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THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

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HANNOVER MESSE

SNOOZE, YOU LOSE

Dear readers

It's now become apparent to most market observers that the energy supply in Germany and Europe is going to fundamentally change. Instead of fossil fuels it'll be up to renewable energy sources to keep the economy and society moving.

Given what we know today, hydrogen will be paramount to this transformation process since there's no way of linking up the various parts of the energy ecosystem without recourse to hydrogen gas.

The underlying conditions that make this possible have already been put in place: Both the German government and the European Parliament have made clear their support for a hydrogen economy. For months now, other national hydrogen strategies have been popping up around the world – surely evidence that the hydrogen industry will be on a global scale. The announcement of the Inflation Reduction Act by the Biden administration in the US made it abundantly clear, if it wasn't already, that hydrogen is the fuel of the future.

Despite current developments speaking for themselves, many industry players are still hesitant when it comes to making concrete investment commitments. And at the numerous trade fairs and congresses in the fall, the overwhelming majority of attendees were heard grumbling about the government, complaining that it hadn't created suitable safety nets.

High-ranking company execs are calling for more regulation on this and that. Sometimes the criticism is directed at the approvals procedures, other times it's EU legislation or local stipulations. The reasons given as to why a decision can't be made right now are many and varied, but most of them are used as excuses for doing nothing.

Yet all those who are just talking while sitting on their hands, need to ask themselves what they are really waiting for. For state guarantees that ensure the maximizing of profits whatever happens? For binding assurances that safeguard the company's survival for the next 20 years?

At the H2Expo in Hamburg, for example, one manufacturer of stationary hydrogen engines said: "We can bring out 1 gigawatt, but there isn't the demand." Elsewhere a representative from the gas industry boasted: "Hydrogen could flow through our pipes if it were there."

Needless to say, we still don't have sufficiently affordable green hydrogen yet, which explains why hydrogen engines, for want of a viable business model, are still not in demand and pipelines continue to carry only fossil gas.

And yes, the electricity market does need overhauling to create more planning certainty. And the shortage in chips and skilled personnel does need addressing. But this reputedly unclear legal situation and the lack of renewables capacity mustn't be used as justification for failing to act right now.

If some people really want to wait for others to solve the challenges we are facing, then they are welcome to do so. Whoever holds off until all issues have been settled between natural gas and hydrogen network operators and the chips are pouring in again, will have months, if not years, to twiddle their thumbs. However, the cake may well have been polished off by then.

Of course, much work still has to be done at a policy and regulatory level – and quickly. The impact that policy can have is now plain to see. Emissions limits or other environmental rules have been introduced in every imaginable branch of industry, be it for the automotive sector, for cement producers or for wind farm operators – and successfully so. The latter are required to reduce their own energy consumption annually by 5 percent (see p. 44).

There are times when the government is able to act relatively quickly if it wants or needs to – something we can see at the moment with LNG terminals on the German coast. But what's the point of having ostensibly hydrogen-ready terminals if they don't get any green hydrogen because those with the cash and the know-how don't get their act together, don't get involved in renewables expansion or building up production capacities for electrolyzers, fuel cells or hydrogen engines?

You'll often hear people citing a "new German swiftness," but this is usually when asking others to move at a faster pace rather than to gauge their own actions. It's fascinating to listen to large companies and corporate groups in particular gladly pointing the finger of blame at politicians and demanding they set up "appropriate framework conditions" without themselves putting in the prep work.

So here's a heads-up: Anyone who genuinely believes that, in times like these, they can palm off all risk to the German government or the taxpayer, is in very real danger of becoming a bystander. Those who avoid taking responsibility today for their own company and/or employees, could soon bitterly regret their lack of action.

And that would be a crying shame because – after 50 years of delays and disputes – we can't afford to waste any more time in bringing about social and environmental change and meeting our climate goals so that ultimately the planet can remain a habitable place. ||

Best wishes

Sven Geitmann
Editor of H2-international

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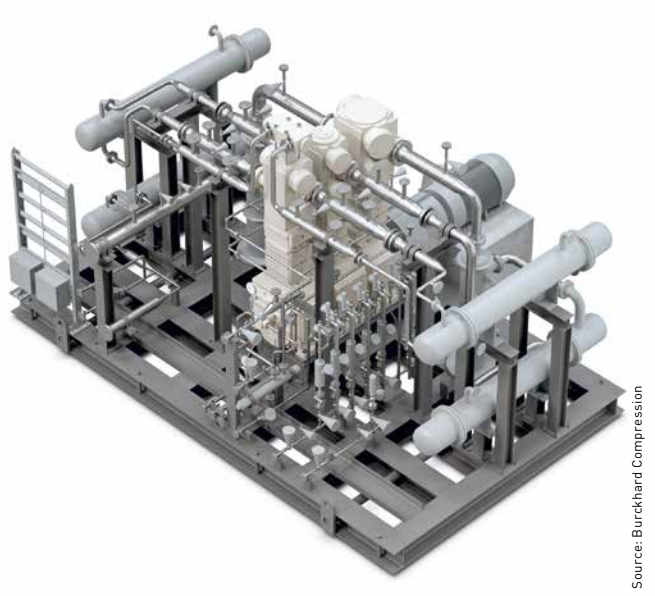

Source: Burckhard Compression

DVGW CHOOSES NEW PRESIDENT

Fig.: Jörg Höhler
[Source: DVGW/Kurda]

At the end of November, the German gas and water industries association DVGW appointed Jörg Höhler as its new president. The move came after his predecessor Michael Riechel left the post earlier than anticipated. The DVGW told H2-international that Riechel, who is also board chairman at Thüga, wanted to install his successor in the role of DVGW president at an earlier date "with a view to his retirement from the company in the course of the coming year." It was said that the 61-year-old recognized the time had come to free up his post and therefore decided not to wait until the executive committee election at the next general meeting, which is why an extraordinary meeting was called.

Höhler previously held the position of vice president and has been a member of the executive committee since 2015. From 2009 onward, the 56-year-old engineer has been a board member of German energy company ESWE Versorgungs and has also been on the board of energy supplier Kraftwerke Mainz-Wiesbaden since 2017. He highlighted that "even in these difficult times, understanding and communication between one another" and "solidarity" are important in order to "mobilize all resources within the association network." He went on to explain: "Over the past few years the DVGW has become a key player in the hydrogen transformation."

The office of vice president is now held by Markus Last who has been a member of the executive committee since 2014. ||

myFC GOES BANKRUPT

For many years Swedish company myFC repeatedly made headlines with its specialist fuel cell applications – ranging from fuel cell systems for cell phones to electrically powered bicycles. In fall 2022 the disclosure was made that the company, which has been listed on the Nasdaq First North Growth Market since 2014, had filed for insolvency at the district court in Stockholm on June 30. Trading platforms indicated a liquidity squeeze as the cause.

The Scandinavian company had previously presented test models of an initial user-friendly portable charging device back in 2008 (see HZwei, April 2011). In 2011 it introduced Powertrekk, a hybrid device consisting of a PEM fuel cell and a lithium-ion battery for supplying power to mobile terminals. The Powertrekk 2.0 came "onto the market" in 2015 but failed to make a profit. ||

TENDERS FOR HYBRID POWER PLANTS

In summer 2022, the German government passed its Easter Package of energy policy amendments designed to accelerate the expansion of renewable energies, a move that it hopes will foster substantial innovation in hydrogen projects. According to the new raft of measures, tenders for inventive concepts that incorporate hydrogen-based electricity storage will be started at the end of this year. The tenders are expected to provide support for schemes with plant combinations comprising onshore wind turbines or solar plants that feature hydrogen as a storage gas and that will feed power into the grid via a common interconnection point. Note that this will exclusively apply to electrolytic hydrogen that is used for electricity generation. It is expected that 400 megawatts of installed capacity will be initially put out for tender in 2023. This figure is then set to increase every year, reaching 1,000 megawatts by 2028. ||

NEW CEO AT SIQENS

Fig.: Thomas Klaue
[Source: Siqens]

At the beginning of December 2022, Siqens appointed a new chief executive officer. Thomas Klaue made the move into management from the company's advisory council where since 2019 he had represented the interests of Siqens' founders. Klaue has relevant experience of capital market areas and has been working in various leadership posts at a range of organizations for over 15 years. His aim is to "replace today's still widespread diesel generators with a carbon-neutral alternative" using the company's own methanol-operated fuel cells. Co-founder Volker Harbusch, who previously ran the company single-handedly, will now concentrate his efforts on the technical side of the business as chief technology officer. ||

HYDROGEN FOR INDUSTRIAL HEATING

The German environmental foundation DBU published a short study in mid-December 2022 which investigated the use of hydrogen for process heat. The organization, working in partnership with the Gelsenkirchen net-zero port initiative, the Wuppertal Institute and Fraunhofer UMSICHT, analyzed the best way for the heating and industrial sector to become climate neutral.

The authors found that: "In addition to electrification with green power, the shift to green hydrogen is shown to be a valid option in many cases. From the initiative's viewpoint, power grid expansion is therefore equal in priority to the construction of hydrogen infrastructure, which not only supplies major industrial corporations but at the same time enables the early connection of process heat clusters that primarily comprise midsize companies."

Lars Baumgürtel, spokesman for the Gelsenkirchen project, said: "Up until now, the electrification of process heat has been the preferred way forward. The study cracks this approach wide open and demonstrates that hydrogen is an equally legitimate alternative. For Germany's energy transition, it therefore makes sense for many businesses to develop redundant, hybrid systems in parallel." ||

Deutsche Bundesstiftung Umwelt (DBU), Dekarbonisierung der Prozesswärme im Klimahafen Gelsenkirchen, December 2022

COMPLAINTS HALT HYDROGEN PROJECT IN SWITZERLAND

Fig.: The machine room at the hydropower plant looks almost exactly as it did when it was commissioned in 1920 [Source: Axpo]

Swiss energy concern Axpo had intended to build a hydrogen production facility at the Eglisau-Glattfelden hydroelectric power plant. However the project, which was to be located directly on the German-Swiss border, has now been stopped due to complaints about the granting of a special license.

The hydrogen plant was expected to have a capacity of over 2.5 megawatts and produce around 350 metric tons of green hydrogen annually. Sufficient to save approximately 1.5 million liters of diesel from road transport every year, according to the supplier's calculations. The plant could have been enlarged to 5 megawatts as demand increased. Plans indicated potential for several refueling stations in the area to be supplied with hydrogen.

Nevertheless, in order for construction work in Eglisau-Glattfelden to go ahead, an existing building belonging to the power plant, located outside the construction area, would have needed to be demolished and replaced. To allow this to happen, Axpo had submitted an application for a special license which was then approved by the local authority. This prompted objections to be lodged by three private individuals at the court of appeal for building matters in the canton of Zürich, which then upheld their complaints. It was said that there are "no particularly significant and objective grounds" for conferring the special license. The public interest in producing energy here was purportedly given less weight by the court than the anticipated traffic noise from trucks resulting from the project.

Commenting on the decision, Guy Bühler, project lead at Axpo, warned: "The decision to narrowly interpret the law even in the case of an environmentally beneficial plant that is in line with the 2050 energy strategy will hamper decarbonization efforts." He added: "We very much regret that we will once again be prevented from making a greater contribution to Switzerland's decarbonization."

Despite the project coming to an abrupt halt, Axpo intends to proceed with other building plans involving green hydrogen and complete further projects in Switzerland. Bühler now sees legislators as bearing responsibility. "Conditions need to be created that enable innovative projects to be carried out and thus make it possible to channel urgently needed investment into the energy transition." ||

200 HYDROGEN UBERS FOR BERLIN

US transport company Uber is currently setting up a fleet of up to 200 hydrogen cars in Berlin. The first automobiles have been giving rides in the German capital since fall 2022, though the Toyota Mirai 2 vehicles were provided not by Uber but by the SafeDriver Group, which is the prime contractor for Germany. The goal of SafeDriver owner Thomas Mohnke is to enable sustainable mobility before cities ban the entry of diesel vehicles to downtown areas.

Mohnke, who has been in the limousine business for 45 years, told H2-international that Uber doesn't have any of its own vehicles; it merely brings drivers and cars together for the purposes of passenger transportation. "My role is to make recommendations rather than to instruct our subcontractors," explained the SafeDriver owner. He continued, saying that he has his own fleet of 150 vehicles, 40 of which are hydrogen cars.

Mohnke fully backs hydrogen as battery electric operation is "not really ideal" for shift work. In his opinion, fuel cell cars are "excellent," especially because of their short refueling times. He revealed that for early 2023 a separate ordering function will be integrated into the Uber app that will enable customers to explicitly request a hydrogen car. ||

Fig.: The first "hydrogen taxis" provided the free shuttle service at the DWV's parliamentary evening in Berlin

FRESH FACES AT DWV

The German hydrogen and fuel cell association DWV elected a new executive committee in early December, thus continuing its rejuvenation. From the original committee lineup there now only remains Oliver Weinmann who will lead the association's executive body for another two years. Silke Frank was reconfirmed as vice president. Uwe Ringel resumes the role of second vice, representing the interests of the German gas and water industries association DVGW within the DWV. Christopher Hebling from Fraunhofer ISE will no longer serve as deputy but stays on the committee as the last remaining representative from a research facility.

Bowing out from the executive body are Birgit Scheppat from RheinMain University of Applied Sciences, Johannes Töpler from Esslingen University, DWV founder member Reinhold Wurster from the company Ludwig-Bölkow-Systemtechnik and Alexander Dyck from the German Aerospace Center, although all of them had stood as candidates. The stepping out of Scheppat and Töpler marks the departure of two colleagues from the association's leadership who played a significant role in shaping the hydrogen education agenda over past decades. Which post will tackle education issues as part of the association's remit in future is uncertain.

Candidates from large corporations in particular were elected by a clear margin – evidence of the association's increasing engagement in industry matters as well as lobbying work. This resulted in several new representatives from the business community joining the ranks, for example Jürgen Guldner from BMW, Dirk Graszt from Clean Logistics and Heinrich Gärtner from GP. Despite the admission of Manuela Heise from Deutsche Kreditbank, the proportion of women on the DWV executive committee is still low at 14 percent.

The collaboration between the DWV and the DVGW, however, is drawing to a close. The word from membership circles is that the DVGW ended its cooperation by submitting a written termination notice. In view of the significant sums of money which the DWV has received as part of the alliance and will continue to do so until the end of 2023, a question mark now hangs over how the financial situation will play out going forward given the association's large and expensive offices in a prime location in central Berlin and much higher numbers of staff. ||

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

BREMEN IS THE PLACE TO BE

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Hydrogen Technology Expo Europe is a resounding success

Fig. 1: The H2BOT charges electric cars in situ without the assistance of an operator

The German city of Bremen was the place to be and be seen in 2022, courtesy of the Hydrogen Technology Expo Europe. It was the first time that such a large and lively hydrogen trade fair had been staged on the continent. In the space of just a year, the organizer had managed to nearly double the number of exhibitors from 180 to 350. On October 19 and 20, 2022, over 5,000 delegates – most of whom were trade visitors – made their way to the two exhibition halls. Such was the level of attendance that at times booth staff were given little pause between conversations. Nevertheless the event's future remains uncertain. Its proximity, both in terms of timing and location, to H2Expo in Hamburg means that there can only really be room for one show.

No two ways about it, Trans-Global Events did an excellent job. In contrast to German fairs, the British conference and exhibition organizer chose the right moment to focus on hydrogen and succeeded in drawing many industry players from Germany and beyond to Bremen, thanks to its attractive concept and professional delivery. Part of the HY-5 initiative involving Germany's five most northerly states, Bremen is now poised to become one of the major protagonists in a future hydrogen economy.

Considering the strength of this trade show, its rival H2Expo, which according to current plans is to take place without WindEnergy on September 26 and 27, is unlikely to stand a chance should the Hydrogen Technology Expo Europe actually go ahead on September 27 and 28. Two other German events are also slated for the fall: the H2.0 Conference in the northern town of Husum on September 11 and f-cell in Stuttgart on September 13 and 14. The need to merge the events in northern Germany or rethink the timetable would appear to be inevitable.

Kathryn Boyd, deputy trade commissioner for Europe at the UK's Department for International Trade, paid tribute not

just to the organizer but also to the German government for its rapid switch to renewable energies in such a large industrial nation. This set the bar extremely high for others, she said.

FROM MOBILE CHARGING ROBOT TO BATTERY ELECTROLYZER STACK Spread across the almost 15,000-square-meter (161,000-square-foot) exhibition space were a number of newcomers, such as Devinn. The Czech development company showcased its mobile charging robot H2BOT – a remotely controlled electric vehicle charger that runs on hydrogen. The presented prototype features a fuel cell system from Nuvera. The engineers from Jablonec nad Nisou are, however, open to additional development partners and are on the lookout for initial customers who want to assist drivers of electric vehicles. Rather than having to travel to a charging point, "instead the charging point comes to them," explained Devinn CEO Luboš Hajský.

Another company pursuing an unusual idea is Battolyser Systems from the Netherlands, whose technology combines a battery and an electrolyzer in a single unit. In 2016, Fokko Mulder's research group demonstrated on a laboratory scale that a nickel-iron battery is also capable of producing hydrogen when overcharged. It is understood that a reference plant is already in use at energy supplier Vattenfall and will continue to be operated by RWE which has since taken over the site. Meanwhile work is underway on a second production generation which will hopefully be ready for commercialization at the end of 2024, H2-international was told in Bremen. ||

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

F-CELL REINVENTS ITSELF

Baden-Württemberg fears being left behind

Last fall heralded the start of a new era in Germany's hydrogen events sector. The trade fair and conference once known as f-cell, organized by Peter Sauber Messen und Kongress for over two decades, took place in Stuttgart on October 4 and 5 – this time under the sole direction of exhibition center operator Messe Stuttgart. The venue, located right next to the city's airport, welcomed 60 speakers presenting the latest developments as well as 126 exhibitors who displayed their products across 5,000 square meters (53,800 square feet) of floor space. Given the ever-increasing number of hydrogen events and destinations, however, the key question is whether the city of Stuttgart, and the state of Baden-Württemberg in general, can keep pace with the competition.

The opening address signaled the official start of the conference under its new name of hy-fcell, the "hy" prefix added to demonstrate the equal footing given to hydrogen and fuel cells at the event. In future this new title will be used for international expos and conferences in a variety of locations – for example in Saudi Arabia which will play host from March 6 to 8, 2023. This arrangement was put in place as part of the visit by German Chancellor Olaf Scholz to the Middle Eastern nation.

As well as switching to a new venue in Stuttgart, the events program had also undergone a shake-up. Things kicked off the evening before the opening with a tour of local bars and eateries where participants who had arrived early could meet in a relaxed atmosphere. At the end of the first day of the conference, a dedicated Networking Night was held directly at the trade fair in the International Congress Center Stuttgart (ICS). The hy-fcell awards in three categories were presented during the opening ceremony.

Running in parallel to the conference was the new Speakers' Corner stage. The main sponsor of hy-fcell, the US federal state of New Mexico, was one of the presenters that took to the podium and invited potentially interested parties to establish the region as a hydrogen hub in the United States. Mark Roper from the Economic Development Department had traveled to the event especially, bringing with him a delegation that included Cabinet Secretary Alicia Keyes and members of the management team from Pajarito Power and Universal Hydrogen.

For several years from 2008 onward, the f-cell was held at Stuttgart's exhibition center under the umbrella of the Battery&Storage show – with Messe Stuttgart serving as co-organizer. Despite trying a range of different formats over a number of years, a critical mass of exhibitors failed to materialize at that location and Peter Sauber returned to the Haus der Wirtschaft building in the city center in 2018. Now Messe Stuttgart has started afresh, ensuring plenty of time for preparation, and has managed to achieve a breakthrough by attracting over 2,000 attendees to booked-out halls at the original exhibition center, as Stefan Lohnert, president of Messe Stuttgart, reported. He said: "I'm particularly delighted by the international reach of hy-fcell – with exhibitors and speakers from around the world and a notable 20 percent proportion of international visitors."

CONCERN FOR STUTTGART AS A TRADE FAIR DESTINATION To date, Baden-Württemberg and the metropolitan region of Stuttgart has played a globally important role in the automotive sector – as well as in the expanding area of hydrogen and fuel cells. Yet Andre Baumann, state secretary of Baden-Württemberg's environment ministry, sees this position under threat. As he remarked in his speech, he has watched the decline of the coal industry in Nordrhein-Westfalen with concern, saying: "If we don't want to become the Ruhr region of the 21st century, we need to be linked up to the hydrogen infrastructure."

He expressed his hope that the area would be connected to the European Hydrogen Backbone system. Nevertheless this is some way off, he continued, since Germany's northern states openly admit they will make locally produced green hydrogen available to their own industries first before transporting it south. "Not that we're being left behind." However something needs to be done in the weeks and months ahead, urged Baumann. ||

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

H_2EXPO MAKES A COMEBACK

Hamburg establishes itself as a focal point for hydrogen

Wind-derived hydrogen – it's a term that's been bandied about for years in the energy sector. In the past it was more of a blue-sky concept than a realistic prospect. Just a handful of demonstration projects were looking into the fundamental practicality of harnessing wind power for the purposes of hydrogen production. 2022 could well be the year that represents the start of the wind-hydrogen era. While relatively little has actually come to fruition, the plans for investment and construction are now so numerous and so definite that the arrival of wind-powered hydrogen production is virtually a foregone conclusion. This was certainly apparent at WindEnergy and H_2Expo, which ran concurrently from September 27 to 30 in Hamburg.

Fig. 1: German economy minister Robert Habeck at the opening of WindEnergy and H_2Expo

After a four-year hiatus, the WindEnergy trade show was once again staged at Hamburg's exhibition campus – live and in person. Due to the pandemic, the 2020 event was only available in an online format. Looking back, Bernd Aufderheide, president of Hamburg Messe und Congress, took stock of the much-altered political situation: "We are now living in a very different world."

A total of around 30,000 visitors made the trip to Germany's second-biggest city. The halls were well populated with roughly 1,400 exhibitors and the atmosphere was buzzing, particularly at the evening booth parties. It was therefore with fitting optimism that Aufderheide announced that the H_2Expo & Conference will, from 2023, be a stand-alone trade fair – held jointly with WindEnergy only every two years.

HABECK OPENS WINDENERGY

The star guest at the trade fair was German economy minister Robert Habeck who was invited to open the exhibition. That he chose to appear in person despite the then volatile political situation, with Germany's coalition government embroiled in arguments over the country's gas bill support scheme, speaks volumes about how much this sector means to him.

This was reflected in his keynote speech in which he emphasized the central role of both wind as an electricity generator and hydrogen as an energy carrier. He stated that he did not understand why some German states continue to hide behind a "10H" rule (which in local legislation dictates a large minimum gap between a wind turbine and residential buildings) and are not meeting the required expansion targets. Habeck said: "It's not the time for business as usual. If the groundwork is not carried out, we will fail."

He also took the opportunity to announce that Germany's national hydrogen strategy would be revised before the year was up. What's more, he indicated that the upswing was already underway, citing the approved IPCEI projects as an example. "The market will ramp up much more quickly than expected," the minister declared.

REGIONAL AND INTERNATIONAL IMPORTANCE OF H_2EXPO

The H_2Expo & Conference, which according to Aufderheide was held in this form for the first time, saw 60 exhibitors gracing the floor in Hall A2 alone. At its center, organized as part of the hydrogen conference, was an extremely diverse program of presentations and podium discussions that ran across the four days of the event – available free of charge and accessible to all participants. That said, the exhibition entry fees were themselves relatively expensive, not that the pricing seemed a particular deterrent given the high number of attendees.

The content covered a range of subjects including production, transportation and utilization of hydrogen on land and

> "We need impetus and prospects to enable the rapid expansion of the wind and hydrogen economy. [...] It's time to put climate first."
>
> *Bernd Aufderheide, board chairman at Hamburg Messe und Congress*

H_2EXPO

The very first H_2Expo was held back in 2001 in Hamburg (see fig. 2) under the direction of Ines Freesen and succeeded in filling an entire exhibition hall. However, the delayed market entry of some products meant that the event then switched to the congress center before disappearing completely. In future the H_2Expo & Conference will again take place on an annual basis, running in parallel with WindEnergy every two years.

Fig. 2: First H_2Expo in 2001

at sea as well as global value chains and the large-scale build-out of local infrastructure and guidelines on the harmonization of international standards. The limelight was shared by both regional and international projects.

For instance Aivars Starikovs, board chairman of the Latvian Hydrogen Association, had explained prior to the event: "Looking ahead, all three Baltic states are in a position to be key suppliers of green hydrogen for EU industry. Estonia, Latvia and Lithuania can, together, deliver 831 terawatt-hours of renewable power for the production of green hydrogen – that's equivalent to at least 16 million metric tons a year." However, he continued, this capacity can only be realized through close cooperation at a political and industrial level. Starikovs also underlined the significance of the city of Hamburg for the hydrogen economy: "The H_2Expo & Conference is able to perform the important task of building bridges between Northern and Eastern Europe so that the economic and ecological challenges can be tackled jointly from a stronger position."

NATIONAL AND INTERNATIONAL DECLARATIONS The wind sector used WindEnergy as a platform to make targeted demands aimed at politicians. In the Hamburg Declaration, leading associations from the wind industry (Global Wind Energy Councils, WindEurope, WindEnergie, VDMA Power Systems, Renewable Hydrogen Coalition) stated their position on the current energy and climate crisis and articulated their needs which, in their view, require energy policy decisions to be taken as a matter of urgency.

In addition, the North German Hydrogen Network signed an agreement on interregional collaboration to support the market ramp-up of the hydrogen industry and the implementation of northern Germany's hydrogen strategy. Organizations involved in this were the Renewable Energy Hamburg cluster agency (EEHH), the Schleswig-Holstein Renewable Energy Network Agency (EE.SH) and the Mecklenburg-Vorpommern hydrogen energy cluster (WECMV) as well as the WindEnergy Network (WEN), the WAB business network and the Cuxhaven economic development agency (AfW).

What's more, Hamburg and the Canadian province of Newfoundland and Labrador signed a declaration of intent that aims to foster cooperation at an international level. Both parties expressed their willingness "to share their experience and knowledge gained and to channel their expertise and strengths in a planned and coordinated way so as to build and develop a global, self-sustaining hydrogen economy." Speaking to H2-international, Tom Rose, mayor of Stephenville in Newfoundland, appeared delighted and "extremely proud" that the agreement was ready to be signed in Hamburg after a preparatory period of just seven months. ||

HUSUM WIND

WindEnergy in Hamburg and Husum Wind in Nordfriesland take place biennially in alternating years. The Hamburg event offers a more international flavor while the trade show held in Husum, famously described as the "gray town on the sea" by poet Theodor Storm, has a more German focus. In October 2022, H2-international asked the exhibition company from the latter about the importance of hydrogen for Husum.

To what extent will hydrogen play a role at Husum Wind in the future?

Due to its primary importance for German industry, the topic of green hydrogen will once again be a particular focus for Husum Wind next year. The trade fair is creating a dedicated platform by providing a separate hydrogen-themed space in Hall 5 for the first time along with an accompanying forum program. It will also offer networking opportunities for leading technology companies in this sector to meet final off-takers.

Will there be a continuation of the previous New Energy fair?

The New Energy fair was held for the last time in 2018 and won't appear again in this form. Instead there will be the Future Energy & Mobility Days which will run in Husum from March 9 to 12, 2023. It's the first trade show that will present all cutting-edge technologies from the mobility and energy sectors in one location – from electric scooters to giant agricultural machinery, from wall chargers to photovoltaic plants and micro wind turbines. It's a chance to pick up and try out the technology of tomorrow. In addition to the large-scale exhibition there will be a program of information and conferences on exciting, forward-looking topics.

What format will the watt_2.0 conference take over the coming years?

Husum Wind and watt_2.0 will continue cooperating in 2023. The H2.0 Conference "Green hydrogen economy in the regions" organized by watt_2.0 will take place as part of Husum Wind on the day prior to the trade fair on September 11, 2023. The "Industry meets Renewables" conference will be held on the first day of the show, and there will be an open expert forum running throughout the four days of the fair.

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

COMPETITION BETWEEN USA AND GERMANY

Hopes for Germany's national hydrogen strategy 2.0

Fig.: Werner Diwald calls repeatedly for greater planning certainty

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Which country will be the first to establish a hydrogen economy? It's not just the German energy sector that has been plagued by this question. Following the introduction of new legislation in the United States – the Inflation Reduction Act – which sets out highly attractive conditions for creating a hydrogen industry, Germany once again risks being left on the sidelines. That's why representatives from German businesses and associations have joined forces to argue the case for swift political action.

The challenge is immense, given that the targets for ramping up future electrolyzer capacity have increased at both a German and a European level: Originally it was a case of reaching 40 gigawatts in Europe by the year 2030. Since May 2022 the goal has been to expand production capacity for electrolyzers tenfold by 2025. In Germany the new expectation is to install 10 gigawatts by 2030. The previous target was just 5 gigawatts. However, to get even close to these figures (the European Union currently has 3 gigawatts installed) would require specific measures to foster the required scaling and create incentives for investment in a hydrogen economy – something that is lacking at present.

One demand put forward by the German hydrogen and fuel cell association DWV, which is now being reiterated by its chairman Werner Diwald at every event, calls for the rapid implementation of the 37th BImSchV (37th Ordinance on the Implementation of the Federal Immission Control Act). For months, the DWV has been pointing out that industries act on a global scale and primarily invest where the best conditions can be found. So long as an absence of clarity prevails in Germany (with regard to the EU's revised Renewable Energy Directive RED II and the 37th BImSchV), industry does not have the necessary planning certainty to make investment decisions, explained Diwald.

> "Everything speaks in favor of quickly creating the legal framework for the use of green hydrogen in refineries. Yet the German environment ministry has been avoiding taking the decisive step for years."
>
> *Werner Diwald, DWV chairman*

Andreas Rimkus, hydrogen representative from the SPD parliamentary group, has also repeatedly made the following appeal to German environment minister Steffi Lemke in unison with the DWV: "Please release the 37th BImSchV!"

Meanwhile the US has acquired a far greater level of planning certainty following the Biden administration's announcement of the Inflation Reduction Act. Since then, an increasing number of European electrolyzer manufacturers are openly considering expanding their production capacity there rather than investing in Germany. Against this backdrop, Diwald warns that in just a few weeks circumstances could arise that mean Europe would lack the capacity to establish a hydrogen economy because the order books of manufacturers may potentially be already filled with US commissions.

The US Inflation Reduction Act, according to the DWV head, is based on Germany's renewable energy law EEG. According to his remarks, those responsible in the US looked extremely closely at the EEG and adapted its principle for hydrogen. What the German response to it could look like is still undecided. Ingrid Nestle, head of the climate protection and energy working group of the Greens parliamentary faction, declared that now isn't the time to provoke a one-upmanship battle.

TAXONOMY

In early 2022 – notably before the Russian invasion of Ukraine – the gas sector had been delighted when Brussels decided that natural gas and nuclear energy are sustainable. Chairman of the German gas and water industries association DVGW Gerald Linke said at the time: "The EU Commission's proposal shows both consideration and foresight: Investment security creates the necessary conditions for the continued reliable and affordable supply of heat, power and fuels to 450 million EU citizens. [...] The gas infrastructure in Germany is critical to the success of the energy transition in connection with the essential use of hydrogen."

HYDROGEN STRATEGY OVERHAUL German industry, however, is hoping for a revision of the country's national hydrogen strategy. Various ministers have, time and again, stated that a new draft is in the pipeline. The original aim was to present the second version before the winter break, though at the time of writing that seems unlikely since the German economy ministry especially is busy tackling issues on several fronts.

To underline the urgency of the current situation, a total of 30 companies and associations from the energy sector sent an open letter to German economy minister Robert Habeck on Nov. 10, 2022. In this communication, a copy of which has been seen by H2-international, the DWV asks on behalf of all signatories not only for a rapid enactment

of the 37th BImSchV but also for more planning certainty in general. Diwald stated: "Germany needs an immediate response to the USA's Inflation Reduction Act which is supporting the scale-up of the hydrogen economy by providing over USD 50 billion in secure resource funding. Unless the German government takes immediate action there is a risk that […] the hydrogen industry will relocate to the USA."

AFIR DECISION On Oct. 19, 2022, meanwhile, members of the European Parliament voted in favor of the Alternative Fuels Infrastructure Regulation or AFIR, demonstrating their agreement with the targets proposed by the European Parliament's transport committee. In doing so they endorsed the recommendations put forward by report author Ismail Ertug and his colleagues from the Committee on Transport and Tourism. One such suggestion is that in future the maximum allowable distance between individual hydrogen refueling stations in Europe should be fixed at 100 kilometers (62 miles).

Hydrogen Europe called the decision to adopt the AFIR proposal "a clear signal that clean hydrogen mobility is a practical and realistic solution to move away from fossil fuels in the transport sector." The association reckons that up to 1,780 hydrogen filling stations could be made available across Europe by the end of 2027 as a consequence. These stations could supply up to 59,000 hydrogen trucks, six times more than had been originally planned. The hope is that the construction of sufficient numbers of hydrogen filling stations will encourage vehicle manufacturers to bring more fuel cell vehicles onto the market at an earlier date.

Jorgo Chatzimarkakis, CEO of Hydrogen Europe, seemed equally pleased with the result of the vote on another legal act – FuelEU Maritime. He said: "Today's vote represents the parliament's strong position and one that goes further than the commission's proposals and sends a positive signal for the introduction of hydrogen in road and maritime transport." ||

TRANSFORMATION OF THE AUTOMOTIVE INDUSTRY

The likelihood and extent to which the German economy ministry is interested in taking a different political approach compared with previous times can at least be partially inferred from the makeup of a new committee of experts. Initiated at the end of June 2022, the 13-member working group entitled "Transformation of the automotive industry" is part of the strategy platform set out in the coalition agreement that is dealing with the readjustment of the automotive and mobility sector. Its members, who were appointed by minister Robert Habeck for this legislative period, include relatively few representatives from large automotive concerns (only the VDA automotive industry association and VW Commercial Vehicles), yet four university professors and two representatives from research institutes. Nonetheless 30 percent of its members are women. The group's task is to smooth the way for around 15 million fully electric cars to be on the road by 2030.

Category: Policy | **Author:** Korinna Jörling

H_2 INDUSTRY HOPES FOR LEGAL CERTAINTY

The long wait for RED II

Without legal certainty, businesses cannot invest. But why haven't European legislators succeeded yet in creating clarity for the hydrogen industry? And what is already known about the future sustainability criteria for green hydrogen?

Producing renewable hydrogen-based fuels is only worthwhile if they can be counted towards fulfilment of the minimum quota in the meaning of the EU's Renewable Energy Directive (RED II). Currently, a binding minimum quota for the percentage of renewable energies in the total energy consumption only applies to the transport sector. However, mandatory quotas for the industrial sector are foreseeable. Once creditability is given, green H_2 producers will be able to earn more money than with conventional gray hydrogen.

WHAT IS THE STATE OF AFFAIRS? Whether a produced RFNBO (renewable fuel of non-biological origin) molecule is creditable depends on whether the sustainability criteria were met during its production. The EU Commission was tasked in the 2018 Renewable Energy Directive with setting sustainability criteria for RFNBOs by December 31, 2021 in two so-called delegated acts. The first of these is to stipulate the electricity obtainment criteria (Art. 27 (3)) and thus the criterion of renewability. The second defines the method for calculating greenhouse gas intensity (Art. 28 (5)) and thus the criterion of greenhouse gas saving.

The challenge for the EU Commission is immense. If the criteria are too strict, production costs could be so high that market ramp-up would be severely limited or only feasible with the help of high financial support. If the criteria are too soft, hydrogen as a climate protection technology would be rendered meaningless. If for example water electrolysis is run with the average electricity from the German grid instead of purely renewable electricity, however, this would produce higher overall greenhouse gas (GHG) emissions than the production of fossil (gray) hydrogen.

The delegated acts have caused real excitement in the course of their preparation. From the beginning, the industrial sector as well as EU member states and civil society organizations have paid them much attention. In addition to stakeholder workshops and consultations with officials, they were the subject of numerous open letters, expert opinions and discussions.

After the Commission had nevertheless, or precisely because of this, kept quiet for a long time, starting 2021 the first details on the shape of the legal acts were announced. Following initial reactions and particularly after the public consultation on the first official drafts in the summer of 2022, the Commission moved towards the industry's concerns on a number of points, but has not however backed away from its basic interpretation of the criteria already laid down in the Directive. The current state of the criteria is as follows:

WHEN IS ELECTRICITY OBTAINMENT DEEMED ADDITIONAL? According to the Renewable Energy Directive, the "additionality" of the electricity used in the production of the fuel needs to be established (obtained from additional renewable energy generation capacity added to energy grid of EU member state). Furthermore, the production of the renewable electricity must be temporally and spatially correlated with its application. This means the electricity needs to be generated in the vicinity of the water electrolysis system and near to the time of the hydrogen production.

According to the current drafts of the European Commission, the delegated act on renewable electricity obtainment stipulates that the electricity for water electrolysis must be obtained through direct supply contracts (power purchase agreements, PPAs) in order to be counted. The renewable energy installations for the power outputs agreed in such a contract must have been put into operation no earlier than 36 months prior to the electrolyzer. They must also not have received any government funding, unless the installation was renovated ("repowered") with investments comprising at least 30% of the investments for a new facility or unless it was a research or development project.

Furthermore, in a transitional phase up to January 1, 2027, softer criteria shall apply. In this time period, the electrical energy installations can have been subsidized. In Germany, for example, this would mean that post-EEG plants would be allowed to be used for PPAs. Plants in operation before January 1, 2027, according to the provisions of the transitional regulation, can continue to be used for up to ten years until the end of 2036 at the latest.

In addition, there is a provision for the use of so-called surplus power. Grid electricity used for the electrolysis that would have otherwise been curtailed can be credited as fully renewable. Still unclear is how the required proof of approval by the respective responsible transmission system operators can be brought forward.

Another exception is RFNBOs that are produced in (geographic) bidding zones with a previous year's share of renewable energy (percentage of total sources for grid generation) of over 90% on average. In these bidding zones, the RFNBOs produced from grid power are considered entirely renewable and the electricity does not need to be purchased through PPAs.

These criteria are intended to ensure the additionality of electricity production. The basis for this was the desire of lawmakers to not divert the existing portions of renewable energy to meet the massive electricity demand of the hydrogen economy, but rather to create additional incentives for the expansion of renewable energies.

HOW WILL THE TEMPORAL CORRELATION BE VERIFIED? The temporal correlation of electricity generation and hydrogen production is considered to be fulfilled when electricity production and consumption lie within the same 60-minute interval. There is also a transitional rule for this criterion. Up until March 31, 2028, correlation within an interval of one quarter of a year is acceptable. To give producers more flexibility, electricity storage systems can be interposed, for which the same criteria shall apply. Furthermore, the non-transitional criterion automatically takes over once the electricity price at the market falls under 20 euros per MWh or under 0.36* emissions trading price (EU ETS).

WHEN IS THERE GEOGRAPHICAL CORRELATION? Geographical correlation is considered to be met if the electro-

lyzer and the electricity generating station are located in the same bidding zone. Alternatively, electricity may be sourced from adjacent offshore bidding zones. If no transmission constraints are present, the electricity can also be obtained at the same price from connected bidding zones. On this point, the EU member states are given room for maneuver, as they are allowed to enact further (stricter) criteria at national level to avoid grid congestion.

For the German federal government, this could be an option to avoid additional grid bottlenecks, which due to the good potential for renewable energies in northern Germany, could increasingly arise in consumption centers in southern Germany. For RFNBO producers, however, the member states' interpretational leeway means additional uncertainty, as it could take more time for national regulations to be set and utilizable.

HOW IS GREENHOUSE GAS INTENSITY CALCULATED? RFNBOs are "low-carbon fuels" if they meet the minimum requirement of 70% greenhouse gas reduction compared to conventional fuels. In order to determine the greenhouse gas intensity, a binding, EU-wide uniform method of calculation is needed. The calculation methodology includes the value-adding steps of production, processing, transport, combustion and CO_2 capture. It also sets the fossil reference value, compared to which the emissions (in CO_2 equivalents) must be at least 70% lower, for hydrogen-based fuels. This reference value was set as 94 g_{CO2eq}/MJ.

If RFNBOs are produced with renewable grid electricity (renewable according to criteria in Art. 27 (3)), the GHG intensity can be input as 0 g_{CO2eq}/MJ. If grid electricity is used for water electrolysis in a way that is not compliant with the electricity obtainment criteria, then the GHG intensity is the CO_2 intensity of the overall national power grid.

The more contentious aspects of the Commission's proposals for this delegated act, however, are the CO_2 sources that may be used for the synthesis of more complex RFNBOs, such as e-kerosene. Acceptable, according to the latest drafts, are biogenic sources such as CO_2 from biogas plants, carbon capture from air (direct air capture, DAC), carbon capture from combustion of RFNBOs and recycled carbon fuels, and natural CO_2 sources that would otherwise not be used.

CO_2 capture from industrial sources such as cement works or power plants would be relatively cheap and is available. Capture from industrial sources, with the exclusion of electricity production plants, is therefore to be acceptable until December 31, 2040. To producers of RFNBOs, this has not been thought out far enough. However, the widely supported proposal to divide industrial sources into long-term avoidable and non-avoidable sources of CO_2 (e.g. cement plants) was not taken up by the Commission.

WHAT IS TO BE EXPECTED NEXT? The proposals have varying appraisal among industrial stakeholders. While some can live with the proposed compromises or even call for stricter criteria, others find them unacceptable. Agreed by all is the need for the process to go faster: There must now be clarity as quickly as possible. This means that, firstly, the Commission should present the final versions as soon as possible and, secondly, that the member states should transpose the requirements into national law without delay after they appear. In Germany, this means the swift enactment of the 37th BImSchV, the 37th ordinance on the implementation of the German emissions reduction law (Bundes-Immissionsschutzgesetz).

In order to exert pressure on the Commission, the European Parliament has also intervened in the meantime. In a vote on the revision of the Renewable Energy Directive in mid-September 2022, the Parliament approved a motion tabled by Markus Pieper (European People's Party) by 314 votes to 310. Accordingly, the Parliament is in favor of not defining the criteria for electricity obtainment in the form of delegated acts but rather in the main text of the Directive, in Article 27 (3). Furthermore, the principle of additionality is to be stricken. Unclear at this time is whether the Parliament will adhere to this position during the negotiations on the revision of the Renewable Energy Directive.

When clear criteria will be defined is still unclear. It would be possible for the Commission to present the final versions not long from now. The publication would be the starting signal for the two-month period during which member states can object to the draft by qualified majority vote. This period could optionally be extended by another two months. In this scenario, the criteria could be transposed into national law starting the second quarter of 2023 at the earliest.

Should trilogue negotiations between the EU Council, Parliament and Commission ensue in response to the Parliament's proposals, the delegated acts of RED II would be in effect until the revision of RED II goes into EU law or until its national implementation (expectable starting 2025).

Another aspect could be clarified during the trilogues: So far, the criteria only apply to hydrogen-based fuels in the transport sector. However, it is possible that in the future they could also apply to other sectors, in particular the industrial sector.

As complex and controversial as the criteria may be, without them RFNBOs will not achieve their climate protection potential. Until an agreement is reached, the oft-invoked development of a hydrogen economy is at a standstill. ||

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REGULATED H_2-PRODUCTION

Unrestricted hydrogen production that is not aligned with the supply of renewable energy significantly increases electricity generation by fossil fuel power plants, thus raising the levels of carbon dioxide emissions. Not only is that disastrous for the climate, it's also something we absolutely cannot afford given the current gas shortage.

Electrolyzers make an important contribution to the energy transition when their operating hours correlate with the times at which a large amount of electricity is available from renewable sources. This is why they should, first and foremost, serve as flexible options in the energy system.

If, on the other hand, electrolyzers run virtually uninterrupted, then they necessarily fall back on the prevailing German power mix which still comprises high proportions of fossil-based energy sources. If there is insufficient green electricity available, then a conventional power plant has to be fired up for the purposes of hydrogen production in order to cover the additional demand arising from the electrolyzers.

Due to the ongoing lack of renewables and the way conventional market mechanisms operate, the facilities that are most-

ly used to cover such peak loads are fossil-fueled and environmentally damaging power plants – particularly quick-starting gas power plants. Consequently, the unrestricted operation of electrolyzers provokes a rise in the consumption of expensive, scarce natural gas. This situation will be further exacerbated if – as planned by the German government and many industry players – large numbers of high-performance and inflexible electrolyzers enter service at an ever faster rate but the expansion in renewables fails to keep pace. That is certainly unwise and definitely not at all good for the climate.

Instead, electrolyzers should primarily serve as flexible options in the electricity system at this present stage of the energy transition. Of course, with highly flexible operation comes challenges: Electrolyzers need to be controlled intelligently according to the availability of wind and solar power. Peripheral equipment, too, must ensure this flexibility. And the off-take of hydrogen needs to work smoothly in the face of fluctuating hydrogen production.

Yet these challenges are solvable, as representatives from the eco-energy space in particular are able to demonstrate. The solutions, however, require further research, development and, undeniably in some areas, also creativity. In other words, it would indeed be feasible. Nevertheless, as it stands there are practically no effective incentives, thanks to the current laxity of criteria for hydrogen production.

As long as the rules governing electrolyzer operation fail to make maximum climate protection their guiding principle, the operators are in no way required to meet the challenges outlined – the upshot being that we will struggle to find the necessary solutions to ensure an efficient and renewable energy system.

The European Commission therefore needs to create a framework which, from the get-go, has the synchronization of hydrogen production and renewables provision at its center. Transitional rules can be helpful at the beginning. However, they should in no way cement the status quo. By contrast, they should put in place the requirements right now that will ensure that the electrolyzer projects being rolled out in the next few years use high and increasing proportions of green power.

For the reasons mentioned above, we need binding and ambitious green power criteria to enable a fast ramp-up of environmentally responsible hydrogen production. This should incentivize the flexible operation of electrolyzers by limiting their full-load hours. This limit could be specified, for example, in line with the renewables share in a particular member state. Furthermore, electrolyzer-based hydrogen production should be harmonized with the supply of renewable energy by means of hourly synchronization.

Further and highly ambitious expansion of renewable energy sources is the central foundation and prerequisite for establishing a sustainable hydrogen economy. Therefore all European member states should likewise be driving forward this renewables expansion. Because of the difficulties of procuring electricity from new plants in the short term, though, unsubsidized electricity supplies should be used for hydrogen production in the interim. This ensures a certain level of financial support for renewable generating facilities thanks to the electrolyzers acting as off-takers for the green power produced, while at the same time older plants could be used to produce hydrogen.

The geographical relationship between electrolyzers and solar/wind plants is highly relevant since the operation of electrolyzers must not lead to an increase in grid congestion. Introducing these rules at a European level is difficult due to major differences in infrastructure, control areas and electricity market design across member states. This is where individual EU states should themselves take action and, where necessary, use the opportunity to further restrict the geographical relationship. In Germany, electrolyzers could, for instance, be considered as part of congestion management within redispatching, with the choice of electrolyzer location taking into account the congestion event.

By implementing these criteria and taking a flexible approach to electrolyzer deployment, it is possible to produce hydrogen that is both low in emissions and low in cost. ||

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FASTER EXPANSION

Hydrogen is not an end in itself, but an important building block for the transition to climate-friendlier infrastructures. An absolute prerequisite for this is the additional expansion of renewable energies. The recent decision by the EU Parliament has left this hanging in the balance.

For the climate-friendly transformation, green hydrogen is an essential factor. It enables some industrial applications and parts of the transport sector to be defossilized or decarbonized. But: To be able to produce green hydrogen, an additional and faster expansion of renewable energies is urgently required. However, a corresponding proposal submitted by the EU Commission in May 2022 was rejected by the EU Parliament. Whether the additional renewable energies so urgently needed for hydrogen production will be available is therefore a question for the time being.

If no additional renewable energy resources are created, to draw on already existing ones would require taking away from the electric power sector. This would, on the one hand, reduce the overall energy efficiency, since the conversion of electricity into hydrogen is accompanied with efficiency losses. On the other hand, the quantities of electricity used for hydrogen production in the power sector would have to be partially replaced through fossil energies, which is counterproductive to CO_2 reduction and therefore to meeting the legally set climate targets for Germany.

In the current situation and against the background of the fossil energy crisis resulting from the Russian war of aggression on Ukraine, it is imperative to not promote fossil structures that are not urgently required for security of energy supply.

The hydrogen economy must additionally be viewed against the backdrop of the energy policy triad of prosperity, energy security and climate protection. This triad must be approached intelligently. The hydrogen economy certainly offers potential in this, since it is sometimes the only decarbonization and defossilization option for important applications in the industrial and transport sectors. For example, it offers immense opportunities as a storage and flexibility option for the power sector and as a substitute for the CO_2-intensive blast furnace process in the steel industry. Furthermore, a variety of jobs and export opportunities for clean technologies can be created.

For assurance of planning and investment security, producers of hydrogen and its derivatives have been placed on a fixed roadmap (Hydrogen Roadmap Europe), by which

stakeholders can avoid bad investments as well. A flexible use of electrolyzers can ensure that hydrogen is produced with low emissions and at low cost. Legacy clauses – with exemption periods for plants built in the early term as well as sensible entry paths into the regulations for additional renewable energies – could combine a quick ramp-up of the hydrogen economy with possibilities for long-term planning.

If the EU Parliament decides to relax the rules on hydrogen production, though, this could drive up electricity prices and thus the production costs of hydrogen even further. Because: The electricity withdrawn as a result would then have to be replenished through expensive natural gas-fired power plants, which in turn would increase the cost of renewably produced hydrogen.

In addition to criteria for electricity obtainment, other sustainability criteria must also be set – and globally. We now have the opportunity to shape and establish a global hydrogen economy that contributes locally and internationally to the achievement of climate targets and sustainable development goals (SDGs), creates value in all partner countries and strengthens international relations. For this, it is crucial that the EU cooperates with all relevant actors in the partner countries to unite the respective interests in the best possible way.

We need climate protection in order to secure our economy in the long term. In short: On a Rhine without water, we will not be able to transport goods efficiently. We must not forget one thing: Climate protection today is always cheaper than climate protection tomorrow. Therefore, we should now implement serious climate protection measures as quickly as possible. We need a rapid ramp-up of the hydrogen economy in order to achieve the climate targets. To this end, we should in particular accelerate and incorporate more in the expansion of renewable energies. ||

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GRID-SERVING ELECTROLYSIS

When is green hydrogen actually green? Defining this is crucial for ramp-up of the H_2 economy in Europe. And that is why it is good that the respective delegated act is finally to be published and provide an EU definition for the first time. This is good – despite its deficiencies, from my point of view.

Three criteria for the definition of green hydrogen are particularly important:

1. Origin: The electricity used to generate green H_2 must come from renewable energy plants or installations.
2. Simultaneity: The generation and the consumption of green electricity should demonstrably occur within one quarter of an hour.
3. Regionality: The production of green H_2 should not lead to more grid bottlenecks. Accordingly, the generation of the electricity and its consumption in the electrolysis must be upstream of the next grid node, or generation and consumption must take place before the next grid bottleneck.

Only when all of these are fulfilled is the electrolysis grid-serving, because only then does it unburden our power grid. The delegated act would therefore have to be structured in a way that promotes the grid-serving nature of electrolysis and thus maximally accelerates the expansion of renewables throughout Europe. Because that is the foundation for the establishment of a green H_2 economy as well as for the decarbonization of all sectors – and for meeting our climate targets.

Unfortunately, the delegated act does not match these criteria in all instances. Until April 2028, the temporal correlation is required within a time interval of one quarter of a year, rather than the quarter-hour interval already stipulated for electric grid feed-in/withdrawal accounting in Germany today. Starting in 2028, the correlation within one hour will be required.

The delegated act also does not try to guarantee the expansion of renewables via a compulsory grid-servitude but rather a so-called additionality, according to which almost exclusively electricity from new plants could be used as a basis for green hydrogen. For electrolysis stations that go into operation by the end of 2026, green electricity obtained from any eligible electricity generating installation that qualifies as renewable under the EEG laws (German renewables expansion) could have been included in some way, but the formulated exceptions only refer to the obtainment of electricity from the grid. Furthermore, in the case of a direct supplying of power, the electricity generating stations had to have gone into operation no earlier than 36 months before the electrolyzer. Yet for this, a spatially near direct supplying – including from old installations – would be much more grid-beneficial.

On the subject of spatial nearness: According to the latest draft of the delegated act, this criterion is already fulfilled when the electrolyzer and power generating structure lie in the same bidding zone. So I could produce electricity in Nordfriesland (extreme North of Germany) and run the electrolysis in Garmisch-Partenkirchen (extreme South). This is certainly not grid-serving.

Why is it nevertheless good that the delegated act will soon be in effect? Because only when legal certainty prevails will investments be made in the domestic green hydrogen economy.

The delegated act builds the foundation for targeted support of the use of green hydrogen via the generation of GHG (greenhouse gas) certificates. For this, the necessary adjustment of the crediting rules for e-fuels in the 37th BImSchV (ordinance on implementation of German emissions reduction law) has still to take place in 2022. Because only when the right incentives are created will significant quantities of green hydrogen be produced here in Germany and Europe.

Haste is needed: As part of the US Inflation Reduction Act, many billions are being invested in establishing the green hydrogen economy there. The consequence: US companies are currently buying up electrolyzers and the components needed for them. European electrolyzer manufacturers are considering moving production there, and US companies are increasingly acquiring interest in manufacturers from the EU in order to secure capacities for themselves.

For ramp-up of the hydrogen economy in Germany and Europe, equally strong incentives are urgently needed. Otherwise, after the solar and wind power plant industries exit, Europe is facing the collapse of the next crucial pillar of the energy transition. ||

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POSSIBLE ROUTES FOR HYDROGEN RAMP-UP

H2-Kompass provides foundation for H_2 roadmap

The looming climate crisis and the inadequate diversification regarding energy source countries made visible by the Russian aggression in Ukraine is evidence that more speed is needed in the energy transition. Hydrogen will play an important role in the energy systems of the future. Due to this time pressure, the German government has taken on the responsibility of making the ramp-up of the hydrogen economy more efficient. But how exactly is this to be achieved? What options are availa ble for carrying out this task, and what advantages and disadvantages are associated with them? Which actions need to be taken, and when, to enable the ramp-up, while avoiding unwanted path dependencies?

Fig. 1: World café "Priorisierung von Wasserstoff-Anwendungen" (prioritizing the uses of hydrogen) during the conference Wasserstoff-Dialog [Source: Svea Pietschmann, acatech]

These are the questions that Acatech (Deutsche Akademie der Technikwissenschaften eV) and DECHEMA (Gesellschaft für Chemische Technik und Biotechnologie eV) have been investigating as part of the two-year project H2-Kompass (Wasserstoff-Kompass) since June 2021. The central product of this project will be an orientation tool of the same name, available starting from the second quarter of 2023. This market-oriented, data- and fact-based tool can be used by policymakers to further develop a national hydrogen roadmap. This is what the German national hydrogen strategy of 2020 envisages. The project is being funded by the German ministry for education and research (Bundesministerium für Bildung und Forschung, BMBF) as well as the ministry for economy and climate protection (Bundesministerium für Wirtschaft und Klimaschutz, BMWK).

The basis of Kompass is, on the one hand, a meta-analysis. It evaluates relevant studies and strategy papers for Germany, the EU and other important countries around the world, and provides an overview of the current and future hydrogen quantities and requirements. This quantity structure and related technological issues are being verified and debated in a multitude of expert discussions.

WASSERSTOFF-DIALOG CONFERENCE IN AUTUMN 2022
The conference Wasserstoff-Dialog from October 10th to 12th, 2022 brought 370 stakeholders from the hydrogen community together in Berlin. Co-organizer of the conference was the research alliance Forschungsnetzwerk Wasserstoff, which held a meeting during the first part of the conference. The joint part midway through the conference culminated in a top-class panel on the topic "Deutschlands Wasserstoffwirtschaft – Einblicke in politische und industrielle Herausforderungen" (Germany's hydrogen economy – insights into political and industrial challenges). Among others were BMWK parliamentary secretary Stefan Wenzel and BMBF innovation officer for green hydrogen Till Mansmann. Subsequently, the H2-Kompass used formats such as a poster exhibition und world cafés to obtain feedback from the participants on the results produced so far.

Secondly, Kompass incorporates the results of a broad-based stakeholder dialogue that lasted around twelve months. This was conducted with people from academia, commerce, public service and community development to obtain their views and to work towards a common vision of a German hydrogen economy. This comprehensive stakeholder dialogue makes H2-Kompass a unique feature in the H_2 project landscape.

BEARINGS FOR POLICYMAKERS A look into the year 2045: A bus is on a newly paved road taking passengers to the next city in the district. But what is the road surface made of?

PUBLICATIONS BASED ON THE META-ANALYSIS CONDUCTED BY H2-KOMPASS
In the course of the project, H2-Kompass has so far published analyses on the following topics:

- Comparison of the hydrogen ramp-up strategies of the different German states
- Fact Sheet Wasserstoff im Wärmesektor (hydrogen in the heating sector)
- International ship transport: climate-neutral drive systems and fuels
- Climate neutrality in air transport
- Hydrogen in the transportation sector
- Fact Sheet Wasserstoff in der Stahlindustrie (hydrogen in the steel industry)
- Raw materials for the production of electrolyzers
- Electrolyzer capacities

Until the end of the project, analyses will follow on hydrogen in the electricity sector, hydrogen in other industrial sectors – such as cement, lime, glass and paper, – hydrogen use in refineries and the chemical industry, and on the infrastructure requirements of hydrogen ramp-up.

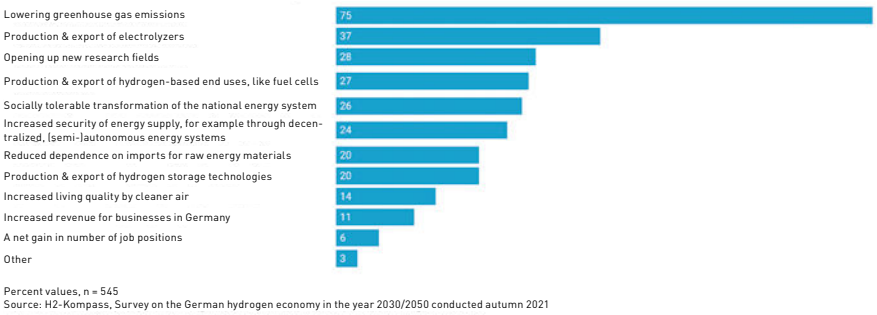

Fig. 2: Example results of the survey "Wasserstoffwirtschaft 2030/2050: Ziele und Wege" from autumn 2021

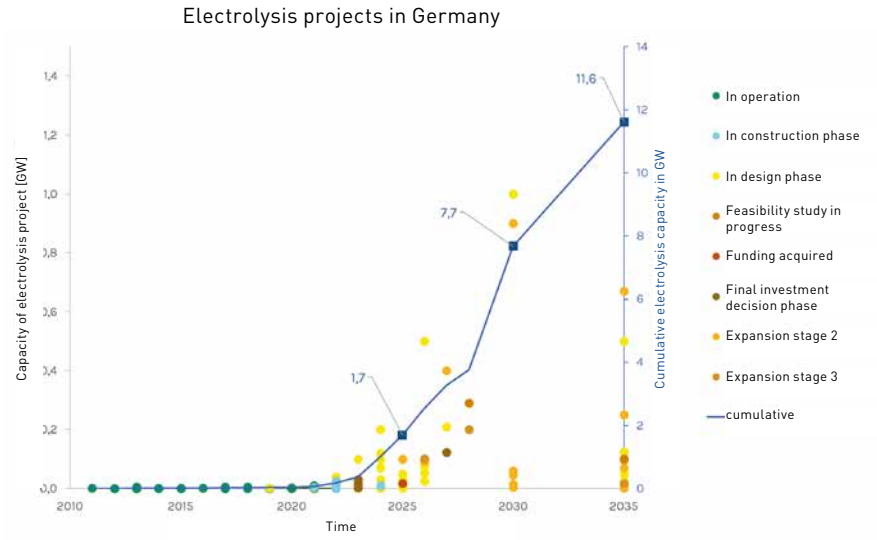

Fig. 3: Electrolysis capacities in Germany. Representation is based on the project database of H2-Kompass. Electrolysis projects are shown according to (planned) start of operation and output. Only projects with known performance could be visualized.

When an asphalt road is built or repaved today, bitumen is used as a binder. This dark, sticky hydrocarbon mixture is produced in today's refineries as a byproduct during the processing of crude oil. When refineries no longer process fossil resources in the future, this byproduct will in all likelihood no longer be produced. Also other classic byproducts, such as sulfur or lubricating oils, refined to their corresponding qualities, are missing in a refinery converted to instead process hydrogen derivatives, and would have to be obtained in future via other process routes or from other sources.

This example shows that the potential use of hydrogen is associated with many overarching consequences along the entire value chain, which include, among other things, a need for policy changes regarding industry and labor markets as well as for security of supply and social acceptance. At the beginning of the market ramp-up will be many possibilities and challenges. Here, H2-Kompass is to provide orientation, specifically through simultaneous consideration of multiple fields of action: production and import, infrastructure, steel industry, chemical industry, refineries, other industries, transport, power generation, and building and process heat.

DEFINING TARGETS FOR THE HYDROGEN RAMP-UP The stakeholder dialog component of the project started in autumn 2021 with the survey "Ziele und Wege zur Wasserstoffwirtschaft 2030/2050" (goals and paths to a hydrogen economy by year 2030/2050). Participating were around 600 people from academia, commerce, community development and public service. From April to September 2022, H2-Kompass organized four workshops with the topics 1) import criteria, 2) policies to enable success of business models reliant on domestic hydrogen production, 3) prioritizing the uses of hydrogen and 4) perception and expectation management. The propositions produced in the workshops were discussed by a wider stakeholder circle during the three-day Wasserstoff-Dialog conference in October 2022 in Berlin. The results from the stakeholder dialog were worked into the end product, that is, the H2-Kompass. A synthesis paper in the first quarter of 2023 will summarize the key discussion points.

META-ANALYSIS COMPILES TIME-DEPENDENT QUANTITY STRUCTURE H2-Kompass continuously collects strategy papers, and studies and analyzes them, and evaluates and verifies them through discussions with experts. Based on this, a time-dependent quantity structure is being creating from hydrogen supply and demand in the individual sectors, taking into account the necessary infrastructures for transport, storage and distribution. Furthermore, H2-Kompass maintains a project database to keep track of the generation capacities in Germany. ||

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Category: Policy | **Authors:** Scientists for Future

SCIENTISTS WARN AGAINST OVERBLOWN EXPECTATIONS

Policy paper from Scientists for Future

According to concerted opinion, hydrogen is now considered the new universal energy carrier that is set to take the place of fossil energy sources in gas heating systems, cogeneration plants, cars, steel works and the chemicals industry. This is also recognized by Scientists for Future. In a recently published policy paper they describe hydrogen's essential place in the energy transition yet also point out that its use is inadvisable in many areas on technical, economic and environmental grounds. The key sections of this paper are set out here:

In principle, hydrogen can be transported in the same way as natural gas via pipelines or tanker vessels and stored in tanks or caverns. This suggests that green hydrogen, in other words decarbonized hydrogen that is produced electrolytically with renewable power, could act as a replacement in all situations where we currently use fossil-based raw materials such as crude oil and – above all – natural gas. This belief is deceptive since for many purposes the deployment of green hydrogen is much too expensive and is an inefficient use of energy. Ultimately we will only use green hydrogen in cases where natural gas and crude oil cannot be replaced by the direct application of electricity or where hydrogen is the base material, for instance in the chemicals industry or in the carbon-free manufacturing of steel. […]

A calculated optimism is clearly evident in some studies by natural gas network operators: The German gas and water industries association DVGW, whose membership includes over 2,000 utility companies, does not work on the basis that there will be a shortage of hydrogen. A study published by the DVGW calculates that high demand will be accompanied by an equally high degree of availability of more or less sustainable hydrogen (Gatzen & Reger, 2022). Underpinning this is the unsupported assumption that there will be an import rate of 90 percent, in other words the same level as today's oil and gas imports.

> "Just supplanting one fuel with another will not suffice for the energy transition. The energy transition inevitably requires a shift away from traditional technologies and habits."

These optimistic assumptions on the availability primarily of imports are at the center of the argument that hydrogen would be available even for heat provision: "In contrast to the frequent assumption, hydrogen does not have to remain a scarce good. The demand for hydrogen can be more than covered from 2030 onward. The quantity exceeds all current demand forecasts many times over" (DVGW, 2022, p. 6). This strikingly optimistic supposition can be confirmed neither technically nor scientifically. […]

At least 10 years will pass before larger quantities can be imported. And what often goes unsaid in relation to desired hydrogen imports is that the transportation is so expensive that imported hydrogen will cost many times more than today's natural gas or crude oil. On this point it makes no difference whether the hydrogen is transported in a compressed, liquefied or chemically bonded form.

The use of hydrogen is only wise if it is produced with renewable electricity (green hydrogen). In future this will also be the cheapest production method. Hydrogen manufactured from natural gas (gray or blue hydrogen) and hydrogen from methane pyrolysis (turquoise) are not carbon neutral due to the use of natural gas and the upstream emissions from methane; and excessive risks and long-term consequences are associated with the use of nuclear energy for electrolysis as an ecofriendly method of producing hydrogen (pink).

ANALYSIS OF INDIVIDUAL APPLICATION AREAS The need to use hydrogen is already on the horizon in certain sectors. This affects, for example, iron and steel production as well as the chemical raw materials industry and hydrogen as an energy storage medium. At present, refineries require hydrogen for several processes, including the cracking of crude oil when manufacturing fossil fuels. This area of current hydrogen demand will disappear in the future. In other applications, hydrogen competes with other good solutions:

In vehicles, e.g., automobiles, electric propulsion is the most efficient and most practical solution. It is for this reason that manufacturers have practically given up on hydrogen propulsion for the future (Clausen, 2022). The situation for delivery vehicles, city buses and railroads can be said to be similar. Even when it comes to long-distance trucks, the Fraunhofer Institute for Systems and Innovation Research points out that, should the first hydrogen trucks be available in 2027, the second generation of battery-electric trucks will already be on the road (Plötz, 2022). The window of opportunity for successfully launching fuel cell trucks onto the market would therefore be essentially closed and all that would be left for hydrogen trucks would be a small niche, namely the transportation of heavy loads to very remote locations (Plötz, 2022).

The situation for local trains is comparable. Due to the progress in battery technology, the deployment of hydrogen trains would only be advisable as a bridging solution for very long routes without recharging facilities until such time that the lines are electrified or long-range battery-powered trains become available (VDE (ed.) 2019, Soller, 2020). […]

The position is similar for the production of heat and hot water. Numerous studies by scientific institutions characterize the use of hydrogen for heating as expensive and inefficient compared with electric heat pumps (for an overview see Clausen, 2022).

Shipping is faced with the problem of how to store large quantities of energy for long nonstop journeys. This is where liquefied hydrogen could be the most efficient solution. Synthetic (power-to-liquid) fuels that are manufactured from green hydrogen are generally less efficient as one or more conversion processes are needed for its production. Ammonia, for example, comes into discussion in this context because it is can be stored far more easily than hydrogen. The advantages of liquid fuels in deep-sea shipping are so considerable that other propulsion systems are difficult to imagine.

Investigations are also already underway on ammonia-fed fuel cells in ships (Fraunhofer IMM, 2021). However this is less energy efficient in comparison with liquid hydrogen. […]

One special case is the "dream of carbon-neutral flying" (Bottler, 2021), as promised by the aviation sector with reference to sustainable aviation fuel, or SAF, from hydrogen. At present, SAF, which may also be bio-based, is the most widely known feasible alternative to fossil kerosene for long-haul flights. Yet even the use of SAF has only a minor impact on climate change, equivalent to around 33 percent of the greenhouse gas effect (cf. chapter 4). As such, there is almost no other option than to radically limit air travel, electrify it or endure a lengthy wait for new inventions.

CURBING UNREALISTIC EXPECTATIONS As it stands, the future deployment of hydrogen is being organized at a much quicker pace than its production. Consequently, the rapid adoption of hydrogen and its intensive use for a variety of purposes risk smoothing a rather direct path toward supply insecurity, a scramble for resources, cannibalism between applications and high prices. One effect would be that damaging fossil fuels would be needed for longer than necessary.

A further risk is that decision-makers and the general public, either through a lack of information or due to wishful thinking, will assume that using hydrogen as an energy carrier will enable the costs of many things to stay the same, for instance in the case of car travel with synthetic gasoline and gas heating with hydrogen in the gas network (which would need to be converted at great expense). This could lead to us introducing a costly and inefficient technology, purely because it seems simple and familiar. We would be committing ourselves to an expensive energy system instead of switching directly to a predominantly electrified system that is better value and more flexible (Zachmann et al., 2022).

Since the production and supply of hydrogen is associated with high energy losses of at least a third of the green electricity used as the primary energy source, we will need much higher volumes of green power to create a "hydrogen world," i.e., many more wind turbines, photovoltaic plants and others. But already there is a lack of clarity surrounding where all these plants will be located, who will build them and which type of material will be used.

Even if the efficiency of electrolysis can be increased by several percentage points, hydrogen would still be an inefficient and expensive solution in all situations where electric alternatives exist.

CONCLUSION Policymakers must not promote hydrogen technologies without proper scrutiny. They should clearly analyze the fields of application and identify the areas where hydrogen represents a good solution and the areas where there are better, more efficient technologies that are less expensive in the long run. By focusing unambiguously on the promotion of electric transportation and heat pumps, the German political establishment shows it is engaged in implementing this key finding. ||

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Authors: Scientists for Future

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MARKET RAMP-UP OF ELECTROLYSIS

When will enough green hydrogen be available?

The market ramp-up of electrolysis is a significant constraining factor for the mass production of green hydrogen. In an article that appeared recently in Nature Energy we analyzed possible pathways for expanding electrolyzer capacity in the European Union and around the world (Odenweller et al., 2022). Using a technology diffusion model we showed that the market ramp-up needs time in spite of initial exponential growth. Even if electrolysis expands as rapidly as photovoltaics and wind energy – the reigning growth champions – there will still be a short-term lack of green hydrogen and its availability in the long run remains uncertain. Nevertheless, it is important to accelerate the ramp-up now in order to ensure ambitious 2030 expansion targets can be reached and to guarantee long-term availability.

Because electrolysis is a key technology for the production of green hydrogen, the market ramp-up of electrolyzer capacity represents a critical area of constraint (IRENA, 2020). The magnitude of the scaling required is enormous, since at the end of 2021 only around 600 megawatts of electrolyzer capacity were in operation worldwide. To meet the 3,670-gigawatt figure in 2050 that the International Energy Agency (IEA) says is needed to achieve net-zero, capacity must be increased 6,000-fold (IEA, 2022b), thereby dwarfing the tenfold expansion in renewable energy capacity that will likewise be required.

METHODOLOGY: TECHNOLOGY DIFFUSION MODEL
New technologies usually penetrate markets in the form of an S-curve. In this situation, there is an initial period of exponential growth which is followed by a virtually linear increase in the growth phase before growth diminishes in the saturation phase and approaches the peak. In our article we extended this standard model of technology diffusion by deploying a stochastic uncertainty analysis. We considered uncertain parameters to be (i) the electrolyzer capacity in the near future, specifically in the year 2024, (ii) the initial exponential growth rate and (iii) the demand for green hydrogen, for which we assumed a continuous increase based on policy targets and net-zero scenarios. The combined propagation of these independent uncertainties finally resulted in what we called the "probabilistic area of possibility" (see fig. 2).

Furthermore, electrolysis expansion poses a coordination challenge in terms of ensuring that not just the hydrogen supply but also the demand and infrastructure for hydrogen are driven up simultaneously. This is the proverbial "three-sided chicken-and-egg problem" of ramping up the hydrogen market (Schulte et al., 2021).

In the following we summarize the key results of our recently published article on scaling up electrolysis (Odenweller et al., 2022). Our synopsis shows updated figures and results based on the most recent version of the IEA Hydrogen Projects Database as of October 2022 (IEA, 2022a).

ANNOUNCED ELECTROLYZER PROJECTS The years ahead are due to see a pronounced upswing in project announcements (see fig. 1). If all the projects announced come to fruition, electrolyzer capacity in the European Union will increase by a factor of 28 by the year 2024 compared with the year 2021; globally it will grow by a factor of 23. However, this positive outlook comes with the caveat that final investment decisions have yet to be made for over 80 percent of these project announcements. Consequently there is a large degree of uncertainty about how many projects will be realized in the short term and therefore whether sufficient green hydrogen will be made available in time to reach net-zero.

We therefore asked the following question in the main scenario outlined in our article: "What would happen if electrolysis expands as quickly as photovoltaics or wind energy in its boom phase?" To cover unavoidable uncertainties we used a model to simulate and then aggregate the technology diffusion of electrolyzers in response to thousands of different parameter constellations (see box).

In the event that electrolyzer capacity expands just as rapidly as photovoltaics and wind energy once did – the two greatest success stories for the energy transition thus far – the primary outcome can be encapsulated as follows: short-term scarcity, long-term uncertainty.

SHORT-TERM SCARCITY Even if similar growth rates are experienced to photovoltaics and wind energy, it still remains the case that electrolyzer capacity and therefore also the supply of green hydrogen will be insufficient for one or two decades. This applies both in comparison with the short-term and medium-term expansion targets and in comparison with the size of the overall energy system. In particular, the EU's aim of producing 10 million metric tons a year of renewable hydrogen by 2030, which requires approximately 100 gigawatts of electrolyzer capacity, is not achievable with these growth rates. The same applies to the 720 gigawatts of global electrolyzer capacity that the IEA says are required by 2030 in its ambitious Net Zero Emissions scenario (IEA, 2022b).

In relation to the energy system as a whole this means that, even if electrolysis expands at the same speed as photovoltaics and wind energy, it will probably only be possible for green hydrogen to cover less than 1 percent of respective final energy demand in the EU by 2030 and worldwide by 2035.

LONG-TERM UNCERTAINTY The long-term view shows that a breakthrough to large-scale electrolyzer capacities is possible and becomes ever more likely. However, the timing and the size of this breakthrough are subject to considerable uncertainties.

In the event of similar growth rates to that of photovoltaics and wind energy, the breakthrough in the EU on average occurs by the year 2038 and globally by the year 2045. Given the great excitement surrounding the subject of hydrogen at the moment, that may be cause for surprise. Of course, when starting from a very small baseline, it takes a long time for high relative growth rates to also translate into high absolute capacities.

GROWTH UNDER EMERGENCY MEASURES Our article describes an unbiased IF-THEN analysis based on the key assumption that electrolyzer capacity mirrors the speed of expansion in photovoltaics and wind energy. In the annex to

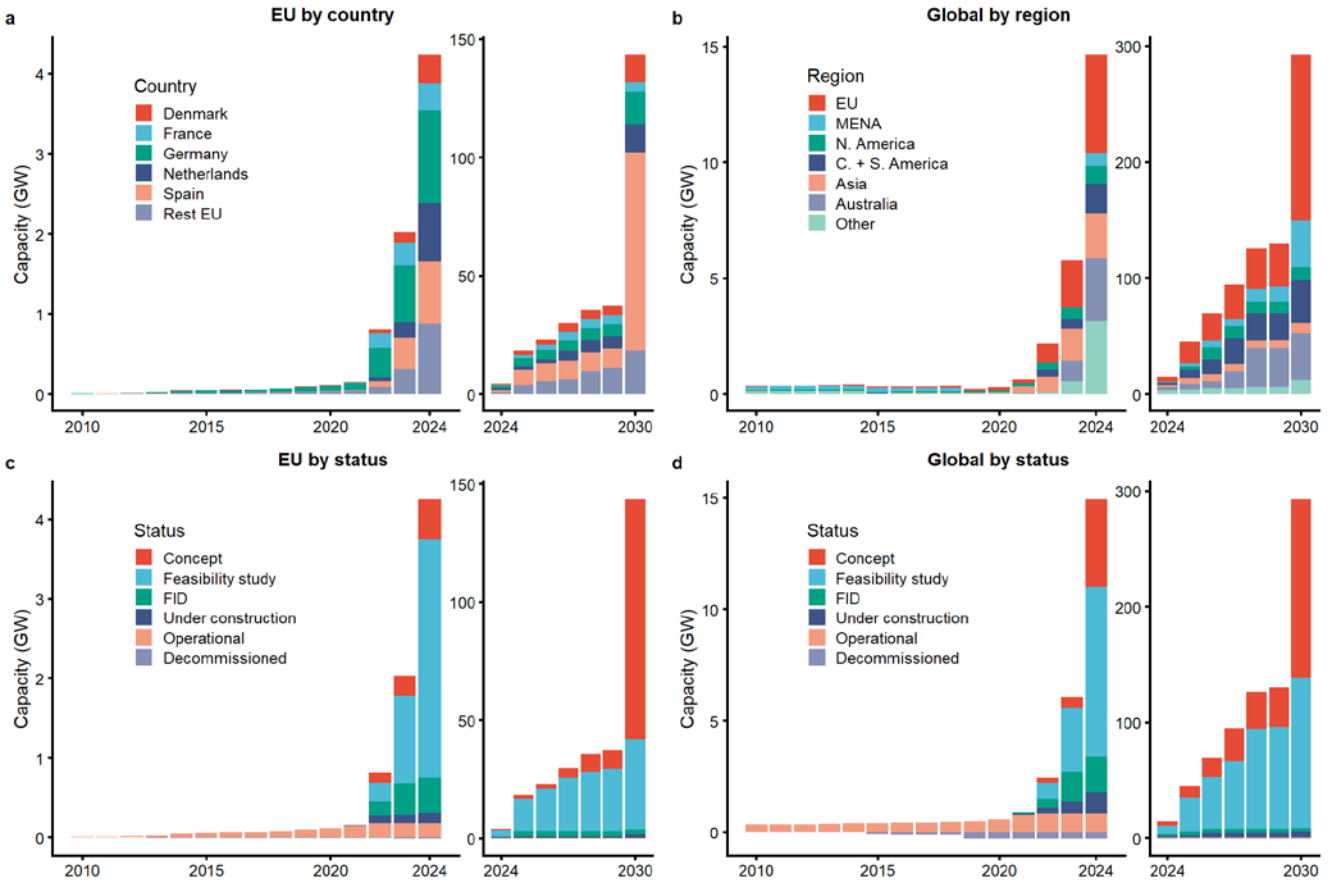

Fig. 1: Announcements of electrolyzer projects in the EU and globally

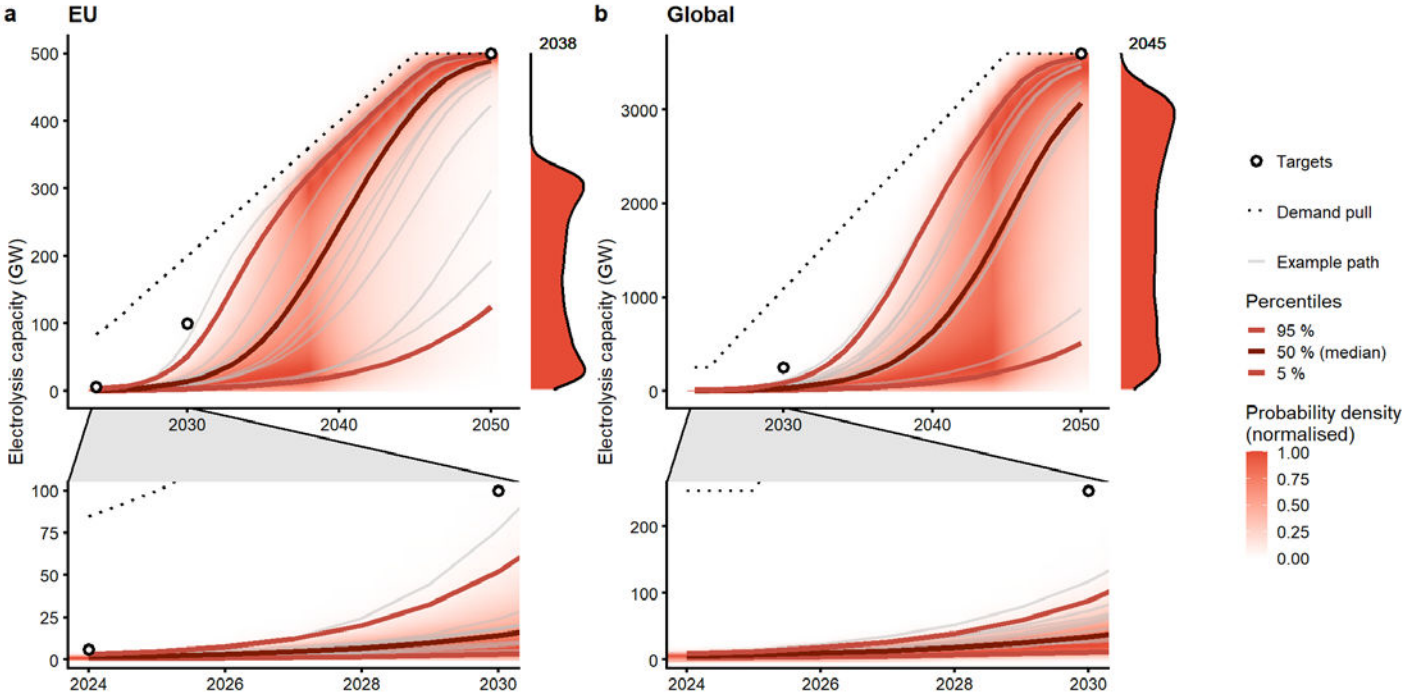

Fig. 2: Probabilistic area of possibility for electrolyzer capacity in the event that electrolysis expands as quickly as photovoltaics and wind energy

the article, we presented a list of arguments for and against the issue of whether electrolysis could grow more rapidly than these successful technologies.

To investigate what might be possible under particular circumstances, we also asked the following question: "What would happen if electrolysis expands as quickly as technologies with the highest historical growth rates?" To answer this we looked at the growth rates of an extremely heterogeneous dataset, ranging from US military production and the expansion of the Chinese high-speed rail network to the market diffusion of web hosting and smartphones. The analysis shows that it is only by assuming these unusually high growth rates that the EU's 2030 hydrogen target remains within reach and that the gap between possible supply and potential demand for hydrogen can be closed.

POLITICAL IMPLICATIONS It will only be possible to achieve these kinds of high growth rates with special political coordination, regulation and financing. Appropriate policy measures will need to safeguard the viability of private hydrogen investments, for example through public co-financing or direct regulation, e.g., via green hydrogen quotas. Furthermore, the ability to ramp up supply, demand and infrastructure simultaneously will require considerable coordination.

Thanks to the European Commission's IPCEI hydrogen projects, the planned EU Hydrogen Bank and the US Inflation Reduction Act, the world's two largest economies have recently given fresh impetus to the promotion of hydrogen. Nevertheless, it is still to be seen whether these measures are sufficient to break the vicious circle of uncertain supply, insufficient demand and incomplete infrastructure.

This study by the Potsdam Institute for Climate Impact Research was presented in February 2022 at the H2-Kompass conference in Berlin and was also reported upon in H2-international, May 2022. As the findings led to exaggerated headlines in the media in some instances, the key elements have been outlined again here in a little more detail.

As long as the availability and the costs of green hydrogen remain uncertain, political decision-makers should be made aware of the risk of overestimating the potential of hydrogen. If future hydrogen supply exceeds expectations, it will not be problematical to find applications for it. By contrast if hydrogen supply lags behind expectations, however, it will then be too late for many applications to switch to alternatives in time to reach net-zero.

It continues to be a political balancing act: On the one hand, the speed of scale-up for green hydrogen needs to be increased considerably. On the other hand, the associated expectation of green hydrogen expansion should not slow down the necessary ramp-up in existing and more efficient alternatives of direct electrification, such as heat pumps and electric cars. ||

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THE PRESSURE IS RISING

Market overview of compressor manufacturers and compressor types

Fig. 1: Screw rotors

In recent years, many compressor manufacturers have intensified their engagement in the hydrogen sector. Several medium-sized companies entered into new partnerships, and there have been several corporate takeovers. And individually dealing with compressors is no longer a separate ordeal for many, but is now offered in package with other services that are also needed for the development of a hydrogen infrastructure. But what distinguishes the different manufacturers and various products from each other? H2-international asked manufacturers about technologies, trends and special features, and has gathered the results here – with no claim of completeness.

MARKET OVERVIEW

H2-international has asked manufacturers of compressors for hydrogen fueling stations about their products, innovations and trends. We did not create a tabular market overview, like that for the electrolyzers in the February 2022 issue of H2-international, as the technical specifications given for different compressors are already too different in nature and there are no uniform standardized conditions for measuring inlet and discharge pressure. But the main features are summarized in this article. If the manufacturer has given us specifications about their product, this information is featured in a profile and sorted under the appropriate parameters. Included were H_2 compressors for fueling stations at which the output pressures generally amounted to 350 or 700 bar.

With its H450 compressor, **Borsig GmbH** manufactures piston compressors for truck fueling stations. A special feature, according to the manufacturer, is the gas seal in the last compression stage. In addition, this compressor can be operated safely even under tough environmental conditions, it was said.

MANUFACTURER	BORSIG
Name of compressor	H450
Compressor type	Reciprocating (without fueling station)
Pressure classes	350 bar
H_2 capacity	275 kg/h
Input power (el)	375 kW
Dimensions (L x W x H)	3.4 x 1.3 x 0.8 m
Energy requirement	1.3 kWh/kg_{H2} (40 bar input pressure, 450 bar output pressure)

Without compressors, hydrogen technology could not go anywhere. In order for H_2 gas to be stored and transported, it is necessary to press as many of these little molecules as possible into gas cylinders, cavities or car tanks, to produce the highest possible energy density. This is more difficult with hydrogen than with other gases, since the tiny molecules can escape through the smallest crevice. At the same time, sealing materials can be potential sources of contamination of the hydrogen.

Compressors differ in both their compression and drive technology. The driver could be, for example, compressed air, hydraulics or an electric motor. Which compression method is right depends, among other things, on the required throughput, the pressure level and the purity needed.

An essential aspect is the initial pressure, so the inlet pressure, for the compressor. If the hydrogen is taken, for example, from a gas container in which the pressure is low or only atmospheric, much more compression work is required than, for example, when already pre-compressed up to 100 bar from an upstream electrolyzer. Since the energy required to compress gases is very high, it may be more economic to apply 30 bar to the feed water at the input side of the electrolyzer than to compress the hydrogen downstream.

RECIPROCATING COMPRESSORS Piston compressors are the classics known from engine technology They are robust and can deliver high pressures and medium to high throughputs (starting from about 4 tonnes per day). Gasoline and diesel engines of common vehicles are lubricated with oil. Even with oil scraping rings, there is always a thin film of oil remaining on the walls of the combustion chambers, which is desirable to reduce friction. In piston compressors of hydrogen vehicles, this is not desirable, as this oil contaminates the medium to be compressed. A downstream fuel cell in which this gas is destined for use would be contaminated

Fig. 2: Sauer Compressors showcased its piston compressors in Bremen, among other places (see p. 9)

and fail after a short time. For this reason, oil-lubricated piston compressors can only be used in hydrogen systems in combination with subsequent purification of the gas.

Such cleaning can be done with scrubbers based on activated carbon. One of the providers of this technology is **Bauer Kompressoren GmbH.** The Bavarians started 15 years ago with a, by today's standards, small H_2 project in Spain. The production rate was 35 m^3 per hour with up to 350 bar. In addition to activated carbon, the Munich-based company used a molecular sieve, which allowed it to provide hydrogen in 3.7 to 5.0 purity grade (≥99.97% to ≥99.999%). Bauer has been active in the high-pressure sector for 77 years, for example with diving cylinders.

Sauer Compressors as well is positioned in the medium power range and offers oil-lubricated piston compressors with downstream treatment. The family-run compressor manufacturer headquartered in Kiel, Germany touts robustness as the foremost advantage of this technology. The piston compressors can handle variation of the load as well as fluctuating temperatures. This makes these compressors interesting for use in microgrids and other applications that require a high degree

The FSS High Capacity Station from the company **Resato** is a modular system. The number of compressors and dispensers can be varied to suit demand. Thus, a high production capacity is possible by joining the standardized components, which are available in the modular sizes for 1,000 or for 2,000 kg_{H2}/day. The hydrogen can be supplied by tube trailers or multiple element gas containers (MEGCs) coming directly from an electrolyzer or from the pipeline. The available hydrogen quantity, according to Resato, sets the limit for the capacity of the fueling station.
According to Resato, the fueling stations are user-friendly, reliable and have a favorable marginal cost. In addition, the supplier has a Europe-wide network for after-sales support.

MANUFACTURER	RESATO
Name of compressor	FSS – High Capacity Station
Compressor type	Electrohydraulic piston compressor and fueling station system
Pressure classes	350 bar, 700 bar
H_2 capacity	>1,000 kg/day, >2,000 kg/day
Input power (el)	185 kW
Base area	10 m x 12 m (without hydrogen provision)

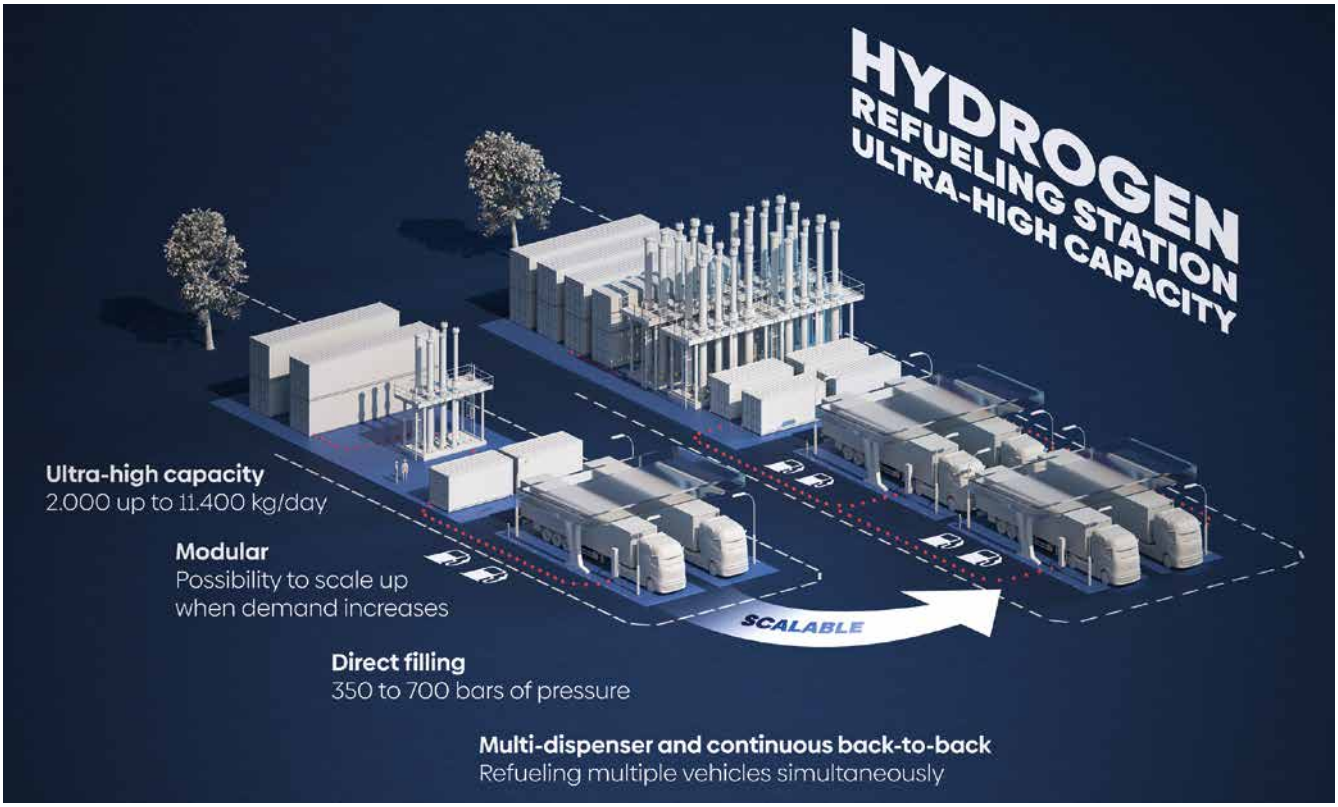

Fig. 3: Schematic of an H_2 fueling station from Resato

of self-dependence. In addition, according to information by the manufacturer, they are easy to repair. One unique thing about Sauer is that the customers are trained so that they can maintain and repair the compressors themselves – and may do so without voiding the warranty.

To Sauer also belongs the St. Gallen, Switzerland-based company **Haug Sauer Kompressoren AG,** which manufactures smaller, oil-free compressors. The dry-running units from Haug can deliver up to 1,000 m^3 per hour. The model HAUG. Mercure 22E presented at H_2Expo, for example, compresses 7 to 13 m^3_{H2}/h from up to 24 bar to a maximum of 350 bar.

Dry-running compressors use, for example, PTFE piston rings as an alternative to oil lubrication in the cylinder. The rings are offered by, among others, ElringKlinger and are quite low-wear, but leave traces of abraded material in the compressed medium, which must then be removed with particle filters. Some of these compressors use an oil pan at the bottom of the crankcase for lubrication. However, in these cases, this area is separated from the compression space by a three-stage sealing system so that no impurities emerge there. Oil-free piston compressors can typically be used for pressures from 150 to 450 bar; some at higher pressures as well.

In 2022, together with Bosch Rexroth, **Maximator Hydrogen GmbH** presented the new compressing unit MAX Compression 2.0 (see H2-international August 2022). This has up to five times the throughput of its predecessor, within the same construction volume. The energy requirement was also minimized by the providers, according to the press release. The highlight is that although compression still takes place in two stages, the hydrogen no longer needs to be stored between these stages. In the 75-kW class, the throughput should increase by 20 percent at the same driving power, which should decrease costs accordingly. The power classes additionally range from 75 to 250 kW. This allows the capacity of a hydrogen fueling station to be increased if necessary without major reconstruction.

Fig. 4: Mehrer works with a triple diaphragm

A special feature is the automatic changing out of the seals (automatic seal exchange, ASX). The bar loader used for this purpose can hold up to 20 interchangeable seals. Per seal, it takes about 15 seconds for the exchange, so seal replacement for the whole system should be complete within three minutes.

In November 2022, the company from Nordhausen reported reception of a major order from Sweden. From autumn 2023 to the end of 2025, Maximator is to provide compressors for the in total 24 hydrogen fueling stations that are to arise in the course of the project REH2. These are to supply primarily heavy trucks, and 23 of the 24 are planned to be installed at highway rest stations. REH2 wants to supply exclusively green hydrogen that is produced primarily with local energy sources such as wind and water. Majority owner of the project is the investment company Qarlbo AB.

DIAPHRAGM COMPRESSORS Membrane compressors are suited for higher pressures up to 1,000 bar. They too essentially use a piston to compress gas. However, this does not act directly on the gas, but on an oil, which in turn moves a membrane. The gas to be compressed is enclosed by this

The MD10-L membrane compressor from **Burckhardt Compression** is available as a standardized mobile container-installed solution or as a bare unit. It can also be supplied with noise reduction and a closed cooling water system, if needed. The size is adapted to a 2.5-MW electrolysis unit. The membrane compressor ensures high hydrogen purity and gas tightness. For higher throughputs, Burckhardt Compression recommends its own 3CS oil-free piston compressor. According to the company, it supplied its first hydrogen compressor as early as 1972. The manufacturer has a service network that reaches around the world and offers a comprehensive after-sales service.

MANUFACTURER	BURCKHARDT COMPRESSION
Name of compressor	MD10-L
Compressor type	Diaphragm compressor
Pressure classes	350 bar
H_2 capacity	45 kg/h
Input power (el)	81 kW (rated power at specifications given below)
Energy requirement	Approx. 1.8 kWh/kg_{H2} (30 bar input pressure, 550 bar output pressure, 45 kg H_2/hour)
Dimensions (L x W x H)	6.1 m x 2.44 m x 2.59 m

Fig. 5: Screw compressor from Aerzen, Germany

membrane (diaphragm). This way, neither hydrogen gets out nor contaminants get in. Membrane compressors are therefore free of contamination and have no loss from leakage. They are suitable for frequent or continuous operation. However, they are technically limited to H_2 throughputs on the order of 1 to 2 tonnes per day. This makes them less of interest for hydrogen truck fueling stations, for example.

Andreas Hofer Hochdrucktechnik GmbH, which belongs to Neuman & Esser (NEA Group), according to its own statement, can guarantee pressures of 5,000 bar with diaphragm compressors and up to 3,000 bar for dry-running, hydraulically driven piston compressors.

CENTRIFUGAL AND SCREW ROTARY COMPRESSORS For lower pressure levels, centrifugal (turbo) compressors and screw compressors are the go-tos. Their typical pressure range lies at about 1 to 20 bar, and the throughput at up to 50,000 m^3_{H2} per hour. For hydrogen fueling stations, they can therefore only serve in the pre-compression stage, to build up the ingoing pressure required for the other compressor types. The operating principle of a screw compressor is two interthreading screw rotors rotating inwards of each other (see Fig. 1).

In this way, the volume to be acted on is increasingly reduced. Similarly to the case with piston compressors, a pulsation accordingly arises in dependence on the rotational speed of the screw, which could be 1,500 to 2,000 rpm for large units and up to 5,000 rpm for small units. In general, screw compressors have a higher leakage rate compared to other compressor types and thus higher efficiency losses. To reduce friction and improve tightness, oil is used similarly to the use for piston compressors.

One manufacturer of screw compressors is **Aerzener Maschinenfabrik GmbH.** A new innovation by the engineering company is the substitution of oil with water. The water film seals similarly well to oil, prevents contamination and, at the same time, leads to a thoroughly desired humidification of the H_2 gas. This method, however, is still in the testing phase.

In addition to this, there are ionic compressors, such as those manufactured by Linde.

MANUFACTURERS, BUSINESS MODELS AND TRENDS Some of the companies listed here are primarily focused on the manufacture of compressors. Others, on the other hand, see their area of business as turnkey hydrogen fueling stations. Especially amongst the makers specializing in compressors are family-owned companies steeped in the technological tradition of the German-speaking area. A prime example and, by its own statement, the world market leader for reciprocating compressors is **Burckhardt Compression AG** from Winterthur, Switzerland, with now 2,700 employees.

According to the company, Burckhardt Compression works on membrane as well as piston compressors that can deliver pressures of over 900 bar and additionally are suitable for high throughput volumes. The company, which has been listed on the stock exchange since 2006, shows – not only in the H_2 sector – a clear willingness to grow globally, as evidenced by recent acquisitions: Industrie- und Kompressorenservice GmbH from Bremen (2016); CSM Compressor Supplies & Machine Work Ltd from Canada (2017); Arkos Field Services from the USA (2019); The Japan Steel Works Ltd from the USA (2020); Shenyang Yuanda Compressor Manufacturing Co, Ltd from China (2021).

In the hydrogen sector, the company founded in 1844 is engaged not only in H_2 station and trailer refueling solutions, but also power-to-gas projects and offshore H_2 production. In spring 2022, Burckhardt Compression began construction of its very own H_2 testing facility at its headquarters in Winterthur. There, the company intends to further develop sealing technologies for heavy hydrogen commercial vehicle fueling stations that would allow oil-free compression up to 900 bar (as booster). The goal is to get in business with Shell New Energies. Burckhardt Compression says it's one of the finalists in the race for the energy giant's fueling station business. The testing facility is to go into operation in early 2023, and the tests should be completed by the end of the year.

In 2022, Burckhardt Compression entered into a partnership with the H_2 fueling station developer HRS (formerly TSM). This involves the delivery of several membrane compressors within the next two years for the fueling stations of HRS, the capacity of each of which is to be between one and two tonnes per day. The target group for these fueling stations is heavy transport (buses, trucks, port vehicles) and light commercial vehicles, like taxi fleets. With the partnership, the two companies want to equip other areas of hydrogen mobility already as well, such as ships, trains and planes.

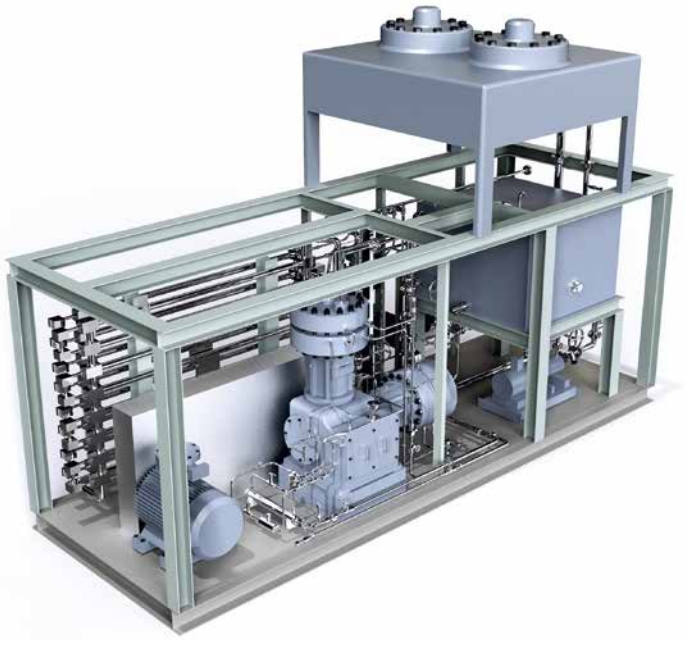

Fig. 6: Structure of MD10-L model from Burckhardt [Source: Burckhardt Compression]

Fig. 7: PDC Machines LLC builds systems of moderate size for small fleets, like for example the SimpleFuel unit that was introduced during Hannover Messe 2017 (see H2-international Jan. 2018)

The **Neuman & Esser Group (NEA)** as well is a heavyweight in the compressor sector. The family business from Übach-Palenberg, with its 1,200 employees, is making a name for itself through, among other things, the two managing partners, as Stefanie and Alexander Peters are both strongly engaged in lobby associations as well as on the political administration level. Stefanie Peters is active in the German hydrogen council (Nationaler Wasserstoffrat, NWR), among other things, while her brother is director of the compressor and vacuum division within the German association for mechanical engineers (Verband Deutscher Maschinen- und Anlagenbau, VDMA). In addition, at the beginning of December 2022, he was voted to become an executive director of the German hydrogen and fuel cell association (Deutscher Wasserstoff- und Brennstoffzellen-Verband, DWV).

PDC Machines from Pennsylvania is, by its own statement, the world's leading manufacturer of diaphragm compressors for hydrogen. H_2 applications are the second mainstay of the US company alongside classic industrial compressors. In addition to the compressors, the portfolio includes a complete mini refueling unit named SimpleFuel as well as turnkey hydrogen refueling stations.

In 2022, PDC Machines announced a cooperation with US supplier Gilbarco Veeder-Root. The company plans to establish an end-to-end infrastructure for refueling that in addition to the compressors from PDC machines and the dispensing stations, also encompasses the necessary software for operation. This is to occur via the wholly owned subsidiary ANGI Energy Systems, which is responsible for Gilbarco's compressed gas business and has already been developing complete solutions for its customers for 30 years.

PDC Machines is currently benefiting, like many US companies, from the US Inflation Reduction Act. Among other things, this provides for a ten-year tax bonus for clean hydrogen and H_2 storage systems. In addition, there are to be tax advantages for fuel cell vehicles and better tax credits for "clean fueling stations."

Hiperbaric, headquartered in Burgos, Spain, has been active in H_2 compression since 2021. The company started in 1999 with solutions for the food industry. In the hydrogen sector, Hiperbaric has devoted itself to compressor units preinstalled in portable packages for use at filling stations and research facilities or for gas storage. In addition to the high-pressure piston compressors themselves, the containerized solutions contain the controls, cooling, ventilation and the pneumatic and hydraulic systems. The compression takes place in two stages.

The compressor unit is available in options for up to 500 or up to 950 bar. The 500-bar unit has a throughput of up to 26 kg of hydrogen per hour, and the 950-bar unit up to 15 kg per hour. With a second compressor installed in the container, the rate can be doubled. The offer includes a complete service, with maintenance. The remote monitoring and diagnostics service should ensure that errors are detected before a failure in the system occurs.

COMPRESSOR TRENDS The question of how to offer more and larger compression and refueling station solutions for hydrogen as easily as possible is on the minds of all manufacturers. Borsig names standardization and scaling as the keys to reducing costs. Resato sees itself well prepared for capacity expansions with the modular approach. The company wants to think less in terms of individual projects in the future and instead turn hydrogen fueling stations into a "business tool." Instead of a single fueling station optimized for low investment and operating costs, customers should receive a complete product with business model included. The decisive optimization variables here are reliability and the question of what it costs to put one kilogram of hydrogen into the tank of a vehicle. ||

Fig. 8: Hiperbaric was a Spanish representative at the Hydrogen Technology Expo Europe

NEUMAN & ESSER

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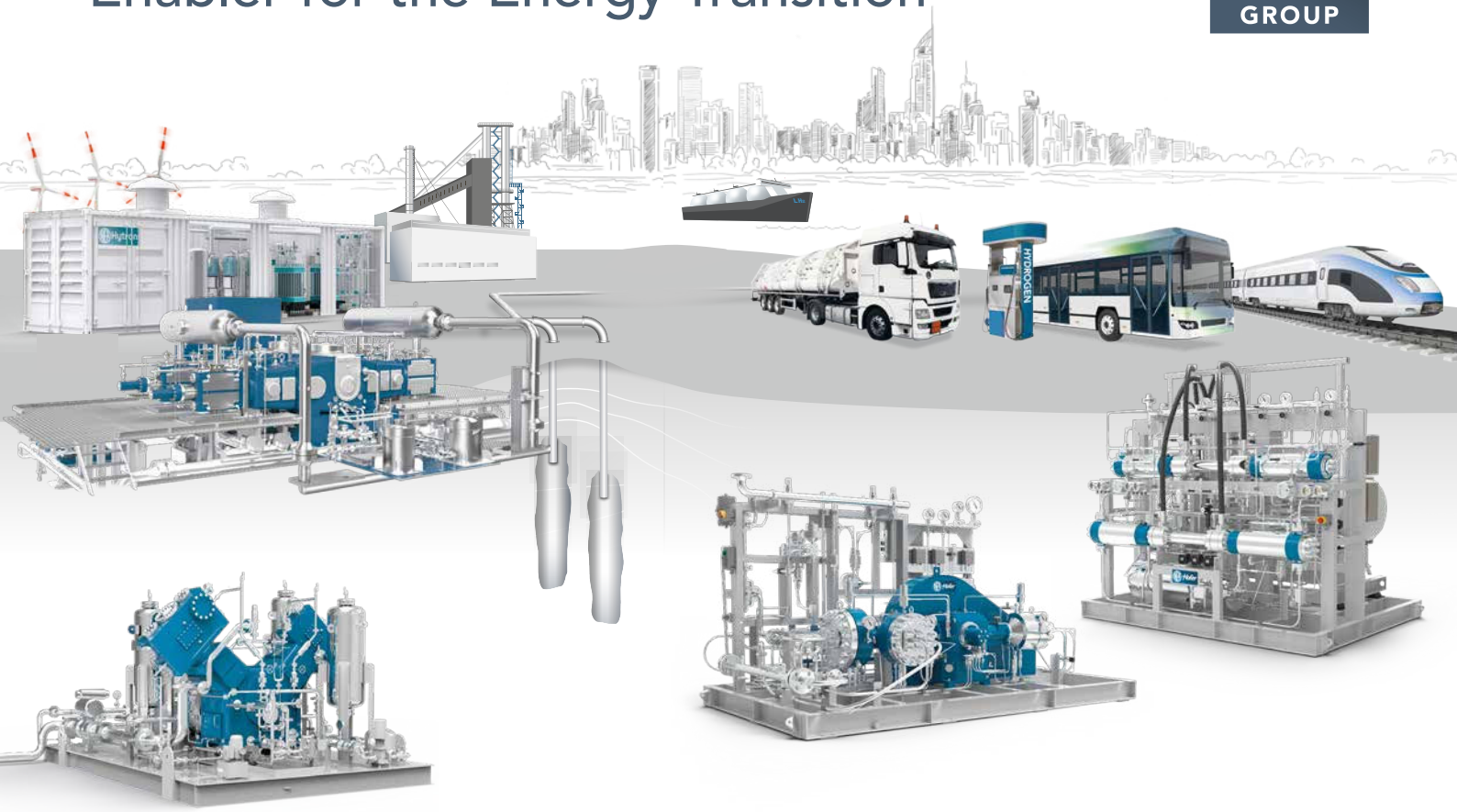

NEUMAN & ESSER is a single-source provider for fully integrated solutions along the H2 value chain. As an OEM for reciprocating compressors, electrolyzers and reformer systems including HRS, the NEA GROUP has the answers to the important questions in energy transition projects. With a century of experience in H2 compression as a trusted partner for tailormade plant engineering NEA GROUP helps to bring the energy transition to life – from evaluating potential sites and project feasibility, through engineering, construction and commissioning to digitally supported 360° service during operation.

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Category: Energy storage | **Authors:** Norbert Fisch, Christian Kley, Benjamin Trippe, Simon Marx

CLIMATE-NEUTRAL NEIGHBORHOODS WITH PV AND ELECTROLYSIS SYSTEMS

Market analysis of the electrolyzer operator and producer market

In the research project H_2-Quartiere, the consultancy Steinbeis-Innovationszentrum Energieplus (here abbreviated SIZ E+) is investigating until 2024 how decentralized hydrogen production near to consumers through electrolysis (ELY) can be implemented. On behalf of the German ministry for economy and climate protection, six model districts equipped with ELY systems in urban and suburban areas of Baden-Württemberg will be analyzed and checked to see if there are technical-economic hurdles. The results will be presented in a market analysis for electrolyzers.

This study is based on 23 interviews with operators and manufacturers, with the analysis of the manufacturer market limited to companies that have a branch in Germany. For manufacturers without a branch in Germany, the rapid availability of service personnel in case of repairs or maintenance would be called into question. The results of this market analysis provide an insight into the current situation with regard to investment costs (CapEx), efficiencies and stack temperatures as well as challenges for operators in the distribution of green hydrogen.

CONSIDERATION OF THE OPERATOR SIDE In Germany, there are currently 13 publicly known electrolysis plants with a power consumption of more than 1 MW in operation (status in 2022, see Fig. 1). Together, these plants have an ELY capacity of around 70 MW. Out of seven interviewed operators of large ELY plants, two complained about the lack of standardization in the stack market. When replacing a stack, it would be advantageous to not be reliant on the same manufacturer that produced the first, it was said. One operator also expressed concern regarding non-European producers when it comes to rapid availability of service technicians in the event of a malfunction.

With regard to the politically envisaged scale-up, five out of seven operators noted that there are not enough customers or demand for green hydrogen to make further investments worthwhile. This is also demonstrated in the ways that green hydrogen has been utilized up to now. So far, six out of 13 large-scale electrolysis plants have fed their hydrogen into the natural gas grid. Only six supply hydrogen to the industrial and one exclusively to the mobility sector. For the benefit of the national economy and the environment, green hydrogen should be used primarily in industrial processes that are otherwise difficult to decarbonize [Agora Energiewende, 2021].

The experience of one plant operator was marked by various challenges. The construction process was delayed in particular due to delivery problems and poor performance by individual construction companies. The putting into operation and the approval process were made disproportionately difficult by additional safety requirements imposed by the responsible regional council. The operation after completion was burdened by sharply rising, volatile electricity prices. Despite these difficulties, the operator is planning to erect another, even larger, ELY plant. The company believes that the long-term ecological and economic potential of green hydrogen will prevail over the medium-term disadvantages.

CONSIDERATION OF THE MANUFACTURER SIDE The investment costs (CapEx) of hydrogen-producing electrolyzers, regardless of process type, is about 1,000 €/kW_{el} for a large plant. Comparison, however, is sometimes difficult, as not all producers offer the same scope with regard to supportive and auxiliary equipment (balance of power, BoP).

Fig. 1: Current commercially operated electrolysis plants in Germany
* (Not yet in operation at the time of publication, but announced for 2022)

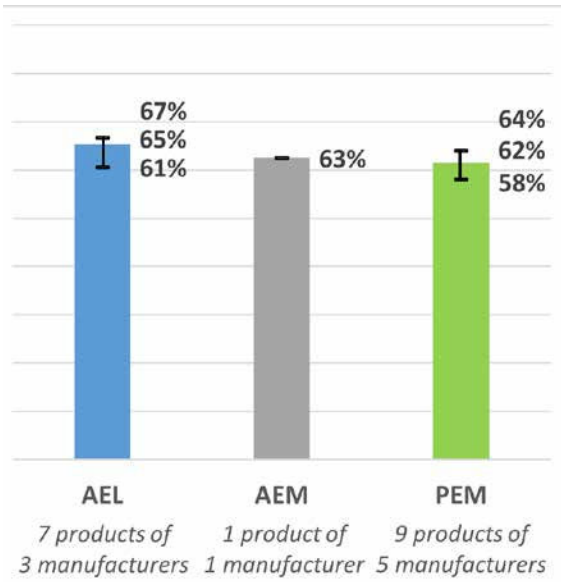

Fig. 2: Energy conversion efficiency (LHV to AC) of electrolyzers of manufacturers based in Germany

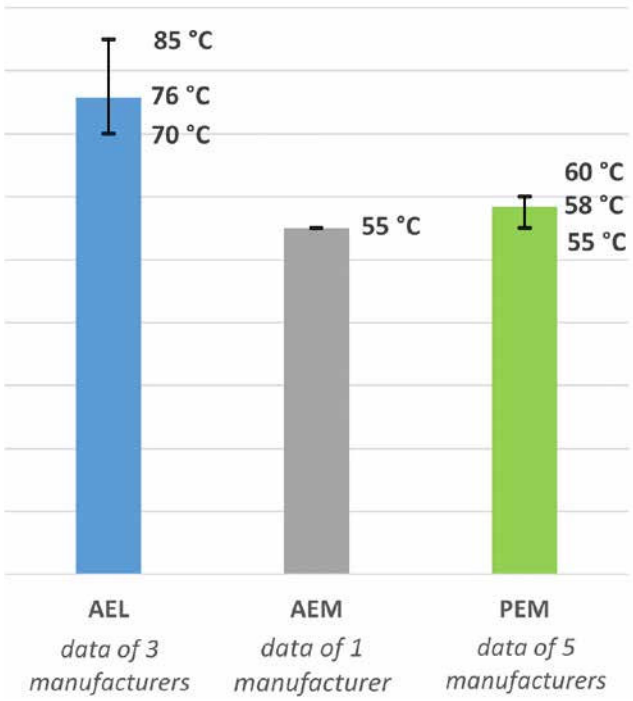

Fig. 3: Stack exit temperatures

The players surveyed are planning expansion with increasingly automated production lines, which could significantly reduce CapEx. For PEM electrolyzers, the share of BoP in the cost lay at 55 percent in 2020 [IRENA, 2020]. Since then, the market volume has increased. However, it can be assumed that here too considerable cost reductions will follow effective scaling.

Figure 2 shows the energy conversion efficiency (LHV to AC = lower H_2 heating value to alternating current) of the total of 17 electrolyzers from nine different manufacturers, anonymized and sorted according to electrolysis process. These are alkaline electrolyzers (AEL) in addition to proton-exchange membrane (PEM) and anion-exchange membrane (AEM) electrolyzers. Only makes from manufacturers who are based in Germany and already have customer references are considered. Solid oxide electrolyzers (SOEL), because of the heat demanded by the process to achieve the high operating temperature, are not considered here.

Shown for each electrolysis process are the minimum, mean and maximum values from the manufacturer's data. Regardless of process type, they vary little between the examined products, with AEL showing slightly higher values. However, the comparability of the manufacturers' data is a question. Currently, there are no norms or policies to define a standard that indicates under which comparable conditions the efficiency should be determined.

It is striking that some manufacturers state the same system efficiency for makes of different sizes. This indicates that the power consumption of the BoP is only roughly accounted for. In the case of some data, it is unclear whether the specifi-

cation of the efficiency is a snapshot of the "beginning of life" or an average over the whole lifetime. Furthermore, there is often no information about the load condition at which the efficiency was measured.

Through waste heat recovery, a significant increase in total system efficiency can be achieved. An important factor here is the temperature level of the waste heat source. Figure 3 shows the specifications of nine manufacturers with regard to the stack temperature during operation under nominal load. The stack temperature is the temperature of the cooling medium midway between the inlet and outlet from the stack.

The stack cooling is usually divided into two circuits via a heat exchanger: a primary circuit for direct stack cooling and a secondary glycol circuit for heat dissipation to the environment, for example via package crossflow cooling towers.

Regardless of process type, the difference between the stack entry and exit temperature is usually not significantly more than 10 Kelvin, as higher spans can lead to higher degradation and inhomogeneous load conditions in the stack [TU Delft, 2019]. The primary cooling circuit, because of the special demands on the cooling medium imposed by direct contact with the cells, is usually separated from the glycol circuit via a heat exchanger. For proper hydraulic separation, another heat exchanger may be required in the secondary glycol circuit for waste heat extraction. If a temperature difference of, for example, 10 K is the target, then the return flow temperature from the waste heat utilizer must be between 15 and 20 K below the stack temperatures in Figure 3.

In light of this, all current products, in combination with a peak demand power station via a local heating network, are suitable for supplying an existing or new building area with heating energy. The temperature of most AELs, at an average of 76 °C, is theoretically high enough to enable the supply of hot tap water where appropriate. In practice, however, there are hurdles that can make the use of waste heat difficult. In containerized systems, compact heat exchangers with small transfer surfaces and high temperature differentials are often used, which requires extremely low entry temperatures on the part of the cooling medium. When using a heat pump, this entry temperature is decisive for the evaporating temperature of the refrigerant. To ensure a high efficiency, or rather coefficient of performance, of the heat pump, larger heat exchangers and higher entry temperatures are advantageous.

CLIMATE-NEUTRAL NEIGHBORHOOD The principle of waste heat utilization for heat supply had already been implemented by SIZ E+ in the climate-neutral city quarter (Klimaquartier) established in Esslingen am Neckar in the state of Baden-Württemberg (see H2-international May 2021). The project is based on the idea of a climate-neutral quarter with the lowest possible carbon footprint. The heart of the energy supply is an AEL plant with an ELY capacity of 1 MW, which receives surplus electricity from local photovoltaic systems as well as from other regions. The ELY waste heat at the same time serves as an energy source for a heat pump. The project follows the innovative approach of power-to-gas-and-heat, in which hydrogen is to be produced close to the consumer on a local level at sensible nodes.

In the new project H_2-Quartiere, the potential implementation of this approach in six other model neighborhoods is being explored. Through the use of waste heat in the conversion process and through the short transport routes to the end users, this system approach is potentially extremely efficient and offers highly synergistic effects to the much needed clean heating and energy transition. According to the 2021 study by the German real estate association ZIA, around 20 percent of the heating demand in the buildings sector could be covered by ELY in year 2045 if half of the German hydrogen demand is produced by local ELY plants within Germany [ZIA, 2021]. ||

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THE GREENEST INDUSTRIAL REGION IN EUROPE

Duisburg establishes itself as the hydrogen capital

Fig. 1: Thyssenkrupp Stahlwerk Schwelgern [Source: City of Duisburg]

Duisburg, being located on the rivers Rhine and Ruhr, is an excellent site for transport activities. Duisburger Hafen, the largest inland port in the world, is one of the most important shipping hubs globally. Settled in Duisburg are, among others, the major research institutes Fraunhofer IMS (Fraunhofer institute for microelectronics) and the ZBT (Duisburg fuel cell technology center). At the same time, the industrial activities there – steel production, coal-based power production, port operation – are one of the city's largest sources of CO_2 emissions. ThyssenKrupp Steel Duisburg alone accounts for 2.5% of the CO_2 emissions in Germany. An excellent place to start actively driving forward processes for the already necessary transformation of the industrial and transportation sectors toward a hydrogen economy and, with that, shape a renewed economic restructuring of the region.

Duisburg is located in the Ruhr area, which consists of eleven district-free cities and four districts. In the region called the Metropole Ruhr live 5.1 million people – of which 0.5 million reside in Duisburg (status on 2020/06/30). The Ruhr area is the largest polycentric metropolitan area as well as one of the largest urban areas and, with 31,000 workers, the largest steel site in the European Union. Each municipality and each district has developed its own field of expertise and industry concentration. Duisburg's specializations, for example, lay in metal production and metalworking, warehousing and shipping services as well as the energy industry and maritime transport.

GREEN TRANSFORMATION Germany's energy transition and phasing out of hard coal represent a challenge for all municipalities and districts in the Ruhr area. Its economic restructuring into a service and knowledge location is in full swing. Throughout the Ruhr area, an increase in activities regarding digitalization, energy, sustainability and circular economy is taking place. How is Duisburg handling this climate and structural change?

Already in 2001, the ZBT in Duisburg – Zentrum für BrennstoffzellenTechnik GmbH – was founded. It was to be a nucleus that supported the needed transformation in the Ruhr area, in particular that involving fuel cell and hydrogen technology. The ZBT is an application-oriented research and development institute for fuel cells and hydrogen and battery technology with global renown. Its focus lies in meeting the needs of industry as an independent service and R&D partner. Currently, 150 full-time employees and about 25 student employees work there.

With numerous projects already early on, the ZBT was able to collect experience in hydrogen and fuel cell technology and to help in its development. Production processes for a mass market were created and, in the first independent testing lab at the time, standards for fuel cell systems were set.

With the hydrogen test field at the ZBT that went into operation in 2018, a research and development platform for high-pressure H_2 applications was established, which today represents the decisive testing platform in various European projects.

H_2 IN STEELWORKING Because of the Paris Climate Accord and national provisions regarding greenhouse gas emissions, hydrogen is gaining momentum throughout the European Union. With this in view, Thyssenkrupp Steel in Duisburg has decided to invest in climate-friendly technology. The company's blast furnace process is to be partially replaced by a hydrogen-powered direct reduction system of pig iron production within the next few years. The goal is to produce premium steel with low CO_2 emission.

The planned direct reduction furnace is conceived for 2.5 million tonnes of crude iron and should avoid 3.5 million tonnes of CO_2, as the CO_2 emission in this first production step is to sink by about 20%. The total investment is 2 billion euros. A corresponding IPCEI project application has been submitted. As soon as the commitment from the EU comes, the building contract can be awarded and construction of the direct reduction furnace can begin. The expected start of production is currently in 2026.

Duisburger Hafen as well, the largest inland port in the world, is obligated, by internal regulations, to reduce its greenhouse gas emissions. As part of the project EnerPort I, it has been investigating which approach should be taken to support the energy transformation process. Using the example of Duisburger Hafen, a strategy is to be developed based on data collection, concept selection, formation of scenarios and, finally, optimization of energy

Fig. 2: Hydrogen test field at the ZBT [Source: ZBT]

infrastructure and operations. This project will be completed shortly and has already spurred a subsequent project, started in 2021, to implement the results.

In the project EnerPort II, the worked out fundamentals are to be implemented and tested in a pilot project that involves construction of the trimodal Duisburg Gateway Terminal (DGT) in Duisburger Hafen. At the terminal, a sustainable energy system would be installed that is designed as a smart microgrid. Renewable energy production, storage and consumption would be coupled and optimally driven, and adjacent neighborhoods and city districts could be supplied through this.

Activities of this sort are bringing international companies as well to settle in Duisburg. Most recently, the US fuel cell manufacturer Plug Power Inc. opened its European service and logistics center in Duisburger Hafen (see H2-international May 2022).

TRHY – "THE HYDROGEN PROVING AREA" TrHy came into being as an ITZ center (Technologie- und Innovationszentrum Wasserstoff) for the western area of Germany through a national competition. It is one of four ITZ centers throughout the country, which are dedicated to hydrogen innovation. Through TrHy, located on the grounds of the steel and power producer Hüttenwerke Krupp Mannesmann in the south of Duisburg, the entire spectrum of innovation development, knowledge transfer, standardization, certification and testing of fuel cell-based drive systems for the heavy transport sector is to be covered, thus giving Duisburg a national center for hydrogen-based mobility across various transport modes.

The plan is to coordinate the activities in the field of standardization and to be available as an independent testing institute to market partners. For this, the state of Nordrhein-Westfalen (NRW) and the federal government have allocated up to 122 million euros of funding. Investigation of the feasibility of such an institute was carried out and confirmed. Wide support from the industry was obtained in the form of documents and assurances beforehand. With the laboratory and testing capabilities that are to be set up, an essential gap in the successful establishment of hydrogen-based transportation will be filled. For the research and development, a large network of partners throughout NRW, as satellites of TrHy, stand available.

Fig. 3: Duisburger Hafen – Conceptual picture of the climate-neutral Duisburg Gateway Terminal (DGT) [Source: duisport]

H_2 INDUSTRIAL PARK The city of Duisburg itself must also be active in order to comply with regulations and reduce greenhouse gas emissions. Over the next few years, it will be investing heavily in the expansion of climate-friendly transportation. The provisions of the EU's Clean Vehicle Directive (CVD) were transferred into German law as the Saubere-Fahrzeuge-Beschaffungs-Gesetz (SaubFahrzeugBeschG) by policymakers in 2021. In response, the public transit provider Duisburger Verkehrsgesellschaft AG (DVG) acquired seven battery-electric buses, which have been in use in the Duisburg urban area since March 2022. In May 2022, the city council made the decision to procure ten H_2-powered buses by 2026. At the end of November, it was decided to purchase a further 100 units by 2030.

The company for municipal operations, Wirtschaftsbetriebe Duisburg (WBD), has also committed to fuel cell drives. In 2021, the nation's first hydrogen-powered trash collection vehicle went into service – another in October 2022 – and five units are yet to be delivered.

With this, Duisburg is well on its way to claiming the title of "hydrogen capital" for itself, since the H_2 demand at this time is the greatest in Duisburg and its state of NRW. The steel and shipping industries are counting on hydrogen to reduce greenhouse gas emissions, which is creating the ideal conditions for establishment of a sustainable H_2 economy. The following map offers an overview of the hydrogen activities in the Duisburg urban area.

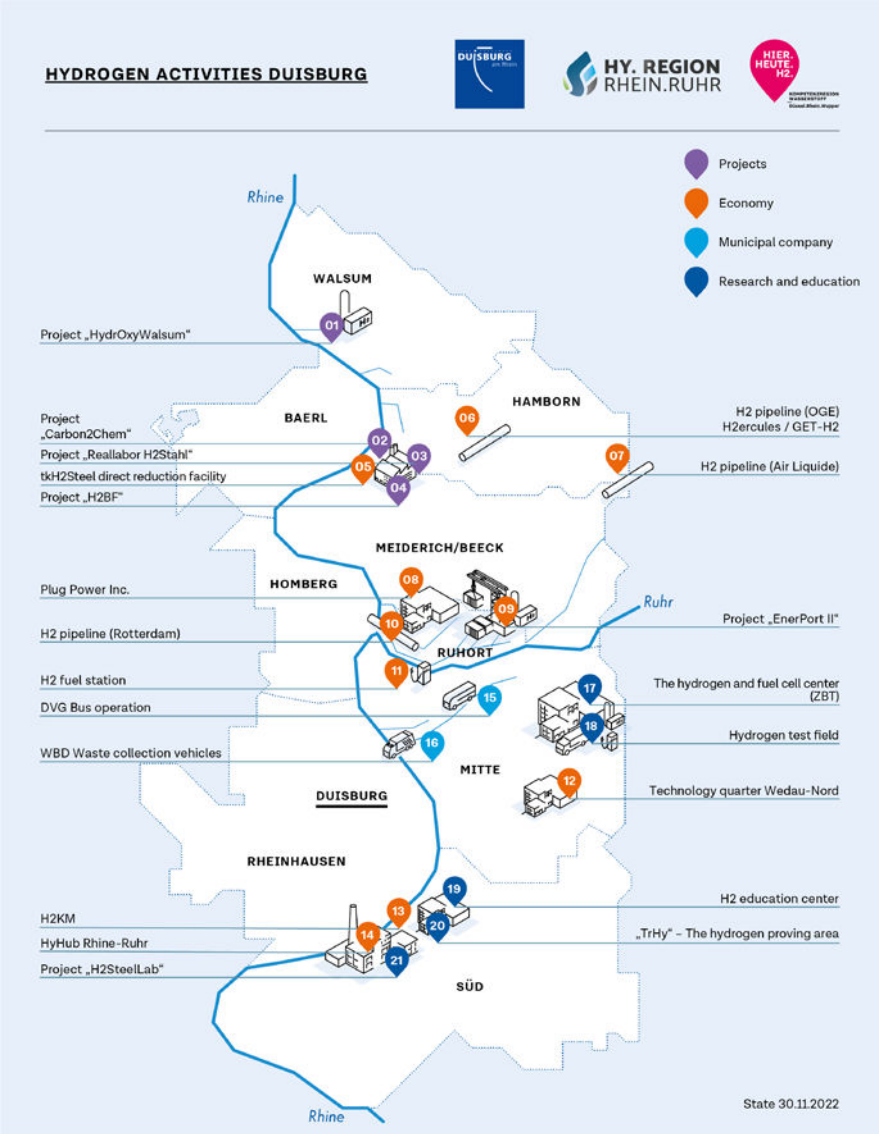

Fig. 4: Hydrogen activities in Duisburg – with no claim of completeness [Source: Stadt Duisburg]

COOPERATIONS AND NETWORKS To participants, it is clear that the market ramp-up of the hydrogen economy can only happen if they work together. Duisburger Hafen (DuisPort) is cooperating with Dutch seaports to study the potentials of various H_2 carrier technologies and to establish an international supply chain for hydrogen. In addition, there is the RH2INE (Rhine Hydrogen Integration Network of Excellence), which is an initiative of the Dutch province Zuid-Holland and the German state Nordrhein-Westfalen, in cooperation with the ports of Rotterdam and Duisburg and the company RheinCargo, founded with the goal of creating a climate-neutral transport corridor in the Rhine-Alpine area (Transportkorridor Rhein-Alpen) and advancing the use of hydrogen in freight transport.

Furthermore, in 2020, the region DüsselRheinWupper, which includes Duisburg, won the NRW competition to become a model region for hydrogen transportation (Modellregion Wasserstoffmobilität NRW). Consequently, the initial concepts for a complete hydrogen-based transportation system in the region were worked out and the fundamentals for an implementation in Duisburg were drawn up.

Duisburg is also actively participating in the project HyMR (Hydrogen Metropole Ruhr) of the regional land use association Regionalverband Ruhr. Within this network, the various regional initiatives exchange information in order to jointly move the region forward in the field of hydrogen through synergy effects.

With the association Hy.Region.Rhein.Ruhr eV, founded in 2021 in Duisburg and in which 40 companies and scientific institutions are now active, a strong network of industry partners stand available in the fields of hydrogen production, distribution and use in the industrial and transportation sectors. The stated objective of Hy.Region.Rhein.Ruhr is to promote the implementation of a cross-sector hydrogen economy. For this purpose, the members want to actively work together and carry out projects in the Rhine-Ruhr region.

H_2 EDUCATION CENTER A green transformation only works, however, if it is accompanied by a social transformation. Employees who are being affected by this need precisely tailored continuing education and retraining measures – this ranges from skilled and technical trades to a strong academic environment in the relevant key technologies. Such measures give employees a hopeful future, not only for themselves, but for a healthy overall social and societal fabric.

This cannot be accomplished by the companies alone, however. That's why the City of Duisburg together with strong partners from the region is planning the construction of an H_2 education center, to be able to offer a wide range of continuing education and retraining services for the region and its companies. By the signing of a letter of intent between the City of Duisburg, DuisPort, KWS Energy Knowledge eG and the ZBT, it was decided that a hydrogen training center would be set up in Duisburg. The corresponding project applications for a systematic analysis of the qualification needs of the different professional groups as well as a system to recognize the skills that they acquire have already been prepared and will be sent off with the support of the various industry partners. ||

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COMMERCIAL VEHICLE SECTOR IS WONDERFULLY UNEMOTIONAL

IAA Transportation – (nearly) everyone's working on hydrogen combustion engines

Fig. 1: The Nikola Tre FCEV holds 70 kilograms of hydrogen at 700 bar

Be it fuel cells or hydrogen engines, (almost) all major commercial vehicle manufacturers are putting their efforts into hydrogen propulsion. A fact that has so far largely gone unnoticed by the average person. While the public debate still rages around the use of hydrogen in the automobile industry, it would seem the trucking sector made up its mind long ago: There's no future without hydrogen. This was proved beyond doubt at Germany's IAA international motor show for commercial vehicles which ran from Sept. 20 to 25, 2022, in Hannover, even if about 90 percent of the vehicles exhibited still had diesel engines.

The trend toward electrification was abundantly clear in every corner of IAA Transportation. While the roughly 1,400 exhibitors still earn their crust from diesel vehicles, the electromobility theme lends itself perfectly to marketing campaigns. Many booths took the opportunity to play around with the concept – as was the case at the IAA car show several years ago. When questioned, however, it immediately becomes apparent that electric vehicles are little more than a glint in the eye for the commercial vehicle sector. Significant volumes are still some way off – not just because of a shortage of staff and electronic chips, but also due to regulatory or technical hurdles.

One exhibitor, for example, explained that trucks with hydrogen engines cannot be classified as zero-emission vehicles since the intake air ends up being measured alongside the exhaust during emissions testing, and this incoming air usually contains pollutants. Automotive supplier Mahle reports that popular electric engines often drop to 60 percent power output after one minute at maximum power. Unlike its own modules which can guarantee a continuous output of 92 percent (240 kilowatts).

An added issue is that fuel cell units experience cooling problems when, say, a 40-ton truck needs to travel over the Alps, therefore requiring a high level of power over a prolonged period. This is where hydrogen engines have the upper hand. On the downside, however, are the high temperatures that combustion entails as these create favorable conditions for the production of nitrogen oxides. While nitrogen oxide emissions can be significantly reduced using a catalytic converter, it doesn't eliminate them completely – a contrast to a purely electric vehicle which has zero local emissions.

COMEBACK OF THE HYDROGEN ICE

The key topic of the moment for the hydrogen sector when it comes to commercial vehicles is the hydrogen internal combustion engine. Keyou, which currently employs 70 members of staff, has been working on it for years. Nothing new there. But now the likes of Cummins, Daimler, Iveco, MAN and even Unimog (to name but a few) are also busy exploring this area of technology. The question posed by Jürgen Nadler, chief marketing officer at Keyou, is telling: "Do you know anyone who's not working on it?"

The reason for the hydrogen ICE's dramatic comeback is said to be the "extremely high number of requests." This has led Keyou to adjust its strategy. From now on the Bavarian technology company is focusing on the conversion of existing vehicles based on the Mercedes Actros. "We are moving away from OEM and toward end customers," said Nadler. Initial trials with its hydrogen truck are planned from summer 2023, with the expectation that a small fleet of eight vehicles will be ready for testing by the end of the year. In 2024 the number of shipments could increase to as many as 50. By then the retrofit time should be around the three-week mark.

Keyou's engine of choice for its refitting work is a Deutz. Its ability to power buses was demonstrated by Keyou using a Solaris model, also on display in Hannover, which was converted by the Paul Group (see below).

One of the large engine manufacturers involved in hydrogen ICEs is Cummins, despite the US corporation possessing extensive fuel cell expertise following its takeover of Hydrogenics. In Europe, where over 10,000 people are now employed by Cummins, the company is cooperating with a number of other businesses, including Scania. Cummins' historical roots are in engine development, which is why Jennif-

Fig. 2: Prototype of a hydrogen truck with KEYOU-inside technology

er Rumsey, president and chief operating officer, backed up its strategy by saying: "Hydrogen engines are able to speed up the rollout of the hydrogen economy. There will be a market for them. There isn't one single solution."

Another competitor that is convinced combustion engines are the future is FPT Industrial. The Iveco Group subsidiary exhibited its XC13, a multifuel engine that can run on diesel, methane or hydrogen. The six-cylinder engine offers 600 horsepower and meets the fleet-wide carbon dioxide emissions target applicable from 2025.

ISSUES WITH VEHICLE LENGTH The focus of an ongoing and controversial discussion is vehicle overlength – an issue which also brings into question how hydrogen tanks are installed. While some industry players claim they solved this challenge long ago, others are still searching out legal loopholes or regulatory assistance. The crux of the problem is that the installation of hydrogen vessels behind the cab makes the trucks 60 to 80 centimeters (24 to 31 inches) too long, meaning that all vehicles would require individual approval. Certainly not a practical option.

Nikola, for example, chose to circumvent this regulatory hurdle, aided by a special rule on fuel economy due to improved aerodynamics. Faun, meanwhile, integrates its hydrogen storage into the chassis.

In Hannover the new Faun subsidiary, Enginius, demonstrated its own solution in the form of a prototype of the new CityPower, which was presented to the public for the first time. This second model released by the Bremen-based company (following the BluePower – see H2-international, August 2022) uses an Atego from Daimler Trucks which features a 9-metric ton payload and a 500-kilometer (310-mile) range with 32 kilograms of hydrogen (at 700 bar). Initial field tests are due to begin at the end of 2023, with commercialization planned for 2024.

"The commercial vehicle sector is wonderfully unemotional – all that counts is the total costs of ownership (TCO)."
IAA exhibitor

Fig. 3: Cummins is taking a multitrack approach: As well as fuel cells the company is exploring engines fueled with biogas, hydrogen and HVO (hydrotreated vegetable oil – a synthetic fuel made from plant waste)

ORDER OF 5,000 HYDROGEN TRUCKS HAS MASSIVE IMPACT

Up until now, there have only been eight 350-bar refueling stations suitable for hydrogen buses or trucks out of a total of 95 hydrogen stations in Germany. Intent on changing this situation by intensifying their cooperation are two self-starters from the north of the country. To this end, Clean Logistics has sold 5,000 new hydrogen trucks to GP Joule Hydrogen which in return plans to build 150 hydrogen filling stations over five years. Both companies want to become joint "enablers," sorting out both the infrastructure and the vehicles for potential customers, wherever they may be.

André Steinau, who heads up eFarming and GP Joule Hydrogen, said: "We are now witnessing the first trucks. Now the infrastructure for them needs to come too." In conversation with H2-international he explained there are companies that make a living financing such projects. The role of GP Joule Hydrogen is to bring those that have the money together with the users, he said. Principally it's about taking the eFarm concept, which has enjoyed great initial success in northern Germany, and rolling it out to the rest of the country, he continued. Furthermore, he promised that hydrogen vehicles with a 700-bar tank will also be able to refuel at their stations, though the tank will only be two-thirds full, while the fuel will be around EUR 1.50 cheaper than at 700-bar stations.

Andreas Rimkus, the hydrogen representative from the SPD parliamentary group, had the following to say on the matter during watt_2.0 in Husum: "The announcement of 5,000 trucks made a real splash." Together with Kurt-Christof von Knobelsdorff he affirmed that the idea is to enable hydrogen for the entire transportation industry since this is the sector with the greatest willingness to pay. Not that anything is likely to discourage hydrogen provision for this sector anyhow, it was said.

Fig. 5: Iveco's road map to become fossil free by 2040

IVECO AND NIKOLA PRESENT TRE FCEV Also not limiting itself to electromobility was the Iveco Group. As well as presenting the battery-powered Iveco Daily cargo van, the corporation unveiled its beta version of the European Nikola Tre fuel cell vehicle, which reportedly has a range of up to 800 kilometers (500 miles). The mass production of this long-haul semi-trailer truck for the North American market is provisionally planned to start at the end of 2023 in Coolidge, Arizona; for the European market it's earmarked for the first half of 2024 in Ulm, Germany. That's in spite of the announced shipment numbers having been repeatedly reduced.

President of Nikola Corporation Michael Lohscheller said: "This will be the beginning of a new era in clean commercial vehicles and innovative energy solutions for Europe." Luca Sra, Truck Business Unit president of Iveco Group, added: "Today we are making history with the first products for the European market resulting from Iveco's strong partnership with Nikola Corp. Our teams have co-developed a modular platform that is suitable for both fuel cell electric and battery electric powertrain technologies [...]. It's the world's first electrically designed modular platform for heavy-duty tractor units that can run on both energy sources. A real revolution."

Fig. 4: British manufacturer Tevva unveiled its hydrogen truck at the trade fair

Fig. 6: The two tanks each hold 40 kilograms at -253 °C

Fig. 7: Unveiling of the Quantron QHM FCEV

Parallel to this, Iveco is also collaborating with Hyundai Motor Company. The Italian group joined forces with the South Korean corporation to exhibit a concept vehicle for a hydrogen-powered version of the Iveco eDAILY. The vehicle comes equipped with a battery pack from FPT Industrial offering 37 kilowatt-hours and 12 kilograms of 700-bar hydrogen as energy storage that allow it to cover 350 kilometers (215 miles) using the 90-kilowatt fuel cell power system from Hyundai, plus 50 kilometers (31 miles) in purely electric driving mode (electric engine: 140 kilowatts).

DAIMLER TRUCK PRESSES ON WITH LH_2 At Daimler Truck, meanwhile, engineers are persevering with liquefied hydrogen (LH_2) and the use of fuel cell stacks produced by cellcentric, which is now working on its gigafactory in Weilheim, Germany (2 x 150 kilowatts; see H2-international, August 2022). A refueling station for this cryogenic compressed gas is also in the offing. For the moment, the exhibited long-distance model of the GenH2 Truck remains just a prototype.

The liquefied hydrogen tanks in this case are built into the side of the chassis while the cooling unit along with the high-voltage battery (72 kilowatt-hours of installed capacity; 50 kilowatt-hours of usable capacity) is positioned behind the cab. When it comes to permissions, the GenH2 Truck doesn't face any problems so long as certain conditions such as the journey range are met, H2-international was told.

Christian Mohrdieck, CEO of cellcentric, explained that the fuel cell systems produced in Weilheim would not just be supplied to its two joint venture partners Daimler Truck and Volvo Truck, but also to Rolls-Royce, which is using them in stationary solutions developed by its mtu brand. Thanks to these three customers, cellcentric has the backing it needs to scale up and thereby reduce unit costs.

QUANTRON MAKES WAVES When it comes to market rival Quantron, meanwhile, many industry players are still doubtful whether the spinoff from long-standing company Haller will actually be able to live up to the heady promises made

500 HYDROGEN TRUCKS FOR THE USA

Just three weeks after the IAA Transportation event, Quantron received a huge order: The Gersthofen-based truck manufacturer is set to supply 500 fuel cell trucks to American transport company TMP Logistics. The contract, which amounts to almost EUR 1 billion, covers the provision and maintenance of the vehicles as well as the fuel.

Fig. 8: The certified all-in-one system includes everything – from the bottle to the fittings, from the controller to the safety equipment

over past months. Doubtless the company, based in the German city of Augsburg, has an excellent marketing department, as evidenced by the unveiling of multiple world premieres in Hannover.

Among them, a battery-powered Cizaris 12 EV city bus and the Daily QLI FCEV, which has subsequently been available to order. Showcased as Quantron's crowning glory, however, was "The Monster" – which was confidently fanfared as the "Champion for Heavy Duty Transport." The QHM FCEV (44 metric tons with 54 kilograms of hydrogen) supposedly achieves 600 to 700 kilometers (370 to 435 miles) on one fill-up whereas the Nordic version (60 metric tons with 116 kilograms of hydrogen) is claimed to reach up to 1,500 kilometers (930 miles). Support for the production of its hydrogen solutions comes from a band of well-known suppliers. The fuel cell stacks are sourced from Ballard, the power unit from Allison Transmission, the hydrogen tanks from NProxx and the refueling system from Neumann & Esser.

All this is tied up in the Quantron-as-a-service (QaaS) operating concept, which CEO Michael Perschke presented as a 360-degree ecosystem – a no-worry full-service package containing everything required, from the production of green hydrogen and appropriate infrastructure through financing and servicing schemes.

The first shipments of the "range champions," as Perschke calls them, are expected to take place in mid-2023. To be able to serve customers from industry, logistics and food processing as well as the public sector, Quantron has ordered an initial batch of 140 latest-generation fuel cells for its heavy-duty trucks from its Canadian supplier.

With regard to the length and permit issue, Quantron stated: "We have our own solution. We have solved it." The company guarantees "maximum range without restrictions on cab or trailer length."

By contrast, Paul Nutzfahrzeuge openly admits that the company hasn't finally resolved how to handle the overlength of its vehicles. To date, the prototypes have required individual approvals. Much more important to the special vehicle manufacturer was the presentation of its fuel cell truck which will be fitted with Toyota stacks as standard from now on. Also on show was Paul's new modular and scalable PH_2P hydrogen storage system, which was developed together with Anleg for original equipment manufacturers and conversion specialists.

In addition, Bernhard Wasner, director of the Paul Group, demonstrated the company's new Transforming Trucking philosophy in which all activities will be organized henceforth under the umbrella of the Paul Group. He reported with visible pride: "We built the two Keyou prototypes that can be seen at the fair."

SUPPLIERS Even heavyweight suppliers such as Bosch are now clearly putting hydrogen front and center. The head of Bosch's supervisory board has announced the company's ambition to have 40,000 fuel cell systems on the road by 2025. It is hoped that Bosch technology will not just be used in the trucks of customers such as Nikola but will also find their way into agricultural and construction machinery that will one day be powered by hydrogen engines. The group is also working with its subsidiary Bosch Rexroth on refueling station construction – together with compressor manufacturer Maximator Hydrogen. What's more, in 2021, Bosch and Chinese vehicle manufacturer Qingling set up the joint venture Bosch Hydrogen Powertrain Systems.

Forvia, which describes itself as the seventh biggest automotive supplier in the world, exhibited a new cryogenic hydrogen storage solution for heavy-duty applications for the first time together with its two brands – Faurecia and Hella. This compact storage system, which was co-developed with Air Liquide, can transport the same quantity of hydrogen at a 40 percent reduced volume. Also on offer from Forvia were

Fig. 9: Markus Heyn, Bosch director and chairman of the Mobility Solutions division

Fig. 10: The S1200 module claims to enable a 54 percent fuel-to-wheel efficiency – compared with 20 to 25 percent for a diesel vehicle

gaseous hydrogen systems, ranging from an 80-kilogram hydrogen storage solution to a 150-kilowatt fuel cell stack, which is provided by Symbio. In terms of light commercial vehicles, the French company is cooperating closely with Stellantis which, still in the form of the PSA Group, was a major shareholder in Forvia until 2021.

Canadian fuel cell manufacturer Loop Energy used the IAA as a springboard for its new S1200 module for the bus and truck market. According to President and CEO Ben Nyland, the unit is up to 60 percent fuel efficient. This comparatively high net efficiency level, which within the output range of 20 to 80 kilowatts only drops by 10 percent (peak power of 120 kilowatts), is made possible by eFlow technology – a mechanical process that allows media to flow more easily through the stack. This system has yet to appear on the market but, in Nyland's words, Loop will "get more involved when the market grows." The current plan is to roll out a test vehicle in the first half of 2023 and to start commercialization in the second half of the year. Initial orders have already been received following the trade fair. ||

NEUMÜNSTER BECOMES HYDROGEN HUB

Shortly before the IAA, companies Hypion and Resato Hydrogen Technology signed a contract stating their intention to build ten hydrogen filling stations in northern Germany. The collaboration is due to kick off with an automated public refueling station with 350- and 700-bar facilities for heavy-duty transport vehicles in the Neumünster Süd industrial park (capacity: 2,000 kilograms of hydrogen per day). The aim is to offer refueling to companies in the logistics, retail and construction industries at the Neumünster hydrogen hub from the second quarter of 2023. Seven hydrogen trucks are expected to be supplied by Clean Logistics (see box on p. 38). Stefan Rehm, Hypion project lead, explained: "It's only possible to achieve commercial viability with a totally different magnitude of sales in the order of several hundred kilograms of hydrogen a day. The project will ideally provide an appropriate boost for the launch of clean freight transport with green hydrogen onto the market." Hypion is a joint venture between engineering consultancy IPP Projects, the Heide regional development agency, EDF Deutschland and HanseWerk.

Fig. 11: Contract signing at watt_2.0 in Husum [Source: Hypion]

Category: Electric transportation | **Interview Partner:** Audrey Ma

EUROPE IS REALLY STARTING TO ACCELERATE

Interview with Audrey Ma, Vice President International Markets, Refire Group

Those who weren't familiar with Refire before can now think of the fuel cell company every time they hear the name Clean Logistics, because the startup from Niedersachsen has a supply contract for fuel cell systems from the company. So it's not surprising that Audrey Ma, Refire Group Vice President International Markets, had been invited to be a guest of honor at the presentation ceremony for Clean Logistics' truck Fyuriant truck launch this past summer in Stade (see H2-international Oct. 2022). H2-international had the opportunity to speak with Ms. Ma during IAA Transportation 2022 in Hannover.

Fig. 1: Audrey Ma

H2-international: Ms. Ma, how long has Refire been around and how long have you been with the company?

Ma: Yesterday was actually the seven-year anniversary of the Refire Group. It started out as a very small team. The founders were three engineers who worked in the area of fuel cell technology. I joined the company at the beginning of 2017 and within these few years, we've grown to a team of nearly 700.

What was your goal at the time?

Our common goal was to further develop fuel cell technology for commercialization, which is now all around us at this trade fair. I believe we've contributed to making fuel cell technology market ready.

Could you give us examples of how?

In 2017, we put our first FC vehicle fleet – 500 7.5-tonne fuel cell delivery trucks – on the road in Shanghai. We engineered and manufactured the fuel cell systems and worked on further development of the vehicle prototype, including FC system integration. Our partner at the time, Dongfeng, which is a major Chinese OEM, then built the 500 trucks. This was a really challenging undertaking, and we learned a lot from it – from hydrogen production to the question of who would do vehicle maintenance work. We managed to find operators that would use these vehicles and market them to end-user companies. When we mobilized drivers, we were also the ones who then organized the after-sales service of those vehicles, not the OEMs or the operators. After that, we redoubled our efforts and, among other things, we installed an H_2 station of our own with partners so that our drivers would have a place to refuel.

In other words, a completely new approach to bringing such technology into the hands of customers.

Yes, we had to take a different path. We had to find ways to make it viable because a traditional approach wouldn't have worked here.

Why are you here today?

We brought a fuel cell system with us today that came straight off the production line. This is not a prototype. We will have covered over a million kilometers with this system by the end of the year. It has a power output of 117 kW and has already been integrated into several hundred heavy-duty vehicles. We are working together with a variety of partner companies – domestically and internationally, including in Germany, to integrate these systems into vehicle powertrains.

So you're a classic system integrator.

Yes, we integrate fuel cell technology in various applications. The Refire Group has three subsidiaries that develop FC technologies and manufacture products. One of the business units, Unilia, produces FC stacks. Another, Pando, makes FC power electronics products, and Refire Technology builds complete FC systems. These three subsidiaries operate independently but under a common umbrella.

So you produce your own fuel cell stack but also use stacks from other producers for your systems, like Ballard for example?

That is correct. In the production of complete FC systems, our own stacks or those from other manufacturers may be used. For example, in one project Toyota is our stack partner. Similarly, there are also German, Canadian and Chinese stack suppliers that we have worked with.

I see. What applications do you address with Refire Technology?

We focus on a variety of applications for commercial vehicles and stationary power. We don't just supply the fuel cell systems and core components, but also offer application engineering services. Sometimes we'll also do turnkey solutions in order to help customers decarbonize specific and unique end use case applications.

Is that what you do for Clean Logistics?

Clean Logistics has a very capable engineering team which already has experience from past work in the conversion of diesel powertrains to battery-electric, and they're now adding fuel cell solutions to their product lineup. The complete engineering solution that we typically provide OEMs is to integrate a fuel cell powertrain based on their own existing chassis. We look at which fuel cell system is optimal for a

given application, and then we assemble the various vehicle components in order to return a fully finished fuel cell vehicle prototype to the OEM.

How many systems have you already delivered?

We have shipped in total about 4,500 fuel cell systems for commercial vehicle integration. Vehicles powered by Refire FC systems have now converted at least 3,500 tonnes of hydrogen into electricity for zero curbside emission driving. Altogether, the fuel cell commercial vehicle fleets have clocked more than 125 million kilometers, a mileage that rises about 1 million kilometers every week. As I mentioned earlier, our aim has always been to commercialize fuel cell technology, and so bringing products to market and into the hands of actual drivers is very important. We work collaboratively to enable OEMs to homologate their prototypes so that at-scale vehicle production can be achieved when fleet operators place their orders.

You're based in Shanghai, and are also active in Germany and North America. Where is your global focus?

That's right – Refire's corporate headquarters is in Shanghai. We currently have two engineering centers – one in Shanghai, and another in Vancouver. A third engineering center is in the works in Germany which will service our European customers.

Okay. Could that also become a European production site?

This is very much a possibility. I think it makes a lot of sense to be strongly rooted right here, where we offer our products and services. However, such a commitment must be made at the right time. Our current production capacity of 5,000 systems annually is sufficient for global demand at the moment. The question and timing of setting up production facilities here will very much depend on the political framework as well as order volumes. The European market for FC commercial vehicles does seem to be on the cusp of a breakout, but we need to wait a bit and see. In the medium and long term, however, we do expect Germany to be an important hub for us within the larger continent because Europe is really starting to accelerate.

When you look here at Europe, where do you see the best framework conditions?

I think for fuel cell technology, if a company wants to enter the EU market, Germany is set to play a key role. We were fortunate to be able to establish solid supply chain partnerships here back in 2016. Then by 2018 we had already found our first end user customers, and in the same year we gained some visibility at the IAA Expo. This year, we have further intensified these co-operations, thereby helping to enable rapid growth our local partners in the FC sector. From hydrogen production to deployment of fuel cell technology we must work together to build a functioning and self-sustaining market.

Are you mostly looking to connect with larger corporations, or do you also consider working with small businesses?

It's interesting to see that the smaller, more agile companies are so willing to take the plunge. They want to see change, and despite the uncertainties and challenges, they are quite daring. As I mentioned, Refire also started out very small with just three automotive engineers as founders. We do work with larger industry players, for example, there's a 3.5-tonne prototype FC transport van on show here at IAA Hall 12 that

Fig. 2: "there's been much dialogue, and more and more companies are getting involved."

Schaeffler and Refire completed together. We also gave an introductory presentation here about a collaboration we have with Garrett. And Continental has been another such partner for our products. On the vehicle side, we've worked with Mitsubishi Fuso, a subsidiary of Daimler Truck, on their first FC truck. Regardless of the size of company, we know that we have to deliver good work with like-minded partners and that we can only succeed together.

How does market volatility affect Refire?

Like all market participants, we have to be fully cognizant of the changing landscape. We try to maintain flexible boundary conditions where we can, and prefer to focus on areas where we can make a positive impact – the confluence of policy, market, and technology. At the risk of repetition, we believe that means prioritizing co-operation. It also means helping to enable hydrogen ecosystem and market growth through knowledge sharing and facilitation of other relationships amongst active as well as potential stakeholders. Ultimately, if we can contribute sustainable value to our customers and partners, we expect to be able to thrive.

And finally, when do you expect a ramp-up to a considerable number of units?

Refire fuel cell systems currently power some 3,500 commercial vehicles on the road. When we talk about ramp-up, we can't ignore the China market. So far, the country has plans to deploy 50,000 vehicles by 2025, which, in our opinion, is an achievable number. Parallel to this, other fleets are being built up around the world. Towards the second half of the decade, we expect to see quite a few more OEM projects and products hitting the roads in Europe, North America and Asia.

Thank you very much for your time and your responses.

Interviewer: Sven Geitmann

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

AT THE SPEED OF A BIG OL' BARGE

Ship transport only slowly becoming cleaner

Green hydrogen is to be used in particular where electrification by other means is not possible or only possible with great difficulty – for example in maritime applications. One of the greatest problems facing the shipping industry, however, is that there are only a few manufacturers who optimize their drive concepts for use on the water or design them specifically for this purpose, because the quantities demanded in this economic segment are generally not very large. How this dilemma could be solved is being discussed in, among other projects, e4ships and e4ports.

Hydrogen and fuel cell technology has now arrived in almost all divisions of technology. Accordingly, the two were presented and discussed during the SMM, the largest ship and maritime technology fair, that took place in Hamburg from Sep. 3rd to 6th. During the accompanying e4ships conference, for example, Achim Wehrmann, director for ship transport at the German transport ministry (BMDV), stated, "(The NIP project) e4ships has been running since 2009 and has shown that fuel cells are extremely important for maritime applications." At the same time, he stressed, "The emissions in this sector need to be significantly reduced. And we need to be quicker about it."

THE SEARCH FOR THE FUEL OF TOMORROW The main question in the industry at the moment is which fuel will be the fuel of the future? It is clear that the move away from fossil fuels such as heavy oil must be implemented as quickly as possible – but what should follow? Dr. Ralf Sören Marquardt, managing director of the German association for shipbuilding and maritime technology (Verband für Schiffbau und Meerestechnik eV, VSM), made clear that the current state of the industry is literally gloomy, as at present dirty clouds of exhaust gas still were obscuring the sun.

The ship companies and builders had been set on using LNG as the alternative, but ammonia, methanol, liquefied petroleum gas (LPG), low-flashpoint diesel (LF diesel) and hydrogen are now being seriously considered. LPG, likewise to LF diesel, can in principle be renewably generated, but not yet however. Hermann-Josef Mammes from the shipyard Meyer Werft stated, "We need more and a diversity of different fuels." He pled for more demonstration projects in this context so that the corresponding technologies could be better tested. Stated Mammes, "The sobering conclusion is that we are nowhere near the market ramp-up stage in this sector."

Christian Allgeier from the BMDV replied that "safety comes first, before speed." In his opinion, the current pace of development is not okay, which is why work is being done to accelerate it. At the same time, however, he said, "We don't want anyone to be left behind."

QUESTION FOR THE WORLD
One question that was discussed but not answered during the e4ships event was whether cruise ships are really necessary. Is it really necessary for floating cities to encroach on what could have been untouched nature, or would a reorientation be desirable here?

THE IMO IS TOO SLOW Much at this time still depends on the regulations that the International Maritime Organization (IMO), in which 175 nations are a part of, will set in the ship transport sector. Kurt-Christoph von Knobelsdorff, managing director of the German administrative agency for hydrogen and fuel cell technology (Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie, NOW), stated, "Many regulations are undergoing revision at this time, including those for hydrogen." Although they are striving for speed in this, it will take years before anything gets done. Dr. Christopher Stanik, NOW team leader for maritime applications, declared, "The strategy (of the IMO) is not fast enough, is not in line with the Paris Goals."

Even more direct was VSM chief managing director Dr. Reinhard Lüken: "We must – especially on the regulatory side – be much faster. We are far behind." Specifically, he criticized that it took "ten years to introduce the IGF code for a fuel that we had been using for years." He also called for a change in the EU taxonomy for sustainable activities so that e-fuels could become viable in the maritime sector.

Marquardt said regarding the IMO, "The goal is correct, but the measures are not ambitious enough. We need more trust and less resistance." Here, there is a "long list of unresolved problems." As long as this framework is not established, there will be the challenge of having to build ships without having solid regulations, which could then always change case. VSM managing director Lüken stated: "If we continue to address tasks one after the other, we will not get things done fast enough. We need to accelerate. We need to achieve all this in less than ten years – and all in parallel. Money may not be the problem right now, but that we need better coordination."

Bingbing Song from the International Maritime Organization stated that while the IMO does not tarry, the fact that the institution is working with so many different countries and other actors inevitably means that the coordination processes are extremely lengthy.

ZERO-EMISSION AT THE WHARF Subject of discussion are ports in addition to ships. In order to, for example, make

Fig. 2: The Hydrocat 48 with H_2 drive [Source: CMT.Tech]

shore power more sustainable, the network e4ports has been running since 2021, which among other things concerns itself with ideas and designs for the energy supply at ports as well as the implementation of EU guidelines. This should help ports become sustainable transport hubs. Since they are not only points of exchange, but also always energy sinks, they are ideal sites for energy renovation.

At the focus is how energy supply, particularly of large ships, is to occur at ports. As the running of diesel engines has been subject to heavy fines for several years due to emissions reduction laws, the supply of power for moored ships must be guaranteed by the shore side. For this, there are several approaches.

When the energy requirement is over 1.5 MW, mobile shore power solutions are generally not practical, since the cost can add up to around 50 cents per kWh. Therefore, stationary solutions are therefore more suitable for this high power segment. Mobile solutions, such as battery systems or trailers with alternative fuels, are more suitable "for smaller marinas or for areas of ports with lower utilization rates" – most import factor being a "highest possible capacity utilization of the systems, in order to be able to use them economically." This was the conclusion of the study "Technologische Möglichkeiten und Voraussetzungen mobiler Landstromversorgung" (technological possibilities and preconditions for mobile shore power), which was presented during the e4ports conference.

Containerized fueling solutions of this kind are already widely established in the event sector, but in maritime use, they are still quite new. There aren't any hydrogen solutions yet, however, with the exception of one example from GP Joule, who tried out an H_2 Container at the rock festival Wacken.

Besides the supplying of power to ships in ports, the discussion is about the supply to vehicles on the grounds of the port. One-third of the CO_2 savings can be achieved there through electrification and automation alone, and two-thirds through the use of alternative fuels. However, solutions for port vehicles with hydrogen as the alternative will probably not be available for another five or ten years, which is why when new equipment is purchased, conventional technology will still be in play in many cases. Down the line, however, increased electrification and possibly the acquisition of H_2 systems awaits.

"This vessel offers the industry a cost-effective solution to significantly reduce emissions from service vessels, which can be applied to any wind farm today. This solution can be seen as a steppingstone to fully hydrogen powered CTVs. By starting with dual fuel combustion engines, we can make hydrogen technology operational in the industry and kick-start further development of the technology, regulation, supply chain, etc."

Willem van der Wel, managing director of Windcat Workboats

"The suitability of this technology for a CTV is mainly because existing diesel engines can be used. No fundamental changes to the main engine are required, which not only means that maintenance and repair remain simple, but also that the engine can easily be switched back to diesel fuel without any modifications. Even if hydrogen is not available, the vessel can continue to run on traditional fuel, making it a very robust and reliable solution for the offshore wind industry... From the initial dual-fuel technology projects we have seen reductions of CO2 emissions up to 80%."

Roy Campe, managing director of CMB.TECH

H_2-POWERED CTVS Also at the WindEnergy that took place end of September (see p. 10), also on the Hamburg Messe grounds, was something to be seen from the maritime sector: the Hydrocat 48, the first hydrogen-powered crew transfer vessel (CTV). In May 2022, CMB.TECH, which is a Belgian company that converts special machinery and ships, announced together with Windcat Workboats that the CTV, after the successful tests, was immediately ready for operation. That is, to bring workers to their posts at offshore wind parks.

The Hydrocat 48 uses a dual-fuel engine from MAN that CMB.TECH equipped with an H_2 injection system. CMB.TECH had retrofitted its first CTV to operate with hydrogen as early as 2017. The resulting technology from this was then installed in a Windcat MK3.5 workboat without incurring significant loss of performance or reliability, explained Frank Wiebe from FRS Windcat Offshore Logistics GmbH to H2-international.

One of the first H_2 ships was the Hydroville, which has been shuttling around Antwerp for three years now. In 2021, it was joined by, among others, Hydrobingo. In the meantime, a total of four additional ships have been ordered, according to Wiebe. And since October 2022, Volva Penta, a subsidiary of the Volvo Group specializing in ship propulsion, has also been a cooperation partner. ||

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Fig.: CEMEX intends to establish electrolyzers in Rüdersdorf to supply the cement factory with green hydrogen
[Source: CEMEX, Thomas Weber]

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

MEGA-TASK ECO-CEMENT

Building materials like cement and concrete must become green

More than four billion tonnes of cement are produced worldwide every year. In the process, the building material inevitably releases large quantities of the carbon dioxide bound in the lime. Cement manufacturers, such as CEMEX from Mexico, are meeting the gigantic challenge of decarbonizing the industry. A bottleneck in the development is lack of green hydrogen. The building materials manufacturer has now set ambitious targets for itself. The site in Rüdersdorf is to serve as a blueprint.

For production of green cement, it is not only the required energy that is a problem, since only one-third of the CO_2 emissions originate from the energy input. Two-thirds are intrinsic to the system. These are emissions that arise in the course of cement production itself. A cement produced with purely green energy still releases huge amounts of CO_2 during the production process. Businesses and researchers want to change this.

Change for the climate also means changing cement to eco-cement. Various scientists are also working on this, among them the research institute Empa in Switzerland, which is developing a CO_2-negative magnesium-based cement. Building materials manufacturer CEMEX also wants to rapidly reduce its emissions. According to the company's calculation, it is already releasing 35 percent less CO_2 than in 1990, Sergio Menendez states. He is president of CEMEX Europe, Middle East, Africa and Asia. By 2030, it should be 55 percent less in Europe, and the manufacturer wants to produce only CO_2-neutral concrete worldwide by 2050.

So far, however, there has been little demand for green products, CEMEX speaker Alexandra Decker laments. The company therefore has the idea of separating carbon dioxide from exhaust gas, storing it temporarily and then converting it together with H_2 into synthetic fuel. Thus providing a product that is planned for in advance and producible on demand. "This is another reason why we only want to use green hydrogen," Decker assured H2-international.

CEMEX has specifically chosen to build electrolyzers at the location in Rüdersdorf so that it can supply the factory there with hydrogen from green electricity. In this way, H_2 that might be needed for other industries would also not be taken off the market. The construction would have to start in 2025/26 for the site to produce CO_2-free from 2030 onwards, Decker states.

THE CONSORTIUM CONCRETE CHEMICALS In order to free not only cement production but also air traffic from CO_2, three companies founded the project consortium Concrete Chemicals. CEMEX, with 56,000 employees worldwide and its own locations in Germany; Sasol ecoFT, a subsidiary of

chemical corporation Sasol; and Uckermark-based Enertrag plan to produce a sustainable aviation fuel that can also be used in cement production. For this, a power-to-liquid method (PtL) will come into use. CO_2 and H_2 are converted into syngas. The mixture of carbon monoxide and H_2 is then, with the aid of the Fischer-Tropsch process, converted into longer-chain hydrocarbons to produce e-kerosene.

The project in Rüdersdorf comprises two scaling levels. First, the hydrogen will be produced on site with electricity from regional renewable energy plants. In this first stage, 15,000 tonnes of e-kerosene are to be produced annually this way. For it, 100 tonnes of CO_2 per day are to be captured in Rüdersdorf, combined with 12 tonnes of H_2 per day and used for PtL production. In the second stage, larger quantities of H_2 are to be delivered by pipeline.

The green hydrogen will be generated as part of the IPCEI project Elektrolyse-Korridor Ostdeutschland (electrolysis corridor Eastern Germany) to build a capacity of 210 MW. This will enable the production of 35,000 tonnes of e-kerosene per year. This project also uses only renewable electricity for the production of 40 tonnes of green hydrogen per day, the consortium states, which requires that another 300 tonnes of CO_2 per day be sequestered.

THE PARTNER NETWORK DOING HYDROGEN Concrete Chemicals as well as Elektrolyse-Korridor Ostdeutschland are part of the IPCEI partnership project Doing Hydrogen. During construction of the pipeline from Rostock to Sachsen, all components of an H_2 value chain will be covered. The resulting transmission system is to be built by 2026, two-thirds by conversion of existing natural gas infrastructure and one-third by the construction of new complementary hydrogen lines. In this way, a starter grid with a total length of 475 kilometers will arise that connects production and use points in Mecklenburg-Vorpommern, Brandenburg, Sachsen, Sachsen-Anhalt and Berlin.

The e-kerosene is then also to be certified for use in aircraft, since no alternative propulsion systems in the aviation sector are in sight for the foreseeable future. Through PtL, fuel of exactly the same specifications as petroleum-based kerosene can be created. With this, no modification of the existing drive technologies is needed. The three companies want to meet the criteria for aviation fuel set out in the EU directive RED II. Fuel having the prescribed minimum percent of PtL kerosene to be blended can be achieved this way.

THE MARKET FOR E-KEROSENE The EU proposal ReFuelEU Aviation represents a first step towards the decarbonization of air transport. At the same time, it should ensure the purchase of synthetic fuels such as e-kerosene. At EU level, the regulation includes a sub-quota of 0.7 percent synthetic fuel out of the required quota of sustainable fuels for year 2030. The quota is to rise to a minimum of 28 percent e-fuels by 2050. "In this way, demand is plannable and ensured," states Enertrag speaker Matthias Philippi.

Furthermore, under the German fuel blending regulation (Beimischungsverordnung), the fuel for all aircraft refueling in Germany will need to contain at least 0.5 percent PtL kerosene starting as early as 2026, and 2 percent starting 2030. This should increase the share of renewable energy in the transport sector to 28 percent by 2030.

CEMENT WORKS IN HÖVER Not only CEMEX and partners are working to solve the Herculean task of creating sustainable cement. In the cement works of Höver, not far from Hannover, the company Holcim is testing out an innovative technology intended to decarbonize the building material. There, Holcim, together with the two partners Cool Planet Technologies, specializing in CO_2 separation, and research institute Helmholtz-Zentrum Hereon, has installed a CO_2 capture plant based on an innovative membrane technology. The first step entails the gathering of practical experience with CO_2 capture. After a few weeks of operation with the test system, the first results were very positive. "We were able to observe a good separation rate and comparatively high purities," rejoiced Stephan Hinrichs, plant manager at Holcim.

The next phase of the research and development project that will span about two and a half years was planned to start in August 2022. A one-year test phase, during which a long-term operation of the plant will be examined, is scheduled to begin in September of next year. If good results are confirmed, the plant will be further expanded step by step. In the final expansion stage, around 90 percent of CO_2 emissions would be captured. The resulting very pure, liquid CO_2 can be stored or further processed. The goal of the Holcim team around Stephan Hinrich is to demonstrate that carbon capture can also be economically efficient on a larger scale.

CARBON2BUSINESS SET ON PURE OXYGEN Holcim has already received a grant out of the EU Innovation Fund for a project in Lägerdorf called Carbon2Business. Funding has been provided for the construction of a new kiln line in the cement works of Lägerdorf, located on the West coast of Schleswig-Holstein. A prototype that uses oxyfuel technology is being developed that should accelerate the decarbonization of cement production on an industrial scale. The CO_2 captured in Lägerdorf is to serve as a raw material for other industries.

Instead of ambient air, pure oxygen is fed in for the combustion processes. The required oxygen is to be produced along with the hydrogen from electrolysis. The oxyfuel method generates highly pure CO_2 gas in the cement kiln, which can then be separated and converted to methanol by reaction with hydrogen. With this, the site can avoid the emission of about 1.2 million tonnes of CO_2 per year. In Lägerdorf, like in Rüdersdorf, the green fuel as a market-ready product will help advance sustainability in the cement industry. ||

MAGNESIUM-BASED CEMENT

Concrete production accounts for around six percent of man-made CO_2 emissions worldwide. Researchers at Empa in Switzerland are striving to change this. They are currently working on a CO_2-negative concrete. The basis for the eco-concrete is a magnesium-based cement. The raw material is sourced from regions where the magnesium-containing mineral olivine naturally occurs. The mineral is mainly found deep in the earth's mantle. However, if it is transported to the earth's surface by volcanic activity, for example in Norway, it can be mined. During the production of cement from olivine, carbon dioxide is added to the raw magnesium silicate material. Since only part of the resulting material is fired in an additional processing step, less CO_2 is released during the combustion than was previously consumed. The end balance is therefore negative. The product has been named MOMS, short for "magnesium oxide derived from silicates."

Category: Education | **Author:** Sven Geitmann

HYDROGEN AS A GLOBAL COMMODITY

Thoughts from Sven Geitmann, editor/publisher of H2-international

Hydrogen is becoming a commodity – an article of commerce. The H_2 industry has been waiting for this for a long time. Decades have passed in which suitable applications for fuel cells were sought – mainly in vain – before it became clear that hydrogen has the potential, as a storage medium for renewable energies, to turn the entire energy supply system around. This has now been understood by not only numerous politicians around the world, but also the big players in the globalized economy. But what does this realization mean for society? Will H_2 now sweep all fossil fuels off the market and thus also halt global warming? Or will the global hunger for energy continue to rise and perhaps even fuel the climate crisis? And what role do the big companies that have dominated the oil and gas market so far, and are now rushing into hydrogen, have in this?

For years, hydrogen was a niche topic. H2-international has been reporting on it for 22 years. Everything is stored and readily accessible in the online archive – when and why which hype arose and which areas of utilization have already been tried. Some major companies were indeed involved in the past. The energy corporation RWE had its own fuel cell division 15 years ago, German automotive companies developed generations of test and demonstration vehicles, and oil companies established and cleared away their H_2 departments over the decades.

All these activities– in particular those of the energy and auto corporations – were always accompanied by large marketing campaigns. Full-page print ads could already be seen of cars with garden hoses stuck into the filler neck. Marketing-effective fuel cell cars traveled around the world, and speed records with H_2 combustion engines were made.

Today, it is a little different, but yet so similar. The difference is we're not talking about another brief hype – the global hydrogen industry is coming, even if it is not yet clear which energy sectors will be most strongly affected. Yet marketing departments have not changed their behaviors very much. Large, globally active companies in particular are using the image of green hydrogen to clean up their own.

This was also the case around 2008, when electromobility experienced its first boom and ladybirds and stickers with "0 g CO_2" were emblazoned everywhere on vehicles at the IAA fair. Then, nothing happened for years. Therefore, the question must be allowed of how credible the announcements of oil companies, gas companies and car manufacturers are if today they loftily describe sustainably produced hydrogen as the "fuel of the future" while at the same time ignoring their fossil-fueled past?

Of course, the clean energy transition will not take place overnight. Obviously, we can't immediately ban petrol and diesel and then only burn solar-generated H_2 gas. But how reliable is it when a Swedish company already advertises green steel today although the amount of this metal produced in the pilot plant with the aid of green hydrogen constitutes only a thousandth percent of what is produced by the company every day?

Is it okay for a petroleum company in this country to portray itself as a pioneer in setting up H_2 refueling stations while it expands a highly controversial heated pipeline for crude oil in Africa hundreds of kilometers through previously untouched nature?

Just as committed as we are to discussing the deals with Qatar – be it the World Cup or the LNG exports to Germany – every energy supplier and every energy consumer should think about what is authentic and what is greenwashing.

Because there is one thing we should always remember: Even multi-millions for marketing campaigns is nothing compared to the investments and profits made by the corporations. Need examples?

BP is heading a 36-billion-dollar project in Australia named Asian Renewable Energy Hub, where 26 GW of solar and wind power plants are to be built for H_2 generation and subsequent ammonia production – against the environmental concerns that were raised beforehand. Likewise, the French TotalEnergies and the Indian Adani Group together intend to invest 50 billion USD in H_2 and ammonia production from renewables for a capacity of 30 GW. Shell and Chevron are also planning comparable gigawatt H_2 projects. Because of course these companies can still profit by staying in the molecule trade. After all, H_2 molecules are like hydrocarbons but without the C. And the use of hydrogen as a commodity is a much better support for continued use of the existing fossil fuel infrastructure than mere electrons.

Indeed, it is definitely worth backing the installation of large solar and wind plants, because we need much more renewable energy worldwide. However, how worthwhile, when the activities disproportionately involve fossil energy carriers, should not be lost from sight. Furthermore, lock-in effects should be avoided, whether in the case of the LNG terminals in Wilhelmshaven or in the continued use of the existing oil-based infrastructure.

Companies that are seriously dedicated to creating the rapid change from a fossil to a renewable system of energy supply are expressly not meant here.

P.S. My daughter suggested donating the money obtained from clear greenwashing campaigns. ||

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Category: Education | **Interview Partner:** Björn Lüssow, Steven Oji

QUALITY OVER QUANTITY

New internet platform to exchange H_2 knowledge

Fig. 1: Steven Oji (left) and Dr. Björn Lüssow [Source: Hyfindr]

An interesting approach to furthering hydrogen education and the sharing of ideas is being taken by the startup Hyfindr. During the Hydrogen Technology Expo Europe in Bremen (see p. 8) mid-October 2022, the young company presented its new concept publicly for the first time: an internet platform with the goal of using the expertise of professionals from the hydrogen and fuel cell industry by setting out targeted technical questions that could – so the hope is – be answered by experienced people. At a time when Xing is in the process of closing its discussion groups, Tech Community could become a fresh forum that focuses less on quantity and more on quality. H2-international spoke about it with the two founders, Dr. Björn Lüssow and Steven Oji.

Hello Björn, hello Steven, you have just presented in Bremen your new expert forum Hyfindr Tech Community for the first time. How was the response?

Björn: Very inspiring, Sven. Almost all of the people that we introduced the Hyfindr Tech Community to were immediately excited about it and signed up right after the trade fair. It is evident to every professional in the hydrogen industry that the development and implementation of projects is accompanied by numerous technical challenges. Our Tech Community makes it possible to resolve technical questions quickly and efficiently. I was particularly pleased with the positive feedback I received from students and young professionals; there is a huge demand for knowledge. Many want to work in the hydrogen industry and need digital tools to educate themselves. This is where we come in.

Before, you had only been granting access to the new platform to a small circle of people. Why the initial hesitance?

Steven: Every community lives on the engagement of its members. Only when members of a community are also engaging, which means in our case also really helping with technical questions, are others inspired to join in. No one wants to be a member of a "dead community." For this reason, we started small, with a few highly motivated professionals that we already knew or suspected would help us. We first invited these people to a beta testing and then asked for feedback. We knew that not everything would be immediately optimal in the beginning.

Among other things, you offered online workshops in advance, where the various functions were explained to the initial participants. What was the feedback?

Björn: That's right. And from this we also received reassurance. We held several video meetings with up to ten participants to personally present the goals of our initiative. Doing this was important to me for another reason: only in personal exchange can we really get a feeling for whether an initiative has usefulness or if we are making presumptions. Luckily, the feedback was – as already stated – very positive. We now have several hundred members already, who are diligently discussing technical topics.

I see. So please briefly explain exactly what you have actually built and now offer.

Björn: Gladly. Online communities are not just private test projects or hobbies these days; they now also have great relevance for professionals in many industries. The best example of this, in my opinion, is Stack Overflow. In this forum, hundreds of thousands of software developers freely help each other with programming problems every day. You can find there more than 23 million questions and answers, and the community is visited over 100 million times every month. The more high-quality content a member contributes, the clearer their expertise becomes in their profile. Software developers are now applying for jobs with the authority they've earned in the Stack Overflow community, and no longer with just CVs. I am very impressed by this community, and I asked myself why there was no comparable community for the hydrogen industry, as there are currently many questions to be answered in the hydrogen industry around the world as well.

What distinguishes your concept from Xing, LinkedIn or other forums?

Steven: LinkedIn and Xing are primarily marketing channels and platforms to establish business contacts. On LinkedIn, people don't ask technical questions. Or have you ever seen a question there like "Does every fuel cell stack really need a humidifier?" The following difference is also interesting. Groups, for example on LinkedIn, that were started for idea exchange mutate once they get bigger and bigger into a pure newsfeed. This reduces the benefit for the individual group member. No one can read all the new project updates on LinkedIn anymore. With a Q&A forum like the Hyfindr Tech Community, it is different, because the value for the individual member increases the larger the community becomes. With a large number of members, the probability of finding an expert or two for a specific question is higher. One person asks a question and the intelligence of the entire community answers. In a community like Stack Overflow, it is also often the case that someone has already had the same problem and can therefore let good answers to the similar

problem be found. That is efficient, and that's where we want to go with the Hyfindr Tech Community. It would therefore be great, Sven, if many of your readers registered as members and participated (community.hyfindr.com).

You two have been active in the hydrogen industry for a long time, but an internet platform is completely new ground for you, right? Björn, what did you do before this?

Björn: I worked at Mercedes for nearly twenty years. As a lawyer, I helped arrange small, and also very large, partnerships and M&A transactions over the course of more than ten years. I got my connection to the hydrogen industry in 2013, when I got to support in establishing the joint venture H2 Mobility. I figured at the time that hydrogen was our chance to get out of oil. An entrepreneur was what I'd always wanted to be. That's why I initially studied business and earned the Diplom-Kaufmann degree before studying law. When I started my studies, I was actually much more interested in economics than law. Even though I have no training as a software programmer, I can assure you that I am truly immersed in the IT world from my independent study during the last three years in preparation for Hyfindr.

And you, Steven?

Steven: I represent more of the technical side of Hyfindr. Like most of our employees, I'm a passionate engineer. Like Björn, I worked for Mercedes-Benz for several years, where last I was developing FC systems. I did that afterwards in another company as well, before I devoted myself completely to the establishing of Hyfindr and everything associated with that. For many years of my life, for professional or private reasons, I lived in countries where energy supply via diesel was a necessary given. Already in my childhood years, I wanted to change this in some way, because it generates a lot of noise and pollution. It already disturbed me back then.

You then found Hyfindr together, which is already off to a pretty good start. Please briefly explain what exactly Hyfindr is.

Steven: Hyfindr.com is the rapidly growing B2B marketplace for the global H_2 industry on which you can find many components, systems and services that are now needed to build this industry. We place particular value in that engineers especially can find all information relevant to the industry directly on the site. I had these problems myself when I was developing fuel cell systems. And it is still very difficult to find the right components. Here is where Hyfindr comes in handy. Products can be compared on the basis of technical criteria with just a few clicks, and price quotes can be efficiently requested from suppliers. This reduces negotiation costs for both the buyer and seller. Unlike a trade fair, Hyfindr.com runs 24/7, 365 days a year. Industry professionals visit us when they have a specific need. We like to point out to sellers of these products, "We drive in customer interest while you sleep!"

This new platform, Tech Community, is now only one of several mainstays of Hyfindr, right?

Björn: It's true that we have developed several formats, but our B2B marketplace is at the core of our business model. Hyfindr Tech Community is not meant for economic advancement. With this, we want to contribute to making it easy for young professionals in particular to join the H_2 industry. For this reason, marketing posts are also forbidden in our Community. It's about helping each other solve technical issues. In our Hyfindr Knowledge Hub, there are already more than 30 neutral articles that convey the technical basics. Here, professionals can find out what they need to know before buying hydrogen tanks, filters or compressors. This collection of knowledge too we are continuing to expand, and it's available free of charge on hyfindr.com.

How is the marketplace there developing so far?

Steven: The development is incredible. We launched it in September 2021, and since then we have been growing on average between 10 to 15 percent every month. In the meantime, more than 100 well-known brands have listed their products and services. Thousands of users visit us every week, who look at several pages. From this enormous amount of traffic, we also generate week after week numerous high-quality leads for the companies. So far, we have not unlocked, as I see it, even ten percent of the potential of Hyfindr, as we still have to become better known. The development, however, is

Fig. 2: H2-international met the starters of Hyfindr during f-cell in Stuttgart

pointing steeply upwards. Since June 2022, we have also been supported by no less a company than Google. We are one of very few companies in Germany to be included in the international program "Google for Startups." This helps us a lot.

Compared to the earlier hype around hydrogen, what is different today from your point of view?

Björn: This time, I think it is a sustained development, as it's not only prototypes or demonstration projects, but strategic investments being made worldwide. In some countries, the fuel cell industry is even scaling up already. However, the actual effects will only become apparent in the next few years, with sector coupling. I am firmly convinced that all doubts whether the hydrogen industry can develop into an economic sector similar to the oil and gas industry will fade within this decade.

Steven: With that, I can only agree. And as an engineer, I would like to add the following. The clean energy transition requires new technical solutions. With battery technology alone, we won't be able to build all the solutions we need to become greener. Hydrogen and fuel cell technology are not the only, but a very important, building block of the energy transition. I've lived in South Africa and Nigeria next to chugging diesel generators that ran air conditioners and produced electricity for lanterns. We can't go on like this as a planet. So I have a personal motivation as well to contribute with Hyfindr to making the growth of the global hydrogen industry faster and better. This mission drives me and also Björn.

Where do you see your marketplace and Tech Community in five years?

Steven: You could say that we have set out to become the Amazon of the hydrogen industry. With Hyfindr.com, we are building a digital supply chain for the global hydrogen industry so that it can grow faster. Professionals should be able to rely on Hyfindr as a place to find all the relevant products available. Everything starts very small, with one or two people who have an idea and pursue it consistently. That's what we're doing with Hyfindr.

Björn: With our Tech Community, we want to become the Stack Overflow of the hydrogen industry. I promise to tell you when we've reached a hundred thousand questions and answers in Hyfindr Tech Community, Sven. Once we do this, we will have significantly accelerated the hydrogen economy. It's inconceivable to build a new industry, like the hydrogen industry, only with the tools from yesterday. Hyfindr wants to offer digital tools to promote the growth of this industry on a global scale. That's what I work for.

Thank you very much for these insights.

B2B Marketplace: → www.hyfindr.com,
Tech Community: → www.community.hyfindr.com
Interviewer: Sven Geitmann

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

POTENTIAL FOR 1,000 BILLION USD ANNUALLY

Sven Jösting's stock analysis

Investors at the stock exchange are betting on good instincts regarding companies, industrial branches and, above all, those shares that in the future will determine development and have an above-average growth. These companies must and should be excellent at earning money, which is a clearly defined criterion for an increase in stock market valuation. In view of climate change, these companies should also produce solution-oriented products that are good for humans and nature in the broadest sense possible. All of this applies to hydrogen and fuel cells.

The companies in this specialization must now prove that they can deliver results and from them develop robust business models. The investor who shares their vision and bets on these new future markets, however, needs a lot of patience and time. Because many companies in the industry are still at the very beginning in terms of the new megatrend hydrogen. Market-ready products need to come out, and this entails the building and scaling of production capacity and addressing the right markets.

The venture capitalist or early-stage investor must see what capital is available to finance the R&D and follow up on the seed (financing). It takes time for the plant, so the company, to establish its growth dynamics and – metaphorically speaking – bear fruit (revenue, profit, orders).

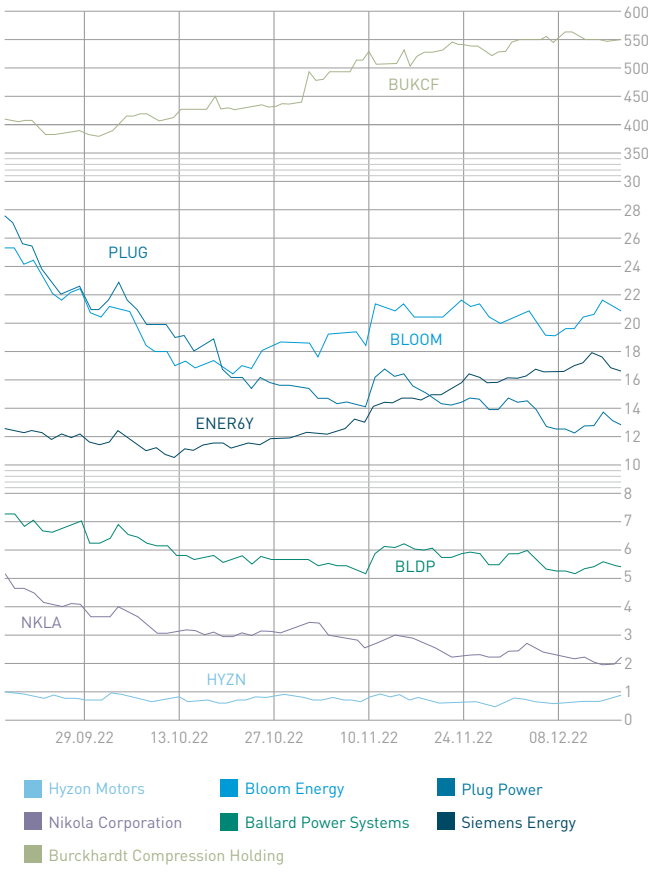

Fig. 1: Share price performance of the companies discussed – final quarter [Source: www.wallstreet-online.de]
Share prices on December 20, 2022

The path will not be a straight line, since of course every company is subject to market storms (like plants are to the weather and the nature of the soil): supply chain issues, interest and inflation conditions, skilled labor shortages and numerous regulatory hurdles set by different countries. At the end of the day, all this will be overcome, as the world urgently needs all these technologies to move in the right direction, meaning to become more sustainable and, above all, address climate change technologically.

On the flip side: With some companies, the development is unfortunately sometimes worse before it gets better. You could say, a little bit of crisis is productive. The increase in energy prices across the world is in all honesty a turbo for hydrogen & co., as they're becoming viable alternatives to fossil energy carriers.

Completely new markets will emerge, according to the trend research, in a timeframe of 15 to 20 years, when the inflection point that signals the start of vigorous growth arrives. The US investment bank Goldman Sachs expects annual turnovers of 1 billion USD worldwide in only a few years – a very high growth potential. Just look at the development of companies like Apple, Google, Amazon, & co., which required many years of positioning in their markets (with high start-up losses) but ultimately experienced an overproportional gain in value on the stock market.

In their early days, these companies needed, and burned through, a lot of capital. Investors followed their visions and new business models, and supported them with their use of capital. The stock market values the visions through the increase of market capitalization along with growing share prices.

So consider, as a co-venturer and investor, the first hours to be filled with many risks (price swings, book value losses), which however at the end of the day may have overproportional gains in store. Regarding hydrogen and fuel cells, we are facing radical developments and growth prospects. Approach this field with the caution of a start-up investor. The ROI, however, can be substantial in one to three years. We bet on the hydrogen horse in the early phase, in 2018/19, and with our correct assessment came out very successful. At the time, the industry was at its beginning. Today, much is set and real. Hydrogen on the stock exchange is the next megatrend.

INDIVIDUAL FC MARKETS SPEED AHEAD: COMMERCIAL VEHICLES The first truly big market for the use of fuel cells and hydrogen is the commercial vehicle sector. This encompasses trucks and buses, but rail vehicles also benefit from this development. The IAA Transportation fair in Hannover September 2022 clearly indicated where commercial trucks are heading (see p. 36). For heavy trucks, fuel cells will assume an important part in long hauls within the next few years. But there are also many approaches that would allow even vans to run on hydrogen, in which batteries would – still – have merit.

In addition, there are a series of research projects to enable hydrogen (liquefied or gaseous) to be used directly in an internal combustion engine – or even e-fuels as well. Much is running in parallel. What's still missing is the ramp-up of production (scaling) and the establishment of the necessary

Fig. 2: Hydrogen was a central topic at IAA Transportation 2022

infrastructure (H_2 fueling stations). Intense competition in this is brewing, which might make batteries less competitive considering the price of the raw materials, their availability and the cost of electricity.

Hydrogen will not only be available in ever greater quantities, but also lead to increasingly favorable share prices, if it is brought via pipeline or packaged in ammonia to Germany. Besides Goldman Sachs (see above), Citicorp also expects high turnovers: over 140 billion USD p. a. from fuel cell systems (also from supply components like compressors). Is there need for more arguments?

A LOOK INTO THE FUTURE Let's look together into the crystal ball for 2023: The clouds of the past two years are gradually dispersing, and it is clearing up. First rays of sunshine can be seen. In accordance with this metaphor, for the shares from the hydrogen and fuel cell sector, 2023 will in all likelihood be a good year with prices rising again, and for the following year, the effects of the H_2 ramp-up allow a continuous H_2 and FC boom to be expected. The stock market anticipates all this.

We will then leave the low price level, since companies will be able to deliver, implement concrete projects, leverage existing scaling effects and significantly expand their number of orders. At the end of the day, decent money can be made with fuel cells and with hydrogen. A gradual upward trend is emerging, which is picking up speed and raising in tempo, as many countries are clearly defining what they intend to do in terms of hydrogen (support programs, etc.) and the competition amongst them increases. We are standing at the H_2 station and are now being picked up. Stay tuned.

BLOOM ENERGY – OUTLOOK CREATES GROUND FOR A GOOD YEAR

The outlook that CEO K. R. Sridhar gave at the press conference on the figures for the third quarter of 2022 sparkled with optimism for the company. The total output capacity in SOFC fuel cell stacks would reach 600 MW within the year. The capacity of the electrolyzers would lie at 1.3 GW that year. Both figures should experience a doubling in 2023, after the new factory in Fremont, California commences production in the third quarter of 2022. There, Bloom has a highly efficient setup regarding the manufacture of both of its stack types (SOFC and SOEC), as the new production facilities can produce these simultaneously or in alternation. I imagine the stacks that will be produced are those that will give the highest margin according to the market environment and demand.

The profit margin in the fourth quarter of 2022 could even exceed 30 percent, as the effects of the Inflation Reduction Act with its many incentive programs are now revealing themselves in the USA. Additionally, Bloom is fulfilling the major order from SK Ecoplant in South Korea according to plan, which has a worth of over 4 billion USD. The stacks and energy servers are being paid according to a take-and-pay arrangement. Bloom is fully on track with deliveries and can increasingly turn to US customers as well.

One sign of how well this cooperation is going is the announcement that SK Ecoplant has paid the second outstanding installment in the amount of 311 million USD for the intended stake in the company (that's 23.11 USD per share, cash inflow expected in the first quarter of 2023). SK Ecoplant is getting Bloom shares in the equivalent amount. The already held convertible preferred stock from Bloom is simultaneously being converted into common stock. After completion of the transaction, SK Ecoplant should hold an over eight percent share in the company.

A big shareholder like SK Ecoplant can only be wished for, because it not only brings capital but also enables increased orders and customer relationships. (Perhaps GDS Holdings in China?) With over 670 million USD in the bank (after the most recent capital increase to 26 USD per share) and the 311 million USD from SK Ecoplant, Bloom has enough liquidity to support its growth with its own means, it was mentioned by the management board at the annual press conference.

BOOM SOFC SYSTEMS IN SHIP TRANSPORT In the area of ships of various types (cruise, container, bulk carrier), Bloom expects a new, robust field of activity. Working with MSC (Mediterranean Shipping Company) means concrete business with cruise ships, in which the SOFC systems from Bloom are all-rounders, meaning they can use LNG as well as green ammonia, green methanol and hydrogen as propulsion energy for the ship. This makes the system from Bloom extremely interesting for many maritime transport companies. This is a major competitive advantage that should not be underestimated. Substantial orders are expected as early as 2023.

ORDER FROM TAYLOR FARMS Recently, an order was obtained from the leading US food producer Taylor Farms in relation to a vegetable production facility in California. The

Fig. 3: Use case for Bloom Boxes [Source: Bloom]

company would like to make itself un-dependent on the public grid through an FC power plant (microgrid) and become more environmentally friendly in terms of energy. For this, 6 MW in FC output will be combined with 2 MW in solar power and 2 to 4 MW in battery output. With this, they can be energy autonomous and on the way to low costs and environmental-friendliness. From the associated press release can be read that Taylor does not want to stop at one FC power plant, but wants to eventually expand this to other production facilities.

POWER OUTAGES FILL ORDER BOOKS Not least in California should the energy networks become more reliable and natural disasters (forest fires, etc.) be better withstood. Here alone, the grid-independent FC power stations from Bloom have an enormous growth potential, as weather conditions there are responsible for power outages of 1,700 to 5,000 MW per year and cause major damage. Energy security is a societal good for which Bloom can provide the right answers and technologies.

The turnover increase in the third quarter of 41 percent compared to the previous quarter, to 292 million USD, is remarkable. That was expected, since 70 percent of the revenue was coming in the second half of the year. What's new is that Bloom sees even 40 percent of turnover for the year coming in the fourth quarter. By our calculation, that would make a plus of 400 million USD. Wow! That would then be a total turnover of 1.1 billion USD for 2022 – everything along the line of expectations and a little more.

SUMMARY With this guidance, it only makes sense to buy more than once. Maybe Bloom Energy will one day have a higher worth than competitors like Plug Power. An exciting 2023 is just around the corner, and the unfolding fourth quarter will serve as fertile ground. The numbers will come in during the first week of February 2023.

BALLARD POWER – EACH MARKET IS APPROACHED INDIVIDUALLY

Ballard Power is positioning itself as a leading player in the use of fuel cells in the transportation sector. The Canadian company wants to occupy a top position in the new megatrend and expand it to benefit from the tremendous growth expected in the coming years (orders and scaling = revenue and profit). As outlined at the last press conference on the accounting for the third quarter, Ballard is developing a global manufacturing strategy that has the goal of approaching cost reduction potentials and scaling effects as well as supply chain topics on site and using this to their advantage. This is referred to as a local-for-local strategy. It means that Ballard is erecting its own production facility within each country or continent so that it can benefit from the local conditions by being locally present. The sourcing of supply parts, but also the research and development as well as supply chain, will be established there. A perfect example is China.

Ballard is maintaining a joint venture with Weichai (49:51), which today already has an FC stack production capacity for 20,000 vehicles (buses, forklifts, trucks) that can very quickly be ramped up and expanded as needed, which is thoroughly the aim. Ballard is now planning, with an invest in the amount of 130 million USD over a period of three years, to establish its own MEA production as well as its own research center in China. The site was chosen to be Jiading Hydrogen Port, located in the Greater Shanghai metropolitan area, as this region has one of the largest clusters of automotive supply companies in China. The MEA production here should provide for 20,000 vehicles.

The membrane electrode assembly (MEA) is the core of the fuel cell and accounts for a considerable 60 percent of its cost. With this production facility, Ballard will become one of the largest MEA producers in the giant land. In addition to the support programs, however, China has set conditions for manufacturing in the country. In order to a) participate in these subsidy programs and b) not be subjected to increasing tariffs, parts like MEAs should be imported from China. We're talking about tariff rates starting at three to five percent and rising to fifteen percent within three years. This would have a massive negative impact on the future profit margin. Ballard president Randy McEwen said on the matter, "Imported MEAs have a competitive disadvantage."

SUPPORT PROGRAMS ARE AT THE STARTING BLOCKS IN CHINA Until now, it was only individual provinces and large cities like Guangdong und Shanghai that recognized hydrogen and fuel cell technology as a growth market for themselves. But the government of China, as proclaimed during the 20th Communist Party Congress with the associated funding programs, however partially defined, is increasing committing to this field. Very large programs are expected. So far, Ballard's China business is turning out smaller than hoped for, which was set back by among other things COVID-related restrictions, which contributed to a considerable 68 percent decline in activities there. However, this is only a slice in time – the potential could not be greater, as China will in great likelihood approach hydrogen and fuel cells in the same way it has done solar cells and wind power.

Fig. 4: Quantron truck with Ballard stack inside

GREAT INTEREST IN RAIL VEHICLES In the transportation sector, Ballard is optimally positioned. From Siemens Mobility already stands an order for 100 FC modules, and also a letter of intent for another 100. In Europe alone, 13,000 locomotives will be converted from diesel to hydrogen or battery-electric within the next 15 years, with 3,000 of these for Germany. This spirit could further spread to the USA and many other countries. In addition to the first H_2 train in India, Ballard has been active in the US. It can be assumed as very probable that after the pilot projects, large orders will arise from there.

For the Canadian Pacific Railway (CP), the FC manufacturer is already in the process of converting four different types of locomotives from diesel to hydrogen power. CP has over 1,400 locomotives in use, so with this customer alone is the potential for many rail vehicles. CP represents the possibility of many other railroad companies, for example Amtrak. FC use in trains is seeing a breakthrough, but for now we're only looking at the start.

Ballard is the first provider of its kind for rail vehicles in the USA. The company Stadler Rail from Switzerland is putting a train on the tracks there equipped with FC systems from Ballard. There are also whispers that Amtrak California has plans for another 27 trains, which would likely mean an order for Stadler and, indirectly, for Ballard. The order from Siemens Mobility (14 modules for 7 Mireo Plus H trains) as well as the declaration of intent for up to 200 further modules – 100 of these fixed – we already reported.

Here, huge markets are arising. In the USA alone, only one percent of all railroads are electrified. The vast remaining trains can be outfitted with batteries (short-range) and fuel cells (long-range) as well as combination models (FC as range extender). In addition, Ballard is associated with the world's largest rail vehicle corporation, CRRC in China, which has already tested streetcars with Ballard inside (first with blue hydrogen, to be replaced by green as soon as sufficiently available).

INVESTMENT IN QUANTRON Together with Neuman & Esser, Ballard has built an H_2 alliance with the German commercial vehicle manufacturer Quantron. This concerns trucks and buses. Both partners participated in the initial invest of 50 million EUR. At the 2022 IAA Transportation event, Quantron presented its truck with type designation QHM (see p. 36), which gets its power from Ballard fuel cells. Eventually, these vehicles could have a range of up to 1,500 km (930 mi) – at least in Norway – with 120 kg of H_2. Hydrogen on board and Ballard inside. Quantron recently announced an initial order for 500 trucks from the USA. There, competitors like MAN (which may also commit to fuel cells starting 2030) and Daimler Truck have let (too much) time go.

The partnership Ballard–Quantron–NEA addresses the issue of infrastructure as well. It is to develop hydrogen fueling stations as well as H_2 production capabilities, to be able to offer customers a complete package. Such cooperations – like already existing, very successful ones with various bus manufacturers –Ballard will be able to mobilize in the coming years to ramp up production capacities for its FC modules and be at the forefront of this new world market in terms of timing. The stock market also cannot avoid valuating this potential.

THIRD-QUARTER FIGURES DON'T SAY MUCH The company figures (turnover, results) will for the foreseeable future not have relevance for Ballard that analysts can see, as the company is positioning itself step by step in different regions of the world to benefit from very high long-term growth as a market leader. In the third quarter, the company had a turnover of 21.3 million USD, which corresponds to a year-on-year decrease of 15 percent. Indicative power: zero. Loss per share: minus 0.14 USD. Cash and cash equivalents lay at 957.4 million USD on September 30, 2022. The stock market value therefore amounts to only 1.6 billion USD. The order volume, however, rose by over 30 million USD, to a worth of 101.7 million USD during this quarter.

LAST BUT NOT LEAST: 25 FC MODULES ORDERED BY SOLARIS According to the latest news, the Polish bus operator Solaris has given Ballard an order for another 25 FC modules to be used in Poland. Such orders we will now see frequently and with an increasing number of modules requested, since many cities, in Europe especially, feel obligated to stem climate change and reduce their carbon footprints with the help of such emissions-free buses. We would not be surprised if cities like Hamburg were also to place larger orders for FC modules or FC buses.

SUMMARY The share price in the next 12 to 18 months will not be driven by quarterly results, but by news from the individual partnerships – so-called platform partnerships – and

by strategically important news. Some of the orders (FC stacks/modules) for rail vehicles, trucks, buses and ships may also greatly shape the development of the price, but the effects of the really big orders, contingent on the ongoing scaling measures in the form of establishing production sites, will not take hold until sometime in 2023 and then properly from 2024/25 onwards. In anticipation, the stock market will be inclined to allow these prospects to flow into the share price development, even if the high investments and capital outflows (invest in production in the USA, in Europe and in China as well as stakes in for example Forsee Power) cause logical losses. Keep in mind that H_2 and FC technology is a new megatrend, which will slowly and then more and more pick up speed and create completely new markets. Whoever lies ahead technologically (for example with competitive products) will be rewarded by the stock market with a good share price performance. Fantastic progressions could always arise as well, in the event that a major corporation like the Adani Group knows how to leverage the currently very low share prices for a stake. All you need is time for the invest to pay off, according to our analysis of all the circumstances. The current prices are clearly buy prices.

NIKOLA MOTORS – SHORT SELLERS DETERMINE THE STOCK MARKET PRICE

Nikola has lowered its targets for year 2022: Instead of 300 to 500 battery-electric trucks in 2022, it will now be 120 to 170 units in the fourth quarter, so the total number will be well under 300. The reason: Nikola wants to slow down production in order to get a better grasp on the cost structure of the company. The reduction of staff in the battery-electric area by up to seven percent was not expected this way, but will also see a turnaround again when capacities reach 20,000 units on an annual basis in 2023/24 and many a new order is in place.

The takeover that took place of Romeo Power will cost money in the integration phase until the cost reduction potentials really take effect. I expected nothing else, as this new subsidiary and its production lines must first be integrated before very positive effects – we're talking about cost reduction potentials of up to 90 percent – can be observed.

THE FUTURE LIES IN FCEV-TRE Unchanged are the plans for the production of the hydrogen-powered FCEV-Tre, which will go into production starting the second half of 2023. Test series are already underway with the battery- as well as hydrogen-powered models with companies like Anheuser-Busch and Walmart. Regarding the last named, Nikola has purchased land nearby for 16.5 million USD in order to install a hydrogen infrastructure. Vision: Orders are coming here, or why else this proximity?

Impressive was the presentation by Nikola Motors together with the European Group Iveco at IAA Transportation. The North American company is far ahead of the competition. After all, deliveries will take place in the second half of 2023, while many competitors still need a few years in this.

LIQUIDITY IS AVAILABLE BUT NEEDS TO INCREASE So far, Nikola Motors has been financing the construction of the production facility in Arizona and the invest in hydrogen (production plants, H_2 fueling stations) primarily with its own capital – through the issuance of shares. The equity on September 30, 2022 amounted to 403.8 million USD plus a financing commitment of 312.5 million USD from the venture financier Tumin that can be redeemed via the issuance of further shares. At the currently very low share prices, however, the latter makes little sense.

The current ATM program (sale/placement via the stock exchange) of 400 million USD is being made use of, with about 100 million USD in offerings sold. Here, however, it is problematic that nowhere is there a mention of a minimum price per share and therefore Citicorp, as the commissioned bank, can place shares on the market at "any" price. For the short sellers – it's been already over 100 million shares sold short (status 2022/10/31) – this is of course an easy score, as the impression has been given that Nikola would want to sell shares at any price, without taking into account the dilution effects.

The establishment of the necessary infrastructure for hydrogen is underway. By the end of 2026, the company is to be operating 50 to 60 H_2 fueling stations. Nikola has placed special emphasis on this, especially since it can be assumed that not only its own FC trucks will drive there for refueling, but in the future also the hydrogen-powered trucks of com-

Fig. 5: Nikola CEO Michael Lohscheller presented the FCEV-Tre with pride at IAA Transportation

petitors. Nikola only has to ensure that it keeps the hydrogen available in the right quantity and at the right price, and produces it itself as far as possible.

Primarily with the consumable hydrogen Nikola wants to make money. There's even talk of a target amount of 300 tonnes H_2 per day by 2026, which alone could correspond to a turnover of over 300 million USD. In 2022, the production volume of hydrogen should be at 30 tonnes per day, which should rise to 150 tonnes per day by 2024. With KeyState Natural Gas, a deal was recently closed for the delivery of 100 tonnes per day starting 2026. With this, 2,500 Nikola Tre-FCEVs could be refueled daily.

NIKOLA PUTTING ITSELF IN WALMART'S RADIUS For 16.5 million USD, Nikola recently acquired an area of land in Buckeye, Arizona. They named the spot Phoenix Hydrogen Hub LLC, which makes it plain that hydrogen will be produced there or made available via fueling stations and possibly even a service center for FCEV trucks will appear. The attraction is that Walmart has a very large shipping center right there (Walmart alone has 12,000 truck drivers and owns over 80,000 trailers). The proximity to Walmart allows the assumption that it could become a major buyer of hydrogen-powered trucks. The distance from Nikola's acquired ground to Walmart is no more than 20 miles (32 kilometers), or about a 20-minute drive. Guess why?

OUTLOOK The company figures were in the realm of expectations: In the third quarter, turnover amounted to 24.2 million USD, which is linked to the delivery of 63 battery-electric Tre-BEVs and a charging station (MCT). In the second quarter, Nikola delivered 48 e-trucks and 4 MCTs. The loss was 263.2 million USD, or minus 0.54 USD per share by GAAP accounting and minus 0.28 USD per share non-GAAP – in the area of expectations. Since the construction of the charging infrastructure for the trucks has been delayed (approval process, installation, electricity procurement, etc.), Nikola will for now lose speed in the production set-up, especially since losses per vehicle are currently still high and will remain so until this changes in the course of 2023, when the production lines for the batteries (Proterra and Romeo Power – post-acquisition integration) and the FC stacks (Bosch) are running and costs can dramatically decrease. This is, however, normal in early-stage adoption of a technology, it was said.

Clear rejection of the SUV-excavator: Rumors were floating that Nikola wanted to build this now after all. However, they're fully concentrating on emissions-free, so battery-electric and hydrogen-powered, trucks. The ambitious targets for the production build-up – about 20,000 units of each of the two models by 2023 – have now been postponed for year 2024 and with that will require about 345 million USD less in capital. At any rate, the capacity of 20,000 units and then 40,000 one year later are only numbers in the sidelines and are far removed from current sales expectations, so this shifting of targets has no current effect.

The test series with companies such as TTSI (for Anheuser-Busch) are running very well for both models – already 9,700 miles (15,610 km) in daily operation for Anheuser-Busch, and 5,500 miles with the battery-electric vehicles and 2,700 miles with the hydrogen-powered vehicles for Walmart. In this year, 17 beta versions in total of the FCEV-Tre will have been delivered – for test trials. The costs for getting the imported components – by ship again instead of as air freight – were able to be significantly reduced in the third quarter from 84 percent to 33 percent. The supply chains too were able to be improved. And then recently came in an order from Zeem Solutions for 100 BEV-Tre units – a good sign.

Very positive should be valued the partnership with Iveco, as they are also providing the dealership network in Europe for the JV, where every 100 km (before it was 150 km) an H_2 fueling station is to appear by 2028. For this, Nikola is also working with E.ON. Additionally, Nikola recently signed a partnership agreement with ChargePoint Holdings (one of the world's largest charging station providers, whose network is larger than that of Tesla) in order to ensure a supply of electricity for the BEV-Tre – a basic prerequisite for the sale of these trucks.

Plug Power and Nikola Motors announced shortly before the editorial deadline that Plug wants to buy up to 75 of the hydrogen-powered trucks of the brand Tre FCEV within the next three years. The two companies want to deal in hydrogen in parallel. Plug will supply the system for hydrogen liquefaction for Nikola's project in Buckeye, which is to initially produce 30 and later up to 150 tonnes of hydrogen per day. In addition, the tanks for Nikola's transport trailers are to be supplied by Plug. We will see several more such joint ventures in 2023.

SHORT SELLERS DOMINATE STOCK MARKET TRADING The short sellers in Nikola are very actively involved in daily stock market trading. Nikola unfortunately has also – surely unintentionally – set up things to make these easy (guidance and at-the-market program). Last but not least, it was published that ex-CEO Mark Russell according to a tax-motivated selling plan is allowing options to be converted to shares in the equivalent value (we're talking 75,000 shares per trading day) via their sale. The total value with Russell may be (relatively) small (currently probably 5 million USD), but it of course does not look good when a top manager – for whatever reason – sells shares. He meanwhile still holds, directly or indirectly, over 45 million shares, so all needs to be seen in relation.

ANDREW VESEY BECOMES A MEMBER OF THE BOARD OF DIRECTORS

Andrew Vesey was until now president and CEO of Fortescue Future Industries North America, the company of Australian billionaire Andrew Forrest. Fortescue is also very closely tied to Plug Power through joint electrolysis activities. Before that, Vesey was president and CEO of Pacific Gas & Electric and CEO of the AES Corporation in addition to his role with various other clients as a consultant.

NEW HEAD OF SALES: BRUCE KURTT

A heavyweight in the North American truck industry, Bruce Kurtt, has newly joined the management of Nikola and is responsible for sales and service. He has held various top positions in the industry over the past 30 years, at Volvo, Mack, Kenworth and Navistar for example. In addition, he was a truck dealer with his own company and therefore knows the industry like the back of his hand. He said, "I joined Nikola for one important reason: they are ready now. Nikola can deliver BEV trucks right away and FCEV trucks next year. I believe we are ahead of every other OEM with sustainable products that are critical for our future."

1.3 BILLION USD IN CREDIT FROM THE DOE? An application has been submitted and is already in the second approval stage. Under the US Inflation Reduction Act, capital funds may be requested if they support the ramp-up of the hydrogen economy. Since Nikola itself is entering the hydrogen production and distribution field to strengthen the basis for H_2 truck sales, this credit – if it can get it – would be useful. If granted, Nikola would have new and very important liquidity for the expansion of H_2 activities. Unfortunately, nothing could be said on how long the approval and award process takes and what amount Nikola will get to fall back on. In any case, a very positive bit of news, especially since the US government is exerting a lot of positive pressure here and wants to see the funds in actual use.

SUMMARY For Nikola, time is needed, as the company has to restructure its liquidity situation. The truck manufacturer is a positive frontrunner in battery-electric as well as hydrogen-powered trucks. The real ramp-up will be seen in 2023, when I expect some (large) orders, as more and more shipping companies want to reestablish themselves in this area and also have to do so due to emissions restrictions. Nikola covers both areas, where in my opinion the much more exciting one – also because more money is earned with it – is hydrogen.

Short sellers still have a significant influence, but this will disappear in 2023 when Nikola delivers what is planned in the next year. That all this is taking longer than originally thought is in the nature of the business of a startup. Wonders could happen if Iveco increases its stake. Or if orders are received. Because the stock market is over 50 percent expectation (André Kostolany).

We're seeing here the establishing of a first mover in hydrogen within the commercial vehicle sector who is clearly ahead of the big players in the industry in terms of time. With a stock market valuation of 1.2 billion USD, the stock market is massively exaggerating downwards, is my subjective view of things. Highly speculative, but with very high potential at the same time. Look at Nikola Motors as one possibility to invest in hydrogen in commercial vehicle transport at the stock exchange.

SIEMENS ENERGY – SHARE PRICE ANTICIPATES GOOD BUSINESS DEVELOPMENT

The turnaround we've been forecasting for some time is in sight. Year 2024, according to the predictions of board chairman Christian Bruch, will bring profit. The share price has turned around noticeably and rose nearly 50 percent compared with the lowest price. The numbers: The turnover of 29 billion EUR lay in the realm of expectations (minus 2.5 percent is due to extraordinary developments – to Ukraine alone is attributed a loss of 200 million EUR). There was a loss in the amount of 647 million EUR, which is a consequence of integrating the nearly 1 billion EUR reported loss from Siemens Gamesa.

The order volume is excellent: This rose in the fourth quarter, based on 2022/09/30 data, to an equivalent of 97.4 billion EUR – a good basis for the future of the corporation. Growth of three to seven percent is now expected and depends on Siemens Gamesa being able to be fully integrated in the next 12 to 24 months and ultimately also generate a positive profit contribution.

STOCK MARKET VALUATION WAS A JOKE Siemens Energy was still valuated a few weeks ago at just 8 billion EUR, but the current value of around 12 billion EUR does not correspond to the potential of this big business. For the weak stock market price, the planned acquisition of the remaining shares in the wind subsidiary Siemens Gamesa was to blame, as there were audits by the Spanish regulatory authority (CMMV) that dragged the integration, or full takeover, out even longer. And clear is also: 2,900 jobs (10% of total workforce) will be cut and the company Gamesa will become part of Siemens Energy.

The positioning of Siemens Energy in important future markets such as hydrogen (order boom!), however, will sooner or later need to lead to a revaluation of the corporation – in accordance with the sustainable profit and increasing sales. Based on the current ridiculous valuation, Siemens Energy could even be a candidate for takeover. Nothing is impossible.

Those who bet on the turnaround will build up new positions or cheapen existing ones. This will not be a quick fix but should be an investment over a period of at least one to three years. There will still be many a quarter of losses, which is the fault of the costs of reorganization and the integration of Siemens Gamesa. On the other hand, there are many exciting technological developments such as rotor blades for wind turbines that can now be recycled, which has been a major problem so far.

Since a few days ago, you can see a turnaround in the stock. The stock market anticipates future developments, so little by little there will be better prices again. Since big investors like BlackRock have the area Siemens Energy is in in focus, a lot of new capital will flow in from here. In addition, Siemens Energy is back in the DAX. Stay tuned. My price target within the next 12 to 18 months: 30 euros plus.

PLUG POWER – TARGETS ADJUSTED TO REALITY

Fig. 6: Commissioning of the first floating electrolysis station [Source: Lhyfe]

Plug Power already announced weeks ago that the target turnover for this year will be five to ten percent lower than the originally projected 900 to 925 million USD for 2022. The third quarter led to a turnover of 188.6 million USD (plus of 31.1 percent from the year before), which however was about 55.6 million USD less than analysts on average had expected. The loss, a minus of 170 million USD, lay in line with expectations. In 2023 should then be a turnover of 1.4 billion USD. Plug still has a healthy cash basis, composed of 1.5 billion USD in liquid assets and around 1 billion USD in marketable securities.

The company is working to be able to produce its own hydrogen and offer it at one-third the price of what industrial gas producers have. By the end of 2022, a production capacity of 50 tonnes per day is to be reached (it was previously to be 70 tonnes per day), and 200 tonnes per day by the end of 2023. Only recently was reported that it will hold off from building production facilities in Pennsylvania and Canada and there would be setbacks at a facility in New York. In the less than informative press conference on the accounting for the third quarter, the large-scale cooperation with Australian company Fortescue Future Industries of billionaire Andrew Forrest – they're jointly building large electrolysis capacities – was not mentioned, to our surprise. In any case, we have not read, but also not overlooked, this.

COOPERATION WITH LIDL – PROJECTS ALL OVER Of projects and cooperations, there is no lack. Recently, Plug Power was able to gain the German supermarket chain Lidl as a customer, who plans to use hydrogen in transport vehicles as well as forklifts. We're missing here, however, concrete figures (order values), but which Plug will certainly provide in due course. A respectable success – no question about it.

SEALHYFE PROJECT STARTING – FIRST FLOATING ELECTROLYZER Together with the French hydrogen project operator Lhyfe, Plug has installed the first floating electrolyzer in a wind park at sea. Off the French coast, 400 kg of hydrogen is to be produced daily, and after six months the floating electrolyzer is to be tried out at two further sites for six months each. It has an output capacity of 1 MW. Lhyfe – we reported – has given Plug orders for electrolyzers in a total capacity of 50 MW.

INVESTOR SYMPOSIUM In an investor symposium held online, it was said that Plug is positioning itself in various hydrogen markets, building a variety of production sites for, among other things, electrolyzers (2.5 GW annual capacity), and investing heavily in the production of hydrogen (liquid, as it is cheaper to transport). Much sounds ambitious. The North American company sees itself developing into a market leader. The Inflation Reduction Act has particular importance in this, as it could enable green hydrogen to have a price advantage over gray (natural gas-based) hydrogen in the US and therefore very good growth prospects.

Plug is on its way, but will still need a great deal of capital before moving into the profit zone, so time needs to be given for these investments. The latest forecast from the company itself, that the envisioned turnover for this year is ending up around five to ten percent lower than planned, does not bode for the time being good quarterly figures nor impute high ongoing, albeit logical, losses (from the invest in production facilities). Thanks to good IR (investor relations), the share price will rise again when the entire industry regains its footing on the stock market.

Our cautious assessment of Plug Power is proving more and more true. The company has too many construction projects going at the same time, which allows liquidity to shrink quickly. With the planned investments totaling 1.5 billion USD, the liquid base will fall to 1 billion USD by the end of 2023, which will maybe have further capital raisings (issuance of shares) as a consequence. With the around 9 billion USD valuation, the stock market has shown its new view of things. Plug is going along its way in the area of hydrogen, fuel cells and electrolysis, and will itself produce hydrogen here very economic-efficiently via scaling effects and be able to earn money this way. We're assuming that sometime in the next two years, the valuation of Bloom Energy can be topped or matched by Plug Power. Since Plug is represented in all major H_2 stock funds, the share will certainly benefit from the overall H_2 megatrend.

CUMMINS ENGINE – HARNESSING THE POWER OF NIAGARA FALLS FOR HYDROGEN

Fig. 7: Cummins president Jennifer Rumsey at IAA Transportation

Cummins has supplied the company Atura Power with a 20-MW PEM electrolyzer for its Niagara Hydrogen Centre in Niagara Falls, Ontario. The electrolyzer is to go into operation at the beginning of 2024 and produce green hydrogen, for supply to industrial customers, with the help of hydropower. The share price has had good development recently. Cummins is going several ways (engines, fuel cell, electrolysis) in its commitment to hydrogen.

The Indiana-based company with a 100-year history (largest diesel engine producer in the USA) covers many areas of the hydrogen value chain. It deals in PEM as well as in SOFC and alkaline electrolysis, and builds prototypes of H_2 engines as well as fuel cell stacks for commercial vehicles, rail vehicles, trucks and construction machines. Here, scaling is proceeding through the construction of large production facilities for ramp-up.

In addition, Cummins is approaching new markets in hydrogen, like waste-to-value customers. And over 600 projects are in the pipeline. For example, in China, together with Sinopec, it is building large-scale electrolysis capacities to supply 1,000 H_2 fueling stations. Clear is that the costs for production need to go down, which however will come with scaling.

Summary: The stock market has driven the price of Cummins share sharply upwards, which is surely due to the orientation toward FC/H_2 markets. Perhaps Cummins will promote further growth of the corporation in this area through strategic acquisitions, which would be seen as very sensible. In terms of valuation, the company is very well positioned – in direct comparison to Chinese company Weichai Power. Maybe it should take the price gain and reinvest it in China, since there too hydrogen and fuel cells are setting off.

HYZON MOTORS – NO NEWS UNTIL FEBRUARY 2023?

"We are working diligently through our filings to target the Nasdaq deadline of 2/13/2023. We look forward to updating the investor community in due course" was the statement from Hyzon. This presumably means that Nasdaq has accommodated the company's schedule by giving this deadline and with it given Hyzon Motors time to provide clarity. Prior to this was an investigation that had uncovered accounting irregularities, which made a complete reevaluation of the company's figures necessary. In the course of the audits, the CEO had to vacate his post immediately, which gives an idea of the scope – we've reported.

A positive, however, is that Hyzon again had a presence at trade fairs (at IAA Transportation for example) and has also notified of deliveries of its vehicles. Recently, a truck was sent out to the leading Belgian tank transport company Vervaeke. Hyzon is also advertising job openings, which should be viewed as positive.

Summary: There's nothing to do until all the facts are on the table. As the company, before the accounting scandal, had over 400 million USD in liquid assets and over 60 percent of the company is held by insiders (founder, management), we are optimistic about the future, even if it is for sure a highly speculative investment. The calculated stock market value of around 400 million USD includes, as we see it, many negative developments. Nearly 20 million shares have been sold short, which will have little impact on the share price in the event of positive news, even if short sellers certainly have a major influence on the price development and price fluctuations.

BURCKHARDT COMPRESSION – FULMINANT RISE IN SHARE PRICE

An astounding share price increase – from around 300 to over 520 CHF – we're seeing for specialist in reciprocating compressors Burckhardt Compression, where I was still calling for rebuys a few months ago after the price slump. This is a company, though, whose shares are in a really narrow market, which is why they should only be viewed as a portfolio addition. However, here it can be seen that many supplier companies and specialist firms are participating in the hydrogen boom.

This development is due to the very good company figures, which have a lot to do with the Swiss company's products in the environment of the rapidly growing global hydrogen

Fig. 8: Hyzon had a comparatively subdued stand at the IAA Transportation

economy. These are impressive numbers: The order volume of over 706.7 million CHF was a formidable 56.8 percent increase from the same period last year. Turnover growth was a good 25 percent in the first half of the year and turnover rose to 335.8 million CHF. Earnings per share even increased by 37.7 percent, to 7.23 CHF.

Burckhardt Compression has delivered very good figures as well as a perfect outlook. Its systems are necessary for among other things the compression and liquefaction of hydrogen (see p. 24). The current share price has now sufficiently factored in the figures in the company's valuation. A big cash out might come out of this, with the share price development almost suggesting that the company could also become a candidate for takeover, as many large companies in the world are currently repositioning themselves and looking for interesting players for a synergistic acquisition.

Fig. 9: Compressor unit from Burckhardt Compression
[Source: Burckhardt Compression]

WEICHAI POWER – TEMPORARILY POOR FIGURES

We're seeing a steep decline in earnings at Weichai Power: 2.387 billion CNY gain (minus 63.3 percent compared with the previous year) with a 35.9 percent turnover decrease to 86.74 billion CNY. The subsidiary Kion (45% stake) even saw its share price fall on the stock market from over 120 to 20 EUR (recently strongly increased again) due to a profit slump in the course of the year: 210.6 million EUR gain after the 691.1 million EUR in the prior-year period of the first nine months, although turnover in the reported period was able to be upped from 8.24 to 8.4 billion EUR. Supply chain problems as well as cost increases (for raw materials, etc.) were cited as the basis.

Weichai's valuation – compared to the 30 billion USD of Cummins Engine – is quite low: just 10 billion USD for the market leader in diesel engines in China. In the third quarter, it suffered a slump in diesel engine deliveries to 136,000 units, which corresponds to a 32 percent decline. Shareholders are viewing all this critically, but there are still psychological influences that can't be accounted for in this type of assessment.

There's no doubting the fact, however, that China is committing increasingly more to hydrogen and fuel cells, and Weichai will clearly be among the beneficiaries, as they are perfectly – also see Ballard – positioned. For us, a key investment in the hydrogen sector of China. The share has moved noticeably upwards again in recent weeks and should be able to reach quite different, and indeed higher, rates in the coming years, when the fuel cell strategy outlined in the national provisions gains momentum in implementation.

USA: THE COURSE IS SET

Fig. 10: Dr. Christian Bruch [Source: Siemens Energy]

It's kicking off in the USA: The Inflation Reduction Act with its billions in funding (369 billion USD), among other things for the ramp-up of the hydrogen economy, is giving hope. I was able to witness this myself live via video stream at the 2nd Hydrogen Americas Summit. In Washington, many board members of well-known companies showed their histories with hydrogen and reported their plans. Hydrogen has always had a place, but the time is now here to massively expand its scope in order to solve environmental and climate issues and to see hydrogen as a game changer for the world.

Energy security too was stressed. The next ten years in hydrogen development will change the world, during which the US plans to produce an initial 10 million metric tons per year. It is fundamentally different today than it was in the decades before. The mix of measures for the ramp-up can be listed as follows:

- Incentives (tax breaks, cash grants)
- Policy framework (regulations, standards)
- Demand conditions (markets)
- Climate influence (climate change questions)
- Energy security (security of supply)
- Inflation Reduction Act as an initial spark

There's need to become H_2-ready. This entails conversion of existing infrastructure (gas pipelines, etc.) for hydrogen. There's already an infrastructure for ammonia, so green hydrogen will see its first big market here if ammonia is used as a medium for transporting hydrogen alongside the use in fertilizer production.

The issue of hydrogen must be approached locally as well as globally at the same time, it was said. For this, cooperation between old industries and new players is necessary, and even a prerequisite and condition for a successful ramp-up of the hydrogen economy. The other side must also be taken into account, however, which is based on jealous competition, market prevention and protection of vested interests, since not all players find the development good.

But healthy competition is also needed. Here, government representatives from Canada and the US came in, and according to their statements, competition in the implementation of a hydrogen strategy will occur with true sportsmanship. Demand must be created for hydrogen. One of the first markets will be transportation (here: commercial vehicles, ships and trains) as the "driving force & source."

A statement from Christian Bruch, board chairman of Siemens Energy, regarding the Act described it best: "This will bring about investments from many companies in the US. One can certainly debate whether America is funding too much and fueling subsidy competition, but the need for renewable energies is far too great everywhere. What makes America different from Europe: the USA is open to technology. There isn't talk about green or blue hydrogen, but about hydrogen. The subsidy eligibility conditions are simple; everyone can understand them. There's a wave coming that has the chance to reindustrialize the USA."

There are 18 sectors in which hydrogen is needed. It will start off with "early mover markets," to which heavy transport belongs (heavy-duty trucking industry). But other markets will also emerge and grow, like communication towers, as there are over 600,000 in India powered by diesel engines and 10,000 police radio towers in the USA that in the future will be powered by hydrogen via fuel cells. In the case of forklift trucks, we can already see that more and more are running on hydrogen instead of diesel or battery-electric.

Many market participants are suddenly all seeing their future in this market at the same time. Here, comparisons can be made to the beginning of the Internet, of the WWW, which changed the whole world as a new disruptive system. Whether financiers (banks, VCs) or technology suppliers, consulting firms, clients or governments – they now all want to enter the hydrogen age.

Also heard were comparisons to the beginnings of the solar industry, where 30 years ago, one kWh cost 2.50 US dollars, and today, only 0.025 cents. With batteries, it took 15 years for the energy density and price to initiate a new market. The same will happen with green hydrogen, for which the majority of analysts foresee a price of 1 USD per kg for year 2040, and expect 1 to 2 USD per kg already by year 2030.

Hydrogen will be obtained from many sources, including biogas and waste recovery. With this, it should also be "grid-friendly," meaning able to be transported and used in the existing infrastructure (for example blended in the natural gas grid). The optimization of all components as well as their integration in particular will take on importance. ||

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HOW EXTENSIVE IS THE H_2 SOCIETY IN JAPAN?

Bright and dull spots in the implementation of Japan's hydrogen strategy

Fig. 1: PV system with H_2 fueling station behind it in Japan [Source: ECOS]

Japan has set itself the goal of becoming the first hydrogen economy in the world. What has been achieved since the country submitted the world's first national hydrogen plan in 2017? The H_2 user base was further expanded, and the government under Kishida is strongly investing in trailblazing pilot projects. However, the focus remains on the import of blue hydrogen. An update since the H2-international report from August 2021.

A milestone in the expansion of the hydrogen infrastructure actually slated for 2021 was reached by Japan in autumn 2022. As of October, 163 hydrogen fueling stations are in operation. A doubling to 320 stations by 2025 is planned, which is to be 900 by 2040. In April 2022, there were nearly 5,270 fuel cell vehicles on the road in Japan. By 2025, according to the energy expansion plans of the government, it is to be however 200,000, and then 80,000 by 2040. Whether the 430,000 mini CHP Ene-Farm units installed in Japan will really be converted to run on hydrogen instead of natural gas sometime in the future is an open question.

A national electrolysis capacity of 15 to 30 GW is to be built up between 2030 and 2050. The system costs for hydrogen production by electrolysis from renewable energies are to be decreased to 52,000 yen, or about 360 euros, per kW by 2030. The planned massive expansion of capacities for offshore and coastal wind power generation in Japan could help in this. Japan is still clearly lagging behind the EU and China in the expansion of domestic production of green hydrogen.

With the goal of becoming climate neutral by 2050, the government under prime minister of Japan Fumio Kishida is also further heavily investing in the nation's transition to a "hydrogen society." "Hydrogen is the key to sustainable development," stated Eiji Ohira, director general of the hydrogen and fuel cell division of NEDO, Japan's energy technology agency, at the World Energy Storage Day event recently held in India.

From the Green Innovation Fund of NEDO, 70 billion yen is to flow into development of large electrolyzer projects for hydrogen production, 300 billion yen into expansion of the supply chain, including imports by H_2 tankers as well as hydrogen transport and liquefaction technologies. Furthermore, 26 billion yen will go towards the support of demonstration projects for H_2 blending in gas turbines – including those abroad.

GERMAN-JAPANESE PROJECT IN LINGEN With support from the New Energy and Industrial Technology Development Organization (NEDO) of Japan, the world's first industrial-scale hydrogen-capable gas turbine was built in Lingen, Germany. Using the turbine from Kawasaki Heavy Industries, the conversion of hydrogen back into electricity is to be tested in the natural gas-fired power plant RWE Gaskraftwerk Emsland. The project is one of the first worldwide in which a gas turbine is converting 100 percent hydrogen into electricity on a large industrial scale. The plant with a capacity of 34 megawatts could go into operation mid-2024. In the course of the project, two fuel cell systems developed by Kawasaki are to be employed. The 1 MW versions of both were successfully tested in a demo project in Kobe, Japan. In Lingen, these technological principles will be scaled to industrial level for the first time.

Hydrogen – and transitionally ammonia – is to be a "decarbonized electricity source" that covers ten percent of Japan's electricity demand by 2050. However, hydrogen is also intended to decarbonize fossil energy production. Old coal plants in Japan are to be converted to operate with a mixture of coal and hydrogen so that they can continue to be run. The advantage for energy companies is that the power plants that would have had to be shut down in view of the CO_2 reduction targets will be able to continue operating.

CONTINUED FOCUS ON BLUE HYDROGEN On the supply side, the Japanese government is continuing to concentrate on blue hydrogen, which although produced with fossil fuels, can be climate neutral or at least low-carbon with the use of technologies for CO_2 capture and storage (CCU/CCS, see H2-international August 2021). However, there is uncertainty whether CCUS technologies (carbon capture, utilization and storage) are cost-effective enough and whether there is enough storage capacity within the country at any rate. Suitable geological formations are situated far from industrial centers, which makes the transport expensive. Some are also subject to earthquakes.

Furthermore, this makes Japan again dependent on energy imports, so the problem of energy security, which has been even higher on the political agenda since Russia's invasion of Ukraine, is not solved. In terms of decarbonization, this is not really progress.

NEW DEVELOPMENTS IN THE H_2 DEMO PROJECTS On the Fukushima Hydrogen Research Field (FH2R) in the coastal town of Namie now stands a 10-MW electrolyzer from Asahi Kasei as well as a 20-MW and 100-MW solar park. In a model project, the locally generated hydrogen is being supplied via a distribution grid to 22 buildings, one school, several supermarkets and fueling stations that can supply 100 fuel cell buses. In the major cities Fukushima and Kōriyama, one

Fig. 2: Research center at Komekurayama Solar Power Plant

to one-and-a-half hours away, the hydrogen is being used as well – in mobile applications enabled by refueling stations and the stationary applications of a public park and a wholesale market. In the currently running second phase of the project, the prefecture is to be further expanded into an "innovation hub" for the hydrogen society, and more and more regional businesses and research institutes will be integrated.

Expanded will also be the H_2 information and demonstration center Hydrogen/Fuel Cell Valley, located just outside of Kōfu, the capital of Yamanashi Prefecture. Here on Mount Komekura is a 10-MW solar park, the 1.5-MW electrolyzer from Kobelco, a hydrogen fueling station and another electrolyzer that was installed this year. In several expansion stages, the electrolyzer from Hitachi Zosen is to be expanded to a total capacity of 16 MW and to supply 450,000 Nm3 of hydrogen per year by 2025.

The fuel cell nanomaterials research center and the clean energy research center at the university there in Yamanashi belong to the world's leading and most respected institutions in the field of materials innovation for fuel cell technology. The technical chemistry institute at TU Braunschweig in Germany (Institut für Technische Chemie und Technische Elektrokatalyse, ITEC) has long maintained close relations with the hydrogen research center in Kōfu. Together with Yamanashi University, it is currently establishing a German-Japanese joint fuel cell technology laboratory. The aim is to optimize water electrolysis, electrocatalysis and hydrogen applications in the field of mobility, particularly through materials innovation. ||

FC EXPO
In KĐfu mid-March 2023, when the FC Expo in Tokyo will be held, is planned a German-Japanese expert workshop on electrolysis technology organized by NEDO and NOW GmbH.

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HYDROGEN VALLEY BY THE GERMAN-POLISH BORDER

Hydrogen for Usedom and Wolin

The idea of hydrogen valleys – regions in which the development of hydrogen technology is specifically promoted – is not new in Poland. There are already a number of projects of this kind, which are not infrequently accompanied by economic development funding for former coal-mining regions. Now, the sixth hydrogen support region throughout northwestern Poland is to appear.

The decision for a hydrogen valley in Usedom and Wolin is, in comparison to the other valleys, a special case in Polish hydrogen policy. The area is relatively small, the maritime economy is the main focus and the gas pipeline, in contrast to the other support regions, plays a central role here.

The Usedom-Wolin hydrogen valley wants to take full advantage of the natural features and infrastructure of the region. The import and production of hydrogen is therefore aimed at supplying the ships on the islands of Usedom and Wolin with this raw material.

The MoU for founding the Usedom-Wolinski Hydrogen Valley (Polish name) was signed on June 3rd, 2022. "The memorandum of understanding is an expression of a common understanding of the necessity to take measures for achieving climate neutrality and for establishing a local low-carbon economy with sustainable development, where focus shall lie on the use of hydrogen as an energy carrier in zero-emission and low-emission land and maritime transport, including its storage and the construction of hydrogen-powered ships," according to a publication about it from the city administration.

WITH POLITICAL BACKING The hydrogen support region specially created around the city of Świnoujście (German: Swinemünde) and its direct neighbors has had the full support of the respective municipal politicians right from the start. As Janusz Żmurkiewicz, mayor of the independent city of Świnoujście stated, "Our local government has a partnership role in this. From the beginning, we have supported the activities for the realization of the project. One of these was the signing of a memorandum of understanding. Because of its location, Świnoujście is predestined for the realization of this type of project. We have buildable land where this kind of activity could find its place. In the immediate vicinity of these sites is a liquefied natural gas terminal, which could be a hydrogen source, so we can expect – as soon as the project is realized –higher revenues and a larger city budget."

As part of the financial safeguards for the support region, a cooperation agreement with Bank Gospodarstwa

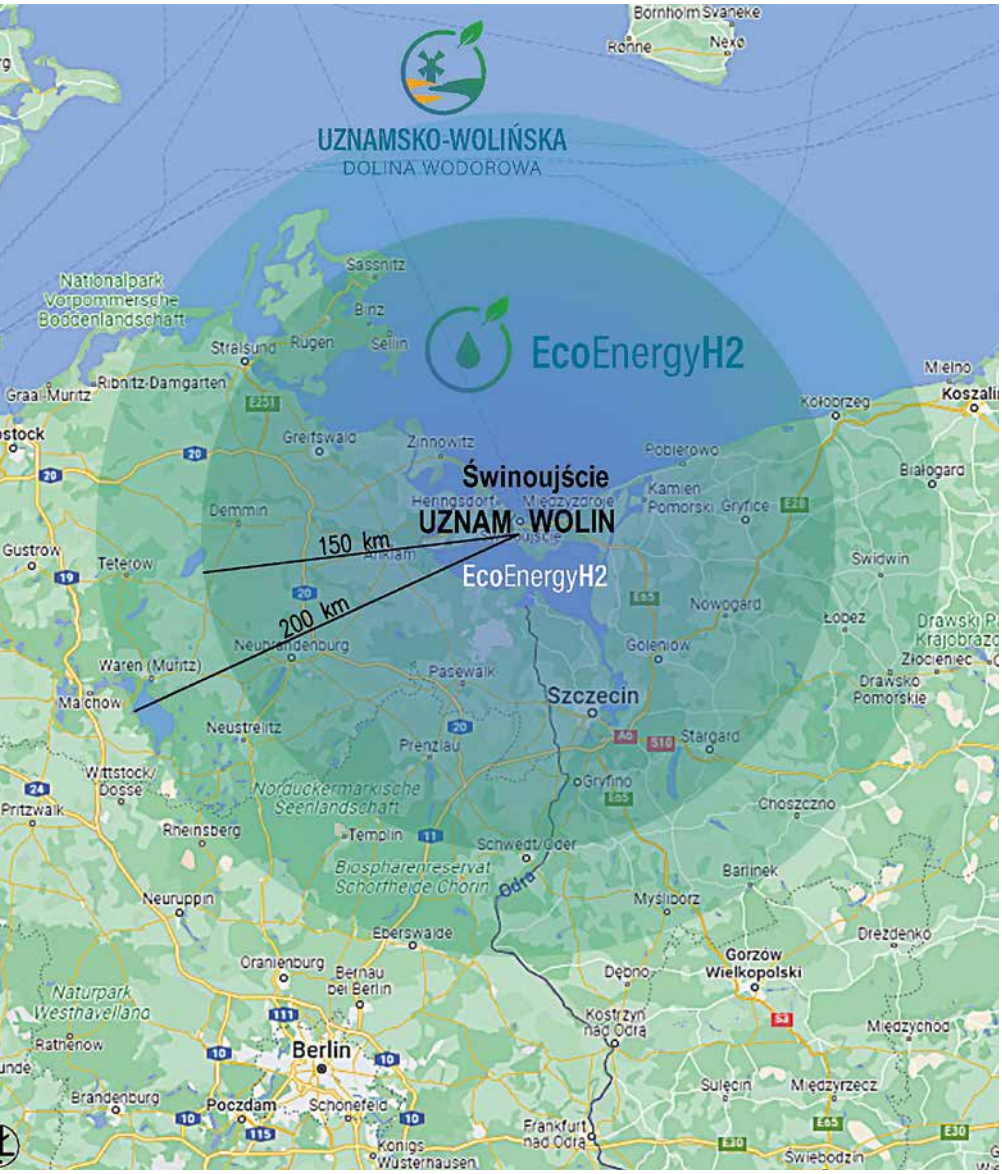

Fig. 1: Alumare shipyard – EcoEnergyH2 headquarters in the port of Świnoujście

Krajowego (BGK) was signed. BGK is implementing on behalf of the Polish government the so-called 3W strategy: woda–wodór–węgiel (water–hydrogen–carbon). This entails the introduction of innovations in the management of water resources, the use of hydrogen as part of the clean energy transition and the development of modern carbon technologies for the development of innovative materials and technologies.

At the center of the economic implementation and utilization is the company EcoenergyH2, which intends to realize H_2 production and storage, export and import of liquid hydrogen, and distribution of hydrogen at this site. The company wants to bundle the synergies of the maritime region for the purpose of a hydrogen economy. This mainly means the optimal combining of the capabilities of the conventional port, the shipyard industry and the LNG terminal infrastructure there.

For Piotr Kosowicz, owner of EcoenergyH2, the location has a special advantage over the other Polish hydrogen regions. Świnoujście lies right on the border with Germany, which according to Kosowicz, is the country where the hydrogen industry is developing fastest.

PYROLYSIS INSTEAD OF ELECTROLYSIS In the business model of EcoenergyH2, electrolysis will not have a part in the hydrogen production for the time being, since Kosowicz wants to first concentrate on pyrolysis of natural gas. For this, Usedom and Wolin offer good preconditions. Via the liquefied gas terminal on site, natural gas can be imported, but hydrogen can also be exported. Another possible scenario in the future is that hydrogen is transported into Poland through this terminal. The storage facilities sitting on the island of Wolin will likely serve as supply reservoirs for the hydrogen project. The transport of hydrogen is to be possible with tank trucks on road or rail and through gas lines. The connections of the transmission grid of the LNG terminal to the national transmission grid could be used to feed hydrogen directly into the natural gas grid. In addition, hydrogen refueling stations for trucks and ships will also be built.

On-site hydrogen fueling stations are to be provided for direct refueling of cars and trucks: "Our end user is an everyday user of energy systems. Therefore, it is important that in the implementation of this project, production of hydrogen from renewable energy sources at a marketable price is front and center," stated Kosowicz.

The business plan of EcoEnergyH2 and thus the prospects of success for the entire Baltic Hydrogen Valley, however, depend to a large extent on the price and availability of natural gas. This raw material could be imported in this case, since the infrastructure of gas ports allows it. The production of a limited amount of gas on site, on the island of Usedom, should also not be completely ruled out. Up until August 2022, the Polish petroleum and natural gas company PGNiG still had not been given approval for fuel gas production at this site, yet the French company Engie applied for approval for production on the German side of the island. The local community, however, passed on this opportunity. According to the estimations of Engie, the gas field is located north of the beach of Heringsdorf at a depth of 2,600 meters, which means that part of the field could already be on the Polish side of the border. In an interview with the online hydrogen academy Wasserstoff-Akademie, Piotr Kosowicz ruled out gas production on the island of Usedom, however, as he feels that the reserves are too small. ||

Aleksandra Fedorska also regularly reports on H_2 projects and developments in Eastern Europe online through the H2-international blog.

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

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ORGANIZERS (EVENTS)

ees Europe – International Exhibition for Batteries and Energy Storage Systems / Solar Promotion GmbH, P.O. Box 100 170, 75101 Pforzheim, Germany, Phone +49-7231-58598-0, Fax -28, *www.ees-europe.com*

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

hy-fcell 2023 | Hydrogen & Fuel Cell Conference and Trade Fair, September 13-14, 2023, Messe Stuttgart, Germany, *www.f-cell.de*

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

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STORAGE

AMBARtec AG, Supplier of compact, efficient and sustainable H_2-storage systems, Erna-Berger-Str. 17, 01097 Dresden, Germany, Phone +49-351-30993666, *www.ambartec.de*

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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*

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

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

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

TesTneT Engineering GmbH,
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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*

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EVENTS

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

FEBRUARY

Hydrogen & Fuel Cells Energy Summit
Updates on the European Hydrogen & Fuel Cells market
March 8 and 9 2023 – in Lisbon, Portugal
mahsan@acieu.net | www.wplgroup.com

MARCH

FC Expo
March 15 – 17 2023, Tokyo Big Sight, Japan
www.fcexpo.jp

HOW – Hydrogen online Workshop
by Mission Hydrogen, March 23 2023, online
www.hydrogen-online-workshop.com

Hydrogen 2023
Reuters Events, March 28 and 29 2023 – in Amsterdam, Novotel City Centre, Netherlands
www.events.reutersevents.com/

APRIL

Hannover Messe
Hydrogen + Fuel Cells Europe
April 17 to 21 2023, Hannover Messe, Germany
www.h2fc-fair.com

MAY

World Hydrogen Summit & Exhibition
May 9 to 11 2023, Rotterdam, Netherlands
www.world-hydrogen-summit.com

Powerfuel Week
at the Swiss Museum of Transport, Lucerne
May 13 to 21 2023, Lucerne, Switzerland
www.powerfuel.ch

JUNE

hy-fcell Canada
5th Annual International Hydrogen and Fuel Cell Event
organized by: Landesmesse Stuttgart GmbH
June 5 to 7 2023, Vancouver, Canada
www.hyfcell.com

3rd H2 FORUM 2023
Accelerating Europe's hydrogen economy now: joint forces for energy autonomy and CO_2 neutrality
June 6 and 7 2023, ECC Berlin + online
www.h2-forum.eu

ees Europe
Fairground München – with Green Hydrogen Forum & Expo
Conference: June 13 and 14 2023, Fair: June 14 to 16 2023
www.ees-europe.com

Hydrogen & P2X
4th European Conference
June 14 and 15 2023, Copenhagen, Denmark
www.fortesmedia.com

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