.95 percent purity) hit a 17-year low on March 19, when the metal was traded at USD 621 a troy ounce. On May 26, however, they rose again, rallying to a two-month high of USD 868 after their fall prompted growing interest from China and the pandemic had interrupted South Africa's supply chain. Since then, prices have been going up and down. On July 1, a troy ounce was traded at USD 843 (Johnson Matthey 2020b).

How platinum and iridium supply and demand, as well as prices, will develop post-Covid-19 depends on several factors and is a question that cannot be answered at this time. How quickly the economy will recover following the crisis is certain to have a significant impact on demand. Other highly influential factors include technological progress, specific applications areas, advances in recycling and the political and economic situation in South Africa, and in Russia. We at DERA are not only tracking these changes to the PGM markets but are also currently updating our study "Raw material risk assessment: Platinum group metals." ||

Reference(s)

- BGR – Bundesanstalt für Geowissenschaften und Rohstoffe (n. d.): Fachinformationssystem Rohstoffe, Hannover. Unpublished. Retrieved July 3, 2020.
- Johnson Matthey (2020a): PGM Market Report May 2020, London.
- Johnson Matthey (2020b): Prices – Price Tables – www.platinum.matthey.com/prices/price-tables# Retrieved July 3, 2020.
- NOW GmbH (2018): Studie IndWEDe, Berlin.
- Schmidt, M. (2015): Rohstoffrisikobewertung – Platingruppenmetalle, DERA Rohstoffinformationen 26, Berlin.

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Category: Research and development | **Authors:** Martin Sekura, Stefan Behrning

HYDROGEN-COMPATIBLE POLYMERS

New ways to achieve comparable and reproducible findings

Vehicle fuel cells contain many non-metals, particularly polymers, for several different purposes. While seals are made from elastomers, Type IV containers are lined with thermoplastics, the same materials that are now also increasingly used to make hardware parts, such as gaskets. The standards and guidelines relevant to the industry require a series of tests to ensure that the chosen polymers are suitable for a given application.

The ozone aging and oxygen deterioration tests required by EU directives 79/2009 and 406/2010, and similarly UN R134, are comparatively well specified and reference tried-and-proven, standardized test methods. Although hydrogen compatibility tests are also part of the regulations, the rules describing the conditions in which these examinations are to be performed are rather vague, relatively imprecise or non-existent. The most likely reason for this is that just a few years ago, there were still considerable gaps in standardization, a problem compounded by the lack of hydrogen expertise in the auto industry when the standards were created.

RULES DISAPPOINT In combination with EU directive 406/2010, EC 79/2009 is often cited when issuing a certificate of conformity for vehicles sold on the European market. While the directive lists specific procedures that must be followed when analyzing metallic materials, i.e., ISO 11114-4 examinations of components or pressure cycling tests for Type I, II and III storage tanks, the regulations on non-metallic components consist of one simple sentence: "Hydrogen compatibility shall be demonstrated."

Additionally, UN GTR 13, or, more specifically, UN R134, make no mention of assessing the compatibility of non-metals, instead referring only to oxygen and ozone deterioration. Despite these missing specifications, proof of hydrogen compatibility is crucial, especially for safety and liability reasons.

The lack of standardized procedures has led to the creation of a variety of methods, and each has its own benefits and drawbacks. Some examples can be found in table 1.

While an optimal test method obviously needs to deliver meaningful, clear and reproducible results, economic viability should also be part of the equation. In many cases, several potentially compatible materials need to be examined at a relatively early stage of development. The findings are then used to select the most promising among them, with a focus on choosing the least expensive material(s).

One quick and easy-to-conduct method is described in SAE J2600. It involves measuring the mass and volume of a sample on a scale or in a liquid bath, followed by a 168-hour static hold in a hydrogen environment at normal operating pressure and room temperature (or at minimal process temperature of mainly around -40 °C). Shortly after the time has elapsed, the container holding the sample is depressurized to ambient to encourage explosive decompression. Subsequently, mass and volume are measured a second time to see whether decompression of the material has occurred, indications being bubbles or ruptures or both, and whether the sample shows signs of increased swelling or shrinkage or a loss in mass.

The method has its drawbacks, however. The associated standard was basically designed to examine only two specific fuel cell system components, the receptacle and the fueling nozzle, which means that it may have limited applicability elsewhere. In addition, SAE analyses make sense only in the context of elastomer (valve) materials. For example, the 25-percent swelling threshold listed in the standard is not relevant to thermoplastics. Consequently, thermoplastics often undergo alternative, individually designed tests. These, however, have their own disadvantages:

- Some offer limited reproducibility.
- Some also require complicated sample geometries, increasing production costs.
- Their non-standardized procedures lack formal recognition.
- There is a risk that the interpretation of procedures and data will vary among departments or organizations. As a result, the findings may only apply to new products.

It is thus in the interest of several groups, including automakers, suppliers, test institutes and laboratories, to find a solution that has none of the disadvantages mentioned above and delivers both valid and reproducible results while being inexpensive and fast.

STANDARDIZING HYDROGEN COMPATIBILITY TESTS The authors of this article are offering a new, easy method to prove hydrogen compatibility for polymers. This method can be performed on both elastomers and thermoplastics and meets current regulatory requirements. >>

Table 1: Known methods for assessing the hydrogen compatibility of polymer materials

METHOD / STANDARD	BENEFITS	DRAWBACKS
ISO 17268-2020	fast and inexpensive	Only useful for examining elastomers
SAE J2600-2015	fast and inexpensive	Only specifies criteria for sealing materials
CSA ANSI CHMC 2-2019	in-depth analysis	Complex, expensive, designed rather for relative than absolute measurements
Non-standardized	adjustable	Lacks comparability and reproducibility

First, samples should be prepared according to CSA ANSI CHMC2-2019 recommendations, that is, dried at 60 °C for 48 hours. The subsequent test procedures resemble those described in SAE J2600. Following initial parameter measurement, samples are examined in suitable conditions with regard to medium, pressure and temperature before parameters are measured a second time. The measurements are then included in the final assessment based on predefined criteria and limit values.

Of course, elastomers and thermoplastics require differing parameter values, stress tests and evaluation criteria. Their chemical and physical properties are simply too far apart. While storing hydrogen in elastomers can cause swelling by several percent, an increase in volume that may have to be flagged as an issue, thermoplastics often do not grow as much in size, which means swelling has a rather insignificant effect on material functionality.

A more relevant criterion in the case of thermoplastics is the impact that tests have on yield and tensile strength, something that plays a lesser role when examining sealing materials, for example, elastomers. Still, it would be desirable and efficient to come up with a design that allows to, at least, test both types of material at the same time.

Table 2 shows the conditions and figure 1 the test sequence required by the new method. While the sequence is based on available procedures, especially those of ISO 17268, SAE J2600 and CSA ANSI CHMC 2-2019, it has been simplified and optimized in several respects. Despite this, the findings not only retain their validity but remain comparable as well. Thanks to its relatively simplicity, the test is also easier to reproduce, especially compared to the method given in the CSA ANSI standard.

In principle, the tests listed below can be performed in parallel. Carrying out all of them would take little more than a week. The number of materials that are to be examined has no considerable influence on how much time is required in total. Theoretically, many different polymers could be analyzed at the same time.

IMPACT OF SAMPLE GEOMETRY To estimate and compare the impact of sample geometry on mass and volume measurements, as stipulated for elastomers, TesTneT performed several analyses. These made clear that the procedure for determining the mass of small, lightweight samples of about 0.1 gram was sufficiently precise, the standard deviation being 0.2 percent. However, measuring volumes or densities following hydrogen storage produced either relatively regular outliers or changing ("run-away") values over time.

This issue was probably caused by gas that entered the sample during storage and, in the form of bubbles, stuck to the sample surface when taking measurements in the liquid bath. Hydrogen is known for diffusing through polymers in comparatively large quantities, exacerbating damage by bubble formation and swelling. The diffused gas then changes the buoyancy of the sample, which can significantly distort volume and density measurements.

The hydrogen that dissolved into the sample later starts to leak out while the bubbles begin to dissipate. What is thus required to make results reproducible is a precise definition of how much time needs to elapse between completing the >>

Table 2: Conditions for new hydrogen compatibility test

	ELASTOMERS	THERMOPLASTICS
Sample geometry	as installed in component (e.g., O ring) or plate/cube	Tensile bar according to DIN EN ISO 3167
No. of samples	>= 15 per material (mass per sample > 1 gram)	>= 15 per material
Evaluation criteria	according to SAE J2600-2015, Section 5.5: - no explosive decompression (visual assessment) - Swelling <= 25 % - Shrinkage <= 1 % - Loss in mass <= 10 %	according to CSA ANSI CHMC 2-2019, Table 7 (ratings 9 and 10): - Tensile strength following stress test >= 94 % of strength prior to test - optionally: flexural modulus after testing <= 94 % of flexural modulus prior to testing

storage procedure and determining mass and volume. CSA ANSI suggests taking measurements 24 and 48 hours after storing the hydrogen.

Additional measurements of heavier samples of about 2 grams indicated that the standard deviation before and after storage is < 0.1 percent. Our recommendation is to use the procedures listed in table 2 for all samples with a mass of > 1 gram. At least five will need to be measured per parameter to remove volume-related outliers from the data without affecting the validity of the findings overall.

One more thing to note is that the samples' surface-area-to-volume ratio has no vital impact on measurement uncertainty as long as the samples are sufficiently outgassed. In the authors' experience, this is true 24 hours after conducting the stress test.

EXTENDED TESTING The new method also allows adding other kinds of stress tests required under certain circumstances. Each would be followed by another parameter measurement. CSA ANSI CHMC 2-2019 mentions some useful additions:

- Initial cycling (20 load cycles at an ambient temperature of 55 °C, one cycle being 37.2 hours long)

- Extended aging (1,000 30-second cycles at 55 °C, 1,000 at -40 °C and 8,000 at 15 °C)

These tests could be helpful especially in assessing blistering, that is, bubble formation inside the material, e.g. through explosive decompression. Blistering is a phenomenon that may already occur after few cycles but could likewise take several more to materialize.

Of course, the procedures described in this article are only meant as a recommendation. They do not mean that other solutions are not possible. None of the rules and standards include the new test sequence in its entirety, which makes this a non-binding suggestion. Nevertheless, the authors will keep improving the new test method based on stakeholder feedback and changes in regulations, codes and standards. ||

Sources and references available on request.

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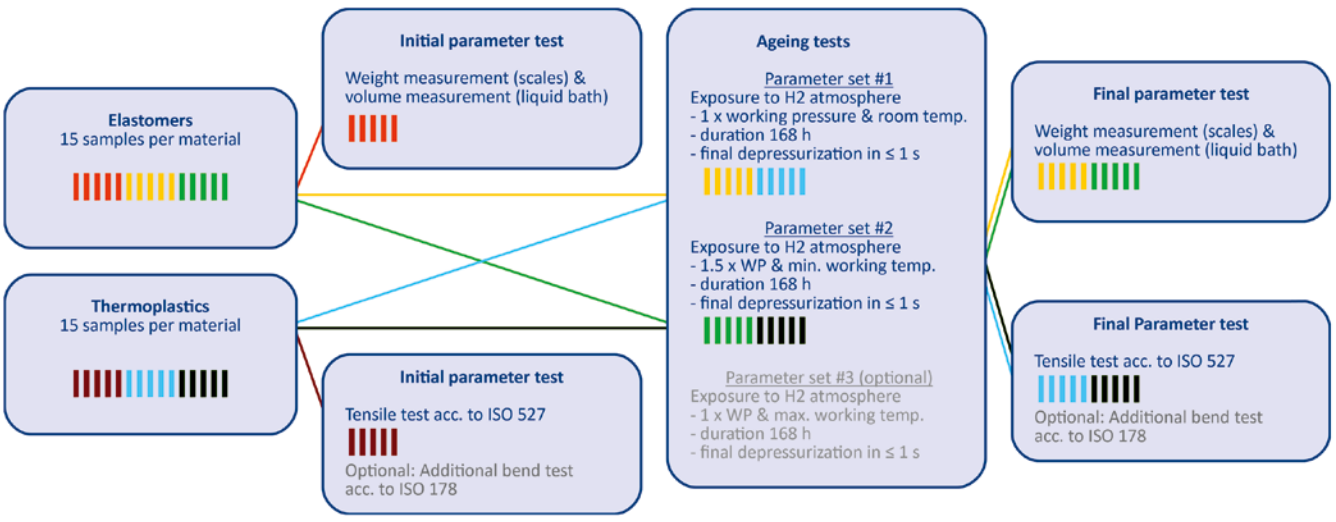

Fig. 1: New test sequence [Source: TesTneT]

Category: Stocks | **Author:** Sven Jösting

FUEL CELL STOCKS ON THE MOVE

Sven Jösting's market analysis

Every day, more and more encouraging stories are popping up on news tickers, saying that companies, cities, towns and entire unions of countries, such as the EU, want to step on the gas in terms of climate action, with hydrogen definitely playing a crucial role in their efforts. While people are still sparring over what production method we should focus on, I am sure green hydrogen will win out in the end. Though we may need some of that blue gas to get to green.

Fig. 1: Historical prices of the six fuel cell companies discussed in this issue [Source: wallstreet-online.de] Retrieved Sept. 3, 2020

The world's hunger for energy shows no signs of letting up. In fact, electrification is becoming ever more popular. But until we see the hydrogen and fuel cell market make a breakthrough on the world stage, providing energy for multiple kinds of applications, we will need to keep coal and gas power stations up and running. Obviously, steam-reforming blue hydrogen is not a zero-carbon business. However, the blue variant emits 70 percent fewer emissions than coal. In other words, we need to be completely open to new ideas and demand that governments take a long, hard look at all technology options on the table. Fuel cell and battery advocates could stop competing with each other, too, if we chose solutions according to suitability.

When Katsuhiko Hirose, once dubbed the 'father' of Toyota's Prius, was asked why German automakers have yet to make use of their head start in fuel cell R&D, he replied: "I have no idea what their issue is. German businesses are dooming themselves." Meanwhile, VW's chairman, Herbert Diess, has been chastised by Bosch CEO Volkmar Denner for ignoring fuel cells altogether. Bosch, which is VW's largest supplier, believes only hydrogen could help electrify several types of vehicles, trucks and buses among them. He expects the same to happen in the passenger car market eventually.

Businesses such as Canadian-based Ballard Power will be very happy to hear that. They will be one of the first to be able to ship fuel cell stacks for heavy-duty vehicles in large numbers, thanks to production facilities in China. Plus, Ballard has already completed several successful tests that put the company's products through their paces.

But not everything is going to be so straightforward during this hydrogen and fuel cell decade, neither in the real world nor on the stock market. If large listed oil and gas corporations, also known as Big Oil, get involved as well, we could see a sharp increase in the volatility of fuel cell stocks.

BALLARD AND THE INGREDIENTS TO A PERFECT SUCCESS STORY

Recent high volumes of trading saw Ballard Power stock shoot past USD 21 at one point. Subsequent profit-taking then caused the price to fall again. I would say this kind of correction is not unusual during an upward trend and gives investors another opportunity to (re)purchase shares. I expect investment banks to set price targets above USD 25 should Ballard provide them with good enough reasons and good news.

ANALYSTS RAISE EXPECTATIONS Some analysts have already begun to increase their targets. Not long ago, financial service firm Raymond James said that it sees the price rising to USD 28. Previously, Bernstein changed its target to USD 22. Plus, the National Bank of Canada put the stock on Buy. Still, there are some crucial questions that have yet to be answered. How well will the new stack factory in China do? What will be the profit margin? How much revenue can we expect? The company wants to provide some clarity on these issues at its Investors Day on Sept. 29. I think the event will be a success. I also believe the stock will attract the attention of many more analysts working for large investment banks. Few of them are watching the fuel cell market these days. That will change as soon as Ballard [Nasdaq: BLDP] partners up with another big OEM. Clearly, China provides the manufacturer with the perfect environment for growth. And a country that huge and populous could likewise serve as a springboard for expanding business globally. Reportedly, the Chinese government will announce the budget for its fuel cell and hydrogen program as early as the third quarter. I expect USD 100 billion at minimum, but we could be talking about as much as USD 500 billion over five to 10 years.

While China is Ballard's largest market for commercial vehicle stacks, a market which partner and shareholder Weichai

can serve with ease, the Canadian fuel cell supplier is not relying on one country alone. It generates 40 percent of its revenue in the People's Republic, another around 40 in Europe and 20 percent in North America, which means it can get through turbulent times pretty much unscathed. I think the company could additionally begin production in Europe, ideally in a partnership resembling Bosch and PowerCell's (where Bosch holds stock and manufactures fuel cells under license).

In a conference call, Ballard boss Randy MacEwen had the following to say about the company's second-quarter figures: "So I think what you can expect is a very comprehensive relationship that Ballard will strike with a major brand name partner, particularly with strong European exposure. We are not in a position yet to comment more on that, but there is a lot of work that has been going for the last six months on this front."

The above quote takes on a special meaning if you know major shareholder Broad Ocean, which has a 9.9 percent stake in Ballard, is rumored to be contemplating the sale of its Ballard stock. Given the fuel cell company's strong performance to date, that would be understandable.

Will Broad Ocean give another investor the opportunity to buy into Ballard? Broad Ocean's stake in the company could go to either Weichai (highly likely) or a strong OEM with European ties, or both, accompanied by another equity change, i.e., a purchase of shares, possibly together with a license agreement. In any case, the stock will not be traded openly on the market.

USD 65 MILLION VIA ATM PROGRAM Ballard said that by June 30, it had raised USD 64.7 million of the USD 75 million that it expected to earn via the issue of new shares, i.e., through an at-the-market program. But it is not like the company is in a rush to complete the transaction. If the price trends upward as much as it has, Ballard will not need to issue that many shares. Weichai's increase of its ownership stake can also be put on the back burner, considering Ballard's cash and cash reserves amount to a healthy USD 170 million. The company used up around USD 14.8 million in the quarter ended June 30. But I think it will be only a matter of time until Ballard can add another USD 25 million in liquidity. This inflow of cash will also indirectly ensure that the USD 30 million the company is planning to invest in its new factory in China is basically paid for so there will not be much of a dip in reserves. Way to go, Ballard!

In September, Ballard then announced its intention to raise another USD 250 million via an ATM program. The manufacturer could use the money to build a stack factory in Europe. It started out the same way in China, where Ballard and Weichai run production facilities at an ownership ratio of 49 to 51 percent. Prior to building the factory, Weichai had bought 19.9 percent of Ballard's shares. Now, a European OEM could either partner with the fuel cell business to erect a factory or directly acquire a stake in Ballard.

UNITED STATES IMPLEMENTS NEW TRUCK REGULATIONS Good news from California: The state government recently introduced new regulations on emissions from heavy-duty trucks, likely giving fuel cells a big boost in this crucial market. By 2024, zero-emission engines are to power between 5 and 9 percent of all new heavy-duty vehicles in the state. By 2030, new and clean Class 4 to 9 trucks are to make up 50 percent of the market. And another five US states signed a memorandum of understanding that commits them to a 30 percent target for HDVs by 2030 (see also pp. 30 through 39).

California's Orange County Transportation Authority intends to use FCEVs, reportedly 500 units, on long-distance trips, for which batteries are not an option because of long charge cycles, among other things. In Europe, multi-billion-euro budgets have been allocated for hydrogen and fuel cells in Germany (see p. 10), Norway and Spain, and a similar program is expected to be set up in the UK. The UK government is thinking about initially ordering 5,000 electric buses, many of which will be outfitted with fuel cells.

CHINESE PROVINCES AND CITIES RUSH AHEAD China is slated to announce its national hydrogen and fuel cell program in the third quarter this year. From what can be gleaned so far, the program will focus on trucks and buses and a hydrogen infrastructure, providing grants to promote the technology. In contrast to Europe, the budget is certain to exceed USD 100 billion. We may even be positively surprised by how much higher it could go.

Some of China's provincial and municipal governments have already rushed ahead. Even today, 200 fuel cell buses run on seven routes in Shandong, using fuel supplied by four stations across the city. The examples below illustrate the fervor with which the People's Republic has embraced the technology.

OUTLOOK More and more investors are beginning to acknowledge the opportunities offered by Ballard, the indisputable leader in several fuel cell markets. No other business has that much know-how or expertise in the field. Just recently, Ballard reported its stacks had run for as many as 50 million kilometers, i.e., over 30 million miles. The company also serves 85 percent of the fuel cell bus market. The price for one bus has reportedly dropped to EUR 375,000 and the target price for green hydrogen is EUR 5 per kilogram, according to Ballard, which would make for running costs of EUR 0.30 per kilometer.

I expect Ballard will grow its business, make strategic acquisitions when it has the chance and win over renowned partners by offering them an opportunity to invest in the company and license products. Another theoretical possibility would be its Chinese subsidiary's IPO – more or less as icing on the cake. Simply put, Ballard has all the right ingredients to become a stock market success story. I believe the company's shares could soon hit USD 25 and my recommendation would be to use the current low to buy stock.

BLOOM ENERGY – EXPLOSIVE NEWS FROM SOUTH KOREA?

Bloom Energy performed strongly in recent months, rising from USD 10 to over USD 19 until it was time for profit-taking. As expected, the stock is beginning to catch up to other fuel cell shares. Plus, Bloom [NYSE: BE] has formed a joint venture with Samsung Heavy Industries to come up with SOFC solutions for cargo vessels and tankers. The venture is regarded as a research partnership aimed at developing technologies Bloom wants to bring to market starting in 2022, with yearly production capacities of 300 megawatts.

Bloom is also profiting from the ambitious goals of South Korea's biggest oil and gas corporation, the SK Group. Expectations are that South Korea's hydrogen production plant capacity will rise to 15,000 megawatts by 2040 and that 6.2 million FCEVs will be driving in the country by then. The group owns 3,400 gas stations and intends to add hydrogen pumps to 1,200 of them by 2040. Its management thinks highly of >>

Bloom. Following a three-year partnership, the SK Group's chief executive said the fuel cell firm has the best electrolyzer money can buy right now. The shared goal is to connect 400 megawatts of fuel cell output to the grid each year.

Bloom said its electrolyzer technology will allow hydrogen production at a cost equal to that of gasoline by 2021. Wow! In a few years, this could lead to orders worth USD 500 million to USD 1 billion annually.

USD 230 MILLION GREEN BONDS PLACED IN THE BLINK OF AN EYE That was fast. While the original plan was to issue USD 200 million in green bonds in the form of green convertible senior notes, they brought in USD 230 million in the end. This provides Bloom with yet another nice cushion to finance operations and growth. The money will be used to redeem a portion of the company's 10-percent notes, refinancing them at low cost. When the bonds expire, borrowers will get 61.7 shares per USD 1,000 principal amount (about USD 16.21 a share). The bonds could also be paid back in cash or both cash and shares. It seems Bloom alone decides how and when. Borrowers get a good deal, as early redemption will net them 130 percent of the conversion rate, which makes sense if the stock trades over USD 20 – and prices over USD 20 or even USD 30 are not unlikely. This way, Bloom will get rid of USD 230 million in debt and gain more equity via issuing shares.

Overall, I think the figures cited in connection with Bloom's project in South Korea are huge but the market has yet to price them out. There is still much untapped potential. My new tentative target is between USD 25 and USD 30. The second half of the year, Bloom said, will bring good news. Is everyone keeping that in mind? Because not long ago, the number of Bloom shares sold short increased from about 18.6 million to more than 21.6 million.

FUELCELL ENERGY – POTENTIAL TO CATCH UP

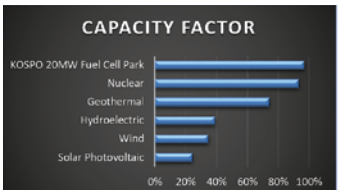

Fig. 2: In June 2018, FuelCell Energy started up a 20-megawatt fuel cell farm in Incheon, South Korea, at Korea Southern Power Company. Since then, the system, made up of eight SureSource 3000™, has been in operation 99 percent of the time. [Source: FuelCell Energy]

FuelCell Energy [Nasdaq: FCEL] has finally closed the chapter on its partnership with Posco. It seemed like a story with no winner. While FuelCell Energy said that Posco did too little with the fuel cell technology it licensed from the manufacturer, Posco stated that it lost around USD 800 million because of the companies' joint venture. It is now up to the arbitration court to work out a settlement.

In my view, FuelCell Energy's carbon capture technology developed in-house will draw in other clients besides ExxonMobil. The company must have also launched an at-the-market program by now in order to raise over USD 75 million. The aim is to become less dependent on Orion Energy Partners' USD 200 million corporate loan facility. At the same time, FuelCell announced the placement of more than 17 million shares, the result of warrants that Orion received for around USD 0.26 a share as part of a refinance deal. But while they may bring Orion a nice profit, the deal does nothing for FuelCell.

Still, I am inclined to believe these kinds of financial transactions will not have a significant or lasting impact on trading. It could even be possible that Orion sold stock short and exercised warrants to again cover its position. I, for one, think FuelCell is moving in the right direction.

And while new orders could soon be coming in from South Korea (see Bloom), fuel cell businesses are hoping for large contracts from European customers as well. In North America, FuelCell will benefit from the clean energy pledges made by several US states, where climate action is moving full speed ahead.

PLUG POWER BUYS GINER ELX AND UNITED HYDROGEN

Plug Power stock is resilient. On the plus side, Plug [Nasdaq: PLUG] completed its USD 123 million acquisition of Giner ELX and United. It will allow the company to not only produce hydrogen but also start making electrolyzers. As I often noted, this kind of deal would be needed for an upward trend in Plug's price. Moreover, the fuel cell supplier announced that it had received several sizeable orders, including a recent one from a new UK customer, Asda, a Walmart subsidiary.

But then, Plug again asked for fresh capital, placing new shares worth over USD 300 million or USD 10.25 apiece. The company is seizing the opportunity, though I think a price and a market cap exceeding USD 14 and USD 5.4 billion respectively is far from reasonable. I am aware that Plug has estimated revenue and profit to top USD 1.2 billion and USD 200 million by 2024. Still, I am wary of these numbers. At least, Plug is doing a good job at investor and press relations, having investors imagine a bullish trend. I would tread carefully, however.

I remain cautious because of the company's financing methods, i.e., debt, restricted cash and stock issues, and the markets in which it operates. What happens once a larger number of forklifts run on fuel cells and are outfitted with hydrogen tanks? It is not like Kion and others have suddenly stopped their activities in the sector. Ballard Power, which supplies stacks to Plug, is part of that market as well, though, as said, not the only company serving customers in this product segment. In the long term, Ballard will also reportedly ship fuel cells to Kion, a Weichai subsidiary and the number two supplier of fuel cell forklifts after Toyota.

I am watching Plug and might buy some stock if and when the company breaks even. In the second quarter, Plug reported a net loss of USD 0.03 per share and a net revenue of USD 68.07 million. I think Bloom and Ballard have much more potential.

And what about the company's major customers, Amazon and Walmart? Each have around 50 million warrants, priced at about USD 1.19 apiece, I assume. With gains of around USD 0.5 billion by now, both could pay as little as USD 119 million to exercise these warrants. We will need to see what happens. Plug could run the risk of losing them as shareholders. After all, both Amazon and Walmart do not need to own part of the business to have their materials handling equipment retrofitted, do they?

Nevertheless, good to read that Plug is planning to sell electrolyzers in Japan and is working on a new fuel cell to power drones aka unmanned aerial vehicles. Both markets are destined for growth.

NIKOLA MOTORS – HEFTY PRICE DROP AFTER PROFIT-TAKING

Fig. 3: Filling up a Nikola Two truck in the United States [Source: Nikola]

A temporary jump in Nikola's market cap to over USD 25 billion and a stock price topping USD 70 – on one day, even USD 90 – were quite the start. And yet, I stayed on the sidelines, which turned out to be the right thing to do. Sales, likely by original shareholders, and the registration of over 30 million shares for eventual placement have brought the price down to around USD 30 in the meantime. Nevertheless, the shares quickly rebounded, rising to more than USD 40, as news broke that Republic Services, the United States' second-largest solid waste collection provider, ordered as many as 2,500 battery-electric trash trucks, to which it could add another 2,500 later (see p. 36).

I believe Nikola [Nasdaq: NKLA] shares are a buy in the range of USD 30 to USD 40. Bookings of more than USD 10 billion are an impressive feat. Still, I would have wished that those who owned stock right from the start would have been subject to a lockup agreement lasting two to five years. Now, it may look like some people were or still are only interested in making a quick buck, a move that generates no extra cash for the business but merely lines the pockets of early stockholders.

While multiple battery-powered Tre trucks will reportedly leave the factory in the first quarter of 2021, the first hydrogen-powered Nikola Two vehicles will be delivered to major customer Anheuser Busch late next year. As for prototypes, they will presumably be available by this September. One thing is clear: Nikola's target market, HDVs for long-distance trips, will become an engine of growth due to many emission regulations in the EU, several individual countries and six US states, including California. The company will also benefit from policies in China, where it can – and, I think, will – position itself perfectly on the market. In collaboration with other businesses, Nikola is additionally planning to build 700 hydrogen fueling stations in the States and 50 in Europe. Vehicles will only be offered via full-service leases. In Europe, the price for travelling one kilometer in one of the hydrogen trucks Nikola intends to ship starting in 2023 will range from EUR 0.50 to EUR 0.75. >>

Of note are likewise Nikola's plans to partner with other industrial companies, Bosch among them. Batteries and fuel cells plus hydrogen will be the perfect combination for several types of vehicles. It will be interesting to see what OEM Nikola will win over for making the Badger. The company said the SUV can run on batteries, fuel cells or both.

WIKIFOLIO – ROLLER COASTER FEELING BUT LITTLE TO COMPLAIN ABOUT

My virtual BZVision portfolio shot up over 350 percent in two years, thanks to the price rallies Ballard Power and Bloom Energy experienced for a while. I sold some stock but overall, I remained fully invested in both companies. I am rather looking for medium-term than short-term gains. Still, if my expectations hold true, i.e., if Ballard, Bloom and FuelCell Energy were only gearing up before going full throttle soon, the current price highs will have been no more than an initial sign of what I believe fuel cell companies could achieve in the coming years.

As for Tesla, investors' euphoria knows no bounds. I wonder how high the price could still go, considering many, if not all, opportunities for growth have already been factored in. If people start selling their shares to take profit, my December puts will rise considerably in value. By contrast, I expect I will have to write off those expiring in September. But a lot can happen until December and I am inclined to believe Tesla's price hike from USD 350 to over USD 2,500 (prior to the 5-1 split) could prompt a move in the opposite direction in exactly the same way. How will the Robinhood fans react? Around 500,000 of them have bought Tesla stock. Is Tencent cashing in? And how will Tesla perform over the following quarters? Will the electric carmaker earn even higher windfall profits from regulatory credits? I have so far purchased an initial put position with a December 2021 expiry and a USD 1,500 (now USD 300) base price and will invest a great deal more if Ballard trades above USD 25.

Making up around 7 percent of my portfolio, the position is small enough not to pose a problem if the three fuel cell stocks mentioned above only grow by 10 percent. If, however, the shares increase by 20 percent or more, or if Tesla's race to the bottom, I will have enough fresh capital to invest in those companies again and perhaps in a business such as Nikola Motors. We will see.

DID ROBINHOOD INVESTORS PUSH TESLA?

What for ups and downs Tesla has seen. High-volume trading each day prior to the 5-1 split pushed the price to more than USD 2,200 – at the beginning of this year, it was below USD 400. A USD 420 billion market cap for what exactly? After the split, the stock continued to rally to over USD 500, or more than USD 2,500 based on the old price. While observing the rally, I was reading comments saying that a kind of swarm-like trade was boosting Tesla [Nasdaq: TSLA]. Investors on portals such as Robinhood, a neo-broker that boasts around 13 million users, nearly 500,000 of whom have bought the carmaker's stock, seemed to be reinforcing each other's bids, which reminded me high-frequency trading.

Short sellers have certainly lost a lot of money by speculating that Tesla's price would fall. However, shorts now add up to no more than 12 million prior to the split and 60 million thereafter. There were times when, according to pre-split numbers, 40 million Tesla shares were sold short. But I feel the current dip left a vacuum that could soon lead to the placement of another large number of shorts based on a market cap of over USD 450 billion. In all, 7 percent short interest is not that much, considering some funds and stockholders may make a hedge to secure unrealized gains while not selling their shares directly.

Well-known short sellers remain convinced that the electric carmaker is completely overrated and point to some questionable accounting entries, for example, in terms of receivables. Among those short sellers is Jim Chanos, who predicted Enron's stock market fall from grace, suspecting the energy company was hiding its debt. He also recently made USD 100 million by shorting Wirecard stock. He will be keeping his Tesla shorts. And David Einhorn, of Greenlight Capital, expects the carmaker's days at the top to be numbered should it join the S&P 500. In other words, "buy the rumor, sell the fact." Einhorn claims the company used some creative accounting methods to meet the requirements for the index.

Can you call all of this healthy? Is that kind of trading even regulated? Can you use it to hype a business to infinity or bring a company to its knees?

I have yet to hear any good reason that would justify Tesla's high valuation today. An analyst working for Credit Suisse recently raised the price target from USD 700 to USD 1,400 but noted the new assessment is based on the general expectation that Tesla will sell over 2.2 million cars in 2025 while showing a price-to-earnings ratio of 30.

OVER 90,650 UNITS SOLD Tesla was expected to sell between 69,000 and nearly 100,000 vehicles in the second quarter when accounting for factory closures because of Covid-19. In the end, it delivered 90,650. I suspect these units were from inventory and could have been highly discounted. The second-quarter revenue of over USD 6 billion was a good look for the company. But the profit of USD 104 million, or USD 0.50 per share, was mostly the result of selling USD 438 million in regulatory credits. Because these credits have little to do with a company's actual profit margin, I would not consider them operating income from selling electric vehicles.

Things are getting interesting now that Tesla will have to compete with Nikola Motors. A USD 5,000 deposit will secure customers preorders for the Nikola Badger. However, the SUV will not be manufactured by Nikola itself but an OEM, rumored to be FiatChrysler. This is of note insofar as FiatChrysler has been buying the bulk of its ZEV credits from Tesla to avoid the penalties imposed on high-emission fleets. As a result, Nikola is turning into a Tesla competitor in more ways than one, albeit indirectly. Not to mention that FiatChrysler subsidiary Iveco is already in a partnership with the fuel cell business.

STOCK SPLIT: A SMART STRATEGY To make the stock at least appear cheaper, Tesla decided on a 5-for-1 split. The move was well received by the market, though it did not change the carmaker's financials. But a lower price could attract new investors, who may be interested in buying shares at USD 450, just not at USD 2,200. Still, it was a purely cosmetic change. As it looks now, the number of shares may eventually reach 1 billion, including the impact of options (convertible notes

Fig. 4: Tesla product family – Model 3, Semi, Model S and Model X [Source: Tesla]

and Musk's milestone payments). The split did have a positive impact for a short time. But that will be all. I see no way the stock can sustain its current high.

My conclusion: While many hedge funds and small-time investors currently have enormous unrealized gains from their Tesla investments, the question is what will happen if the US market drops due to an ever-growing number of Covid-19 cases or if the brawl between President Donald Trump and the Chinese government leaves a mark. And how will the 500,000 Robinhood investors respond? I agree with people such as Chanos, even though I would never short a stock. Rather, I would pursue a limited-risk approach and buy some puts (see BZVision on Wikifolio). In my view, that is the best pro-fuel cell and anti-battery investment you can make. ||

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: Education and training | **Author:** Christine Uphues

CIRO INTRODUCES FUEL CELLS TO COESFELD STUDENTS

New class on hydrogen at German secondary school

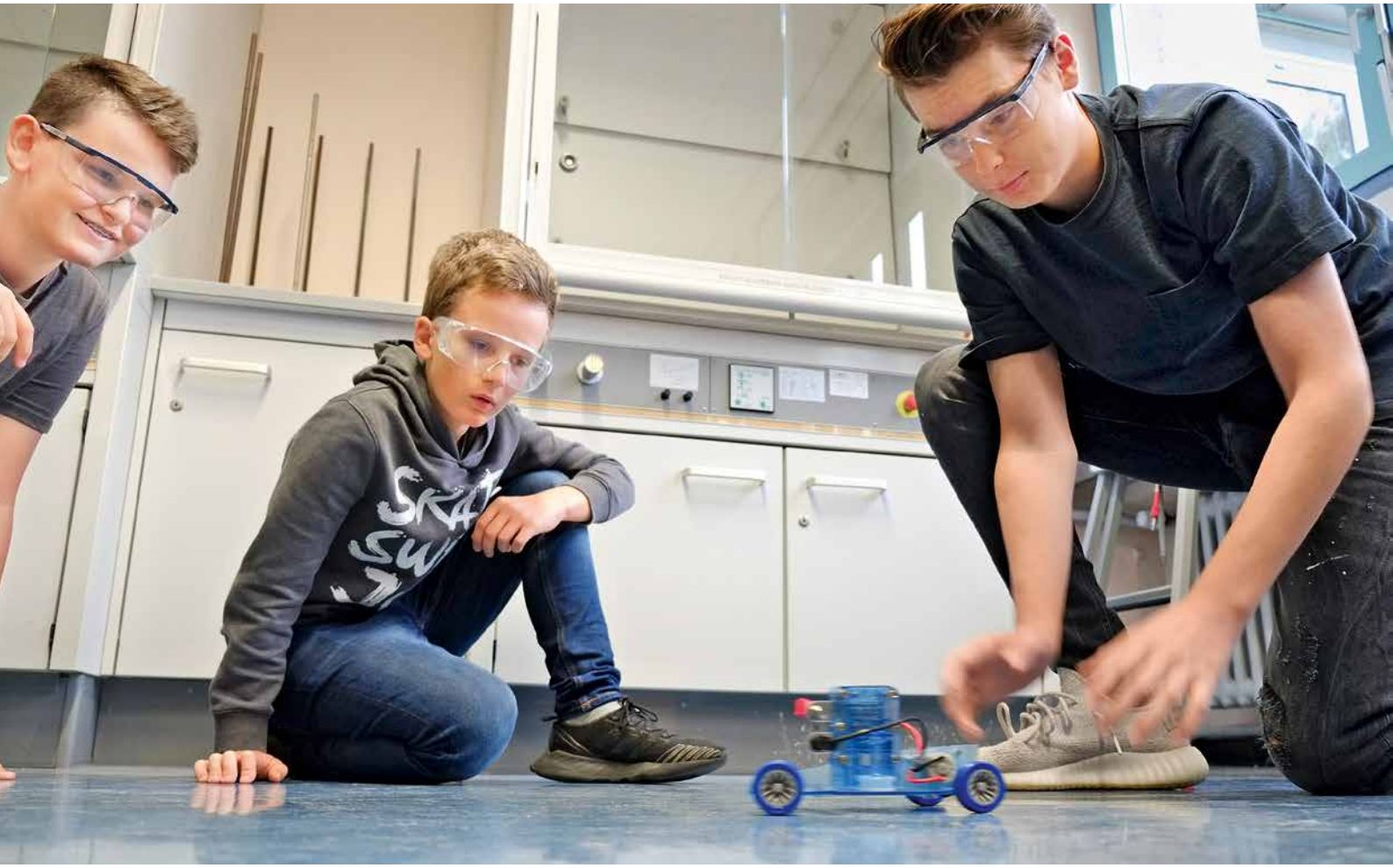

Fig. 1: Students stand next to an FCEV model [Source: CIRO]

From where will we get our electricity in the future? What will we use to power our cars and trains? How can we live sustainably, without the use of fossil fuels? Finding answers to these and other questions is the aim of an Erasmus+ project involving students and teachers at Heriburg-Gymnasium, a German secondary school in the state of North Rhine-Westphalia, as well as British, Greek and Spanish partner organizations. The project is led by Ariema Energía y Medioambiente, a spin-off from Spain's National Institute for Aerospace Technology. British partner Cyber Coach Smart is developing a digital learning game.

The three-year endeavor, called CIRO, consists of multiple phases. Phase 1 led to the development of new, partly interactive teaching materials on energy generation and climate change. In a one-week meeting at Greek partner institute Center for Renewable Energy Sources, the teachers from the participating schools in Spain and Germany agreed to create five modules for the CIRO project. They then gathered and sketched out ideas for experiments as well as class projects and published them on Moodle. The modules are:

1. Climate change and sustainability
2. Renewable energies
3. Energy storage
4. Integrating hydrogen into clean energy systems
5. Hydrogen applications

These modules will now be completed in the second phase, extended because of the Covid-19 virus outbreak. At Heriburg-Gymnasium, this meant adding an optional course to the mandatory curriculum. The current CIRO class, made up of eleven 8th graders, spends three hours a week working in the chemical lab under the supervision of Christine Uphues, the school's chemistry and English teacher.

With the help of digital measuring tools and carbon dioxide sensors, the students initially conducted combustion experiments to gain a deeper understanding of the anthropogenic greenhouse effect. These experiments were followed by research on renewable energy to impart basic knowledge of green hydrogen storage requirements. The school also bought a large number of fuel cell toy cars to demonstrate to the class how the technology works. In January, at open house, a large solar panel then powered a

INSPIRED BY CYRUS SMITH

The project takes its name from engineer Cyrus Smith, known from "The Mysterious Island," a Jules Vernes novel published in 1877. In it, visionary Vernes paints a picture of the future in which fossil fuels are no longer needed and the only means of powering the globe is water: "I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable."

ERASMUS+

The project is being supported with EUR 235,000 by the Erasmus+ program. This European Commission program promotes education, training, youth development and sports, focusing on partnerships that help people acquire skills and key competencies in an increasingly digitized world. Its aim is to support collaborations among young people so they can learn from each other and shape the future of Europe together.

Hofmann's voltameter despite rather gray weather. On the same day, oxyhydrogen samples illustrated to the younger and older guests how much energy hydrogen contains, while the in-house 3D printer was used to create a model of a fuel cell's inner workings.

The students also visited Wuppertal's Bergische Universität, examining microbial and enzymatic fuel cells in the university's school student lab in an effort to broaden their knowledge of fuel cells. A trip to Mülheim-based Max Planck Institute, which was scheduled for later this year, would have given them an opportunity to gain deeper insights into hydrogen storage technology. But that visit had to be postponed because of the pandemic.

The main language used in Heriburg's CIRO class is English so students can communicate with their partner school peers and come prepared for the third phase of the project. This way, the course is not only a sensible addition to Heriburg's bilingual European School curriculum but also offers students a glimpse into the world of science, where English is the de facto standard. Additionally, it helps them see that speaking another language is not as hard as they may think, even if giving a presentation in a foreign language can seem quite challenging to a 14-year-old with a bad case of the jitters.

In the third and last phase, the project will turn into a competition allowing students to showcase their creativity. Because of Covid-19, the contest was rescheduled to take place in spring or summer 2021 in Huelva, Spain. The task will be to come up with innovative ideas for improving air quality and reducing local dependence on climate-damaging means of energy generation in the partner cities. In Heriburg's case, the question will be what Coesfeld could look like in the future and what can be done to lower the school's carbon footprint.

If possible, solutions are to include hydrogen technology. Two groups from each school will subsequently present their ideas and visions, with a panel of experts choosing the winners. Plans are to improve the competition in the following years and open it to new participants.

PROJECT RESULTS The teaching materials developed during the project have been adapted for use in different grades and at varying degrees of difficulty. While students in higher grades could be taught the Carnot process and be asked to perform efficiency calculations, Heriburg's 8th graders first had to learn the difference between molecules and atoms. In addition to the teaching materials posted to Moodle, the CIRO working group aims to develop learning kits that include fuel cell vehicle models, efforts complemented by the creation of the digital Ciro City game. The European Commission's funding of the partner schools' projects offers them an opportunity to purchase material that they would otherwise not have due to budget constraints. For example, Heriburg spent the EC funds on electrolyzer kits and digital tools to measure carbon dioxide levels, equipment that the school will also be able to use in other classes for a long time to come.

CLIMATE ACTION AT HERIBURG-GYMNASIUM In November 2019, Heriburg-Gymnasium held a Heriburg For Future event to raise awareness of sustainability and climate change among a higher number of students and a wider section of the local community. The results can be viewed on the school's website. In May, on Europe Day, a weather balloon equipped with a GPS unit was supposed to be sent into the sky to collect measuring data. Sadly, its launch was postponed too. Climate change, however, will not be stopped by Covid-19's path of destruction. The students continue to complete the modules while adhering to social distancing regulations. One can only hope that when the summer break is over, they will again be able to attend regular classes to develop their ideas. The students attending the first-ever German CIRO class will then be in the 9th grade and the organizers will be preparing for the competition in Spain. Another 8th-grade CIRO course is already ready to start working on the modules.

CONCLUSION Coesfeld's Heriburg-Gymnasium intends to use the chance CIRO provides to answer important questions about climate action and why people are pinning their hopes on hydrogen. Another aim is to see students become eco-conscious, responsible citizens, some of whom might later credit CIRO when taking up a job in the clean energy or the hydrogen industry. ||

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

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

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

STORAGE

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

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

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

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

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

MicrobEnergy GmbH, Specialist in Methanisation, Bayernwerk 8, 92421 Schwandorf, Germany, Phone +49-(0)9431-751-400, Fax -5400, *info@microbenergy.com, www.viessmann.co.uk*

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

Worthington Industries – Stako Sp. z o.o., 54 Poznanska, 76-200 Slupsk, Poland, Phone +48 598424895, *Sales-PL@worthingtonindustries.com, www.worthingtonindustries.com*

SUPPLIERS

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

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

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

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

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

TESTING

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

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

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

TesTneT Engineering GmbH, Schleissheimer Str. 95, 85748 Garching / Munich, Germany, Phone +49-(0)89-237109-39, *info@h2-test.net, www.h2-test.net*

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

TEST STANDS

AVL List GmbH, Hans-List-Platz 1, 8020 Graz, Austria, Phone +43-316-787-0, Fax -400, info@avl.com, *www.avl.com*

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

EVENTS

Please have also a look at the following homepage, where you can find upcoming online and live events and regular updates to the schedule:
www.h2-international.com/events

European SOFC & SOE FORUM EFCF-Conference with Exhibition
October 20 to 23, 2020,
in Lucerne, Switzerland
www.efcf.com

North America Smart Energy Week with Hydrogen + Fuel Cells International
October 21 to 22, 2020,
Las Vegas, USA
www.solarpowerinternational.com

WindEnergy
global on and offshore event
December 1 to 4, 2020,
in Hamburg, Germany
www.windenergyhamburg.com

Next Generation Electrolysers
online only December 8 to 9, 2020
www.nextgen-electrolysers.com

2021

Fuels of the future
International Conference on Renewable Mobility
January 18 to 22, 2021,
in Berlin, Germany
www.fuels-of-the-future.com

EL-motion
10th Austrian Electric Mobility Congress
January 27 to 28, 2021, in Vienna, Austria
www.elmotion.at

HyVolution
Hydrogen event for energy, industry and mobility
February 10 to 11, 2021, in Paris, France
www.hyvolution-event.com

Hypothesis XV
HYdrogen POwer THeoretical & Engineering Solution International Symposium
February 15 to 17, 2021, Muscat, Oman
www.hypothesis.ws

FC Expo
International Hydrogen & Fuel Cell Expo
March 3 to 5, 2021, Tokyo Big Sight, in Tokyo, Japan
www.fcexpo.jp

World Hydrogen Fuels Summit
Accelerating Hydrogen Policy, Strategy & Projects
March 10 to 11, 2021,
in Amsterdam, Netherlands
www.worldhydrogenfuels.com

IRES
International Conference and Exhibition for the Storage of Renewable Energies
March 16 to 18, 2021,
in Düsseldorf, Germany
www.eurosolar.de

Energy Storage Europe
March 16 to 18, 2021,
in Düsseldorf, Germany
www.eseexpo.com

Connecting Green Hydrogen APAC
March 23 to 24, 2021,
in Melbourne, Australia
www.greenhydrogenevents.com

European Zero Emission Bus Conference (ZEB)
Learn what is next in clean transport
March 23 to 24, 2021,
in Paris, France
www.zeroemissionbusconference.eu

ZEROEMISSION 2021
together with H_2 HYDROGEN & FUEL CELLS
March 31 to April 1, 2021,
Piacenza Expo, Italy
www.zeroemission.show

Hannover Messe
Hydrogen + Fuel Cells Europe
April 12 to 16, 2021,
Hannover, Germany
www.h2fc-fair.com

Energy Storage World Forum
organized by Dufresne
May 19 to 21, 2021,
in Berlin, Germany
www.energystorageforum.com

Innovationsforum Mobility
June 8 to 9, 2021,
GDI Gottlieb Duttweiler Institute,
Rüschlikon, Switzerland
www.innovationsforum-mobility.ch

ees Europe & Power2Drive Europe
exhibition for batteries and energy storage systems
The exhibition for charging infrastructure and e-mobility
Conference:
June 8 to 9 – Fair: 9 to 11, 2021,
in Munich, Germany
together with Intersolar Europe
www.ees-europe.com
www.powertodrive.de

The Hydrogen Technology Conference & Expo
co-located with Carbon Capture Conference
June 9 to 10, 2021,
in Stuttgart, Germany
www.hydrogen-worldexpo.com

International Hydrogen Symposium
June 14 to 15, 2021,
Chamber of Commerce,
Hamburg, Germany
www.h2symposium.de

World Hydrogen Technologies Convention WHTC
together with f-cell + HFC
June 20 to 24, 2021,
Montreal, Canada
www.whtc2021.org,
www.hyfcell.com

COMPRESSORS
Energizing the Transition to the
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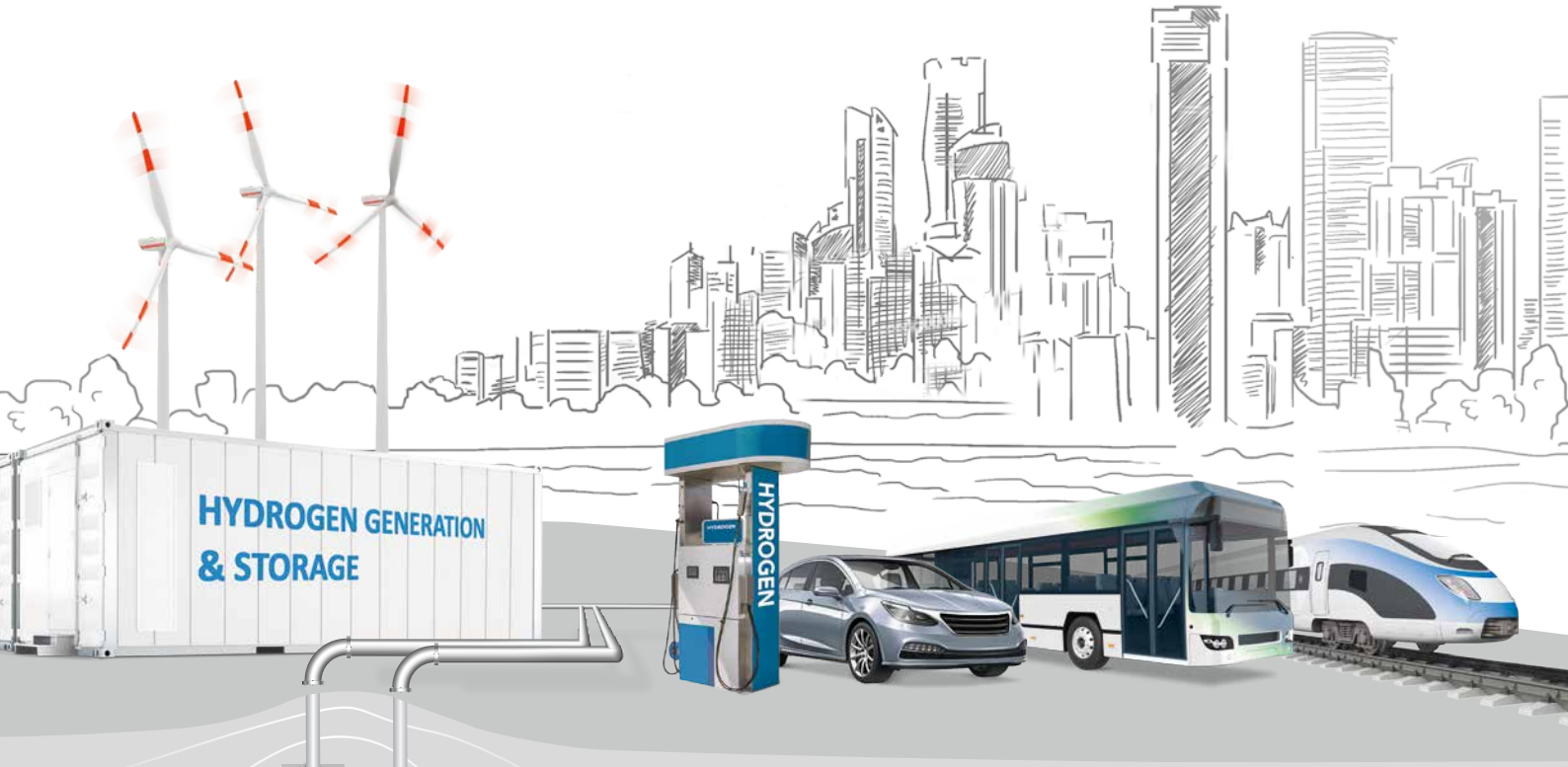

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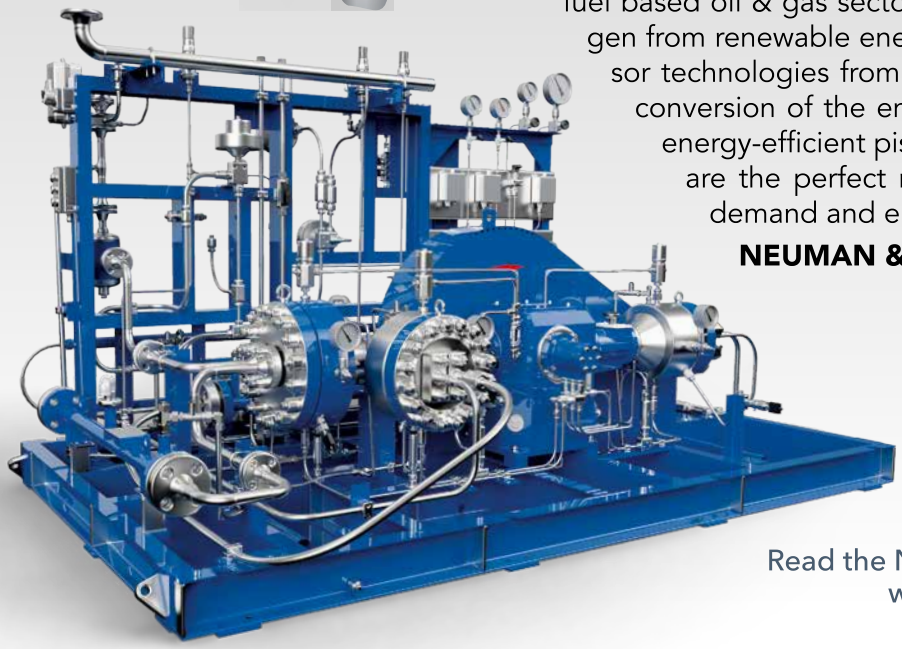

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