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H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

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→ HYDROGEN NETWORKS OR BLENDING?

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Cover image Hydrogen shut-off valve in Hamburg, Germany
Editorial image derBildmacher, Rüdiger Tesch-Zapp

SHAPING UP

Dear readers

The reshaping of the energy landscape is well under way. And as the energy industry begins its transformation, it's become apparent that hydrogen has a major role to play in the new world order – albeit not straightaway, but in the near future. Hence we see every imaginable organization jostling for position to take advantage of this restructuring and perhaps also to shape its direction.

2022 is the year in which Germany's last atomic power plants are to go offline and the number of coal-fired power plants is also set to fall. As traditional power generation declines, the renewable energy sector takes on a greater significance. Nevertheless, the figures for new and existing renewable generating capacity are yet to reach the desired level. As such, the gas sector remains an important industry pillar.

While gas power plants may not be as environmentally damaging as their coal-fired counterparts, they are a hangover from a fossil fuel era which, in order to meet the Paris climate targets, must ultimately come to an end no later than 2050. What the transitional period will look like as we move to that point is currently the subject of much debate among stakeholders.

For the time being, the gas grid – with its ability to act as an energy store and distribution mechanism – remains the cornerstone of the energy supply system, despite the onward march of electrification. Yet for the gas network to clean up in the medium term requires more than the odd bit of biogas or hydrogen blending here and there. Instead, new pathways must be found to store and convey sustainably produced methane or, better still, hydrogen gas.

Where these pathways lead and which route they take is something that's splitting opinion wide open. Should synthetic gas be mixed with its fossil fuel equivalent, or is building new infrastructure or repurposing existing pipelines the better choice?

The question is: Who is going to stump up the cash to finance the restructuring? The German government's view is that the costs should not be borne universally by all gas users, rather only by those who are set to benefit from hydrogen. The blending of hydrogen in the natural gas grid is not envisaged before 2030, at least that's the takeaway from the present amendment to Germany's Energy Industry Act. In the meantime, gas network operators are busy pursuing their own interests which don't necessarily fit with what the government has in mind (see p. 22), especially since there's money and power at stake.

The heating sector, too, is also on the cusp of change. Oil-fired heating systems are out, but the days are numbered for gas boilers too. While condensing boilers may be relatively efficient and affordable to buy, any appliances that are installed now are likely to be in operation for a good 20 years, so they'll be consuming gas and emitting carbon dioxide for some time to come. The same can be said for fuel cells (see p. 16).

Electrification in this sector i.e., a switchover to heat pumps, brings with it a multitude of changes – not just for manufacturers and installers but also for the gas and power industry since there'll be less demand for gas and more demand for green electricity.

The strength of the gas industry's attachment to fossil fuels shows itself in the almost beseeching tone of Andreas Lücke, general manager of Germany's heating industry federation and chief spokesman for the IBZ fuel cell initiative, when he said: "We absolutely need blue hydrogen."

Derived from natural gas with subsequent carbon dioxide sequestration, blue hydrogen has been backed by several industry representatives including the industry network Zukunft Gas, which up until the beginning of the year was known by its "natural gas" moniker Zukunft Erdgas. The lobby group received the support of Norway during a digital event at the end of February 2021. The country's ambassador Petter Ølberg promoted carbon capture and storage, aka CCS, as a "cost-effective and competitive" way forward, although critics consider the injection of carbon dioxide into disused gas fields as being neither secure nor efficient.

Up until now, the majority of politicians and industry experts have favored green hydrogen since it enables the creation of a truly sustainable, future-proof energy supply – while at the same time skirting the acceptance problems and the hard-to-calculate risks of CCS.

Even if the gas sector still has difficulties with the new medium of hydrogen, a process of reconciliation is, however, taking place. Timm Kehler, second IBZ spokesman, had this to say on the subject: "The gas sector has come some way in shaking off its aversion to hydrogen." In his pointed summary, Kehler maintains that the negative feelings harbored at first have been put to one side. There is now, he believes, a recognition that hydrogen has a much more positive image than natural gas.

Meanwhile, the industry is busy rearranging itself. The wave of company mergers continues unabated: Neuman & Esser Group took over the Brazilian electrolyzer manufacturer Hytron Energy & Gas in November 2020. Shortly before this, Proton Motor Fuel Cell announced that it would be entering a close partnership with KST-Motorenversuch. Just a few weeks prior, Proton Motor together with Schäfer Elektronik had founded NEXUS-e for the production of fuel cell rapid chargers for battery electric cars. And October 2020 saw the takeover of ElringKlinger Fuelcell Systems Austria by Plastic Omnium and the establishment of their new joint venture EKPO Fuel Cell Technologies (see p. 5). These are just a few examples of the many recent mergers and acquisitions happening in the marketplace.

All this goes to show that a nation-first strategy is being superseded increasingly by a more international approach. Just as the climate crisis cannot be solved by Germany or Europe alone, it's clear that the responsibility for remodeling the energy industry cannot fall to just one country or continent. This is a global task – and one that will take generations. ||

Best wishes

Sven Geitmann
Editor of H2-international

THINK TANK IN LUSATIA

A former coal region in Germany is attempting to transform itself: At the beginning of March 2021, in the city of Cottbus, German environment minister Svenja Schulze and Minister President of Brandenburg Dietmar Woidke started work on a new center of excellence. The PtX Lab Lausitz aims to become a think tank, discussion platform and launch pad for new projects focusing on green hydrogen and its derived products within Europe. Funding comes from an investment of around EUR 180 million from the structural enhancement law in the run-up to 2024.

In the first power-to-X discussion, scientists and industry representatives exchanged views on hydrogen production and its further refinement into synthetic fuels. Svenja Schulze explained: "The think tank is set to become the first point of contact in Germany for this major industrial policy initiative." Dietmar Woidke expanded: "The center of excellence brings high-quality jobs and also helps to boost regional value creation. I'm certain that the PtX Lab Lausitz with its demonstration plant will be a lighthouse project for the Lusatia area and for Brandenburg as a whole." ||

Fig.: Minister Schulze has long been pushing PtX, seen here at an opening conference at the German environment ministry in 2019 [Source: BMU/Sascha Hilgers]

ELRINGKLINGER + PLASTIC OMNIUM = EKPO

In early March 2021, ElringKlinger and Plastic Omnium declared their intention to give fresh impetus to the production of fuel cell stacks and components with their new join venture – EKPO Fuel Cell Technologies. According to company reports, the aim of EKPO, in which ElringKlinger holds a 60 percent ownership stake, is to manufacture fuel cell components at competitive prices "at first mainly for commercial vehicles and buses and then also for cars." A production figure of up to 10,000 stacks a year is forecast. Company bosses explained that there is sufficient production capacity available to be able to realize a sales volume of between EUR 700 million and EUR 1 billion by the year 2030 which equates to a market share of 10 percent to 15 percent.

EKPO is led by three company directors: Armin Diez from ElringKlinger is chief technical officer, his colleague Gernot Stellberger is chief financial officer, while Julien Etienne from Plastic Omnium New Energies takes up the role of chief marketing officer. An important part of the joint venture deal, which was struck in October 2020, was the takeover of ElringKlinger Fuelcell Systems Austria by Plastic Omnium. ||

HYDROGEN CAMPUS FOR OBERHAUSEN

In the German city of Oberhausen, a consortium is planning the development of a new hydrogen center. The Campus for Hydrogen Technologies Oberhausen, or HydrOB for short, aims to help bring hydrogen technologies to large corporations, the trade sector as well as private households. In order to support stakeholders at a local, regional and also international level and encourage the development of a hydrogen economy, the new center of excellence intends to provide production and laboratory space. Information events are also planned. Esther Stahl from the Fraunhofer Institute UMSICHT told H2-international that digitalization expertise will also be an important focus for the new center. First, however, a detailed conceptual plan needs to be drawn up before the campus can open its doors which will not be until 2023 at the earliest. Participating in the initiative alongside Fraunhofer UMSICHT and Oberhausen authorities are MAN Energie Solutions and OQ Chemicals in addition to several regional organizations. ||

→ www.oberhausen.de/hydrob

COORDINATION OFFICE FOR HYDROGEN OPENS

Fig.: Philipp Braunsdorf [Source: NOW]

Although Germany's Coordination Office for Hydrogen officially launched at the end of last year, at that time it was not yet clear who would be working there or where it would be based. Premises are now due to be acquired in April, with central Berlin earmarked as the location. Taking up the leadership role is Philipp Braunsdorf from the National Organisation Hydrogen and Fuel Cell Technology, or NOW. He is supported in his role by two deputies, one from the German energy agency dena and the other from the non-profit company ZUG.

The hydrogen coordination team consists of two officers each from dena, acting on behalf of the German economy ministry, NOW, on behalf of the German transportation ministry, and ZUG, which represents the country's environment ministry. They could also potentially be joined by a representative from the international cooperation agency GIZ, on behalf of the international development ministry, and a further delegate from the project management agency Jülich, acting for the education ministry.

Talking to H2-international, Braunsdorf indicated emphatically that the coordination office – in contrast to the National Centre for Charging Infrastructure – is not an official hydrogen bureau; instead its primary function is to act as a "link between the government departments involved and the National Hydrogen Council." In accordance with its government mandate, the office is responsible for helping the federal departments to implement Germany's national hydrogen strategy as well as supporting the hydrogen council in the coordination and formulation of recommended actions. The task of monitoring the national hydrogen strategy also falls within its remit. ||

NEW DIRECTION FOR VDMA

Fig.: Fabian Kapp [Source: Gräbener]

The fuel cell working group of Germany's association for the mechanical and plant engineering industry VDMA has been bolstered by the appointment of Fabian Kapp. At the general meeting held online in February 2021, the Gräbener Maschinentechnik director was elected to the board and now sits alongside four fellow board members. Kapp explained: "The working group has decided to take a new strategic direction and focus more intently on fuel cell manufacturing technologies." ||

COLD CHAMBER FOR HYDROGEN TRUCK TANKS

In February 2021, JA-Gastechnology, also known as JAG, shipped a permeation climatic chamber to a U.S. commercial vehicle manufacturer. Based in Burgwedel, Germany, JAG reported that it is the "world's biggest climatic chamber for hydrogen trucks," capable of carrying out pressure cycling tests and permeation measurements. With an internal diameter of 10 feet (3 meters), the unit can be used to put complete Type 4 tank systems through their paces under extreme conditions in temperatures ranging from -40 °C to +85 °C. ||

RESEARCH NETWORK LAUNCH

Feb. 9, 2021, witnessed the kick-off of the newly established Hydrogen Research Network (see H2-international, February 2021). The association, which has more than 1,100 members from various research disciplines and business fields, was initiated by the German economy ministry and forms part of the government's national hydrogen strategy.

During the virtual launch, clarification was provided on the structure of the new scientific group, which is one of nine national research networks. The hydrogen group is divided into four clusters representing the breadth of the hydrogen value chain: production, storage, utilization and safety. Its activities are coordinated by Beate Wörz from the project management agency Jülich. The hydrogen network's stated intention is to help shape the schemes that will support the next generation of energy research. To achieve this, members will have input into the creation of a road map for the German hydrogen economy, for example. Thorsten Herdan, head of the economy ministry's energy policy division, had declared on a previous occasion that the ministry intends "to give you in the science community the help that you need." ||

→ www.forschungsnetzwerke-energie.de/wasserstoff

FUEL CELL MEGAWATT SYSTEM FOR AVIATION

Hot on the heels of the fuel cell-powered motor glider HY4, which was awarded a test flight permit in late 2020 (see cover story in H2-international, February 2021), another venture was given the green light at the beginning of this year. As part of the follow-up BALIS project, whose approval arrived in just six weeks, the four-seater HY4 aircraft is set to become a 40-seater. On Jan. 21, Steffen Bilger, parliamentary state secretary at the German transportation ministry, handed over EUR 26 million in funding to Josef Kallo from the German aerospace center DLR.

Kallo told H2-international that the aim is to develop and trial a fuel cell powertrain with two 750-kilowatt modules. In order to subsequently build regional aircraft with 40 to 60 seats and a range of 620 miles (1,000 kilometers), the DLR plans to set up an appropriate testing facility. "There is a barrier at 1.5 megawatts when it comes to the architecture and performance of today's components in fuel cell systems. We want to go beyond this threshold while at the same time combining as few high-powered fuel cell stacks as possible," explained the pilot.

André Thess, director of the German Institute of Engineering Thermodynamics, added that the importance of BALIS today is similar to the significance of marine diesel in the shipping industry in the middle of the 20th century. Then as now, it doesn't make sense to connect up 30 individual generator sets, he said. Instead, it's much more effective to build one large generator, he continued.

Bilger delivered the funding confirmation on behalf of the ministry, stating: "This decade is all about flipping the switch. […] The goal is emission-free aviation – preferably with the creation of jobs and added value within Germany." ||

ELEMENT EINS AND HYBRIDGE STOPPED

Two prominent power-to-gas proposals – Hybridge and Element Eins – have received a rejection from Germany's Federal Network Agency. The network operators Amprion and TenneT had hoped for an easing of regulations as part of the national hydrogen strategy (see H2-international, August 2020). However, the companies have now suffered a setback in a tussle that has since begun over future market share and profitable business areas.

In their plans for the Hybridge project, Amprion and Open Grid Europe, OGE, had intended to set up a 100 MW plant near Lingen in the Emsland District of Lower Saxony by 2023. In the case of the Element Eins initiative, TenneT, Gasunie and Thyssengas had planned to install an equally sized facility at the Diele substation in the town of Weener, also in Lower Saxony. The operation of these electrolyzer facilities and the production of hydrogen would, nevertheless, mean that the two network operators would no longer be acting within their original field of activity. According to the Federal Network Agency, BNetzA, this would lead to a concentration of power that would be detrimental to other parties.

Parallel to this, another factor in the agency's decision-making was the warning issued by the "Alliance for fair competition in the hydrogen market." Established in late 2019 by Enertrag, Greenpeace Energy, Naturwind and Nordgröön, the campaign group had cautioned against a distortion of competition in the future hydrogen market. The alliance fears that Amprion and TenneT could potentially refinance the hydrogen price via the grid fees charged to customers, a move that would conflict with the European Union provision to unbundle electricity network operators.

"Rolling the electrolyzer set-up costs over to network charges would put a premature end to an economically sensible development in the hydrogen market," explained Jörg Müller, chairman of Enertrag. Sönke Tangermann, chief executive of Greenpeace Energy, said: "The decision of the Federal Network Agency safeguards the opportunity for a fair and competitive ramp-up of green hydrogen." Matthias Kaulmann from Naturwind added: "We expect there to be a major upturn in the market in the next few years which can also help to recoup the financial losses incurred due to the pandemic."

Amprion stated: "The rejection of the investment applications by BNetzA was not unexpected. Amprion and OGE are still convinced of the rationale, feasibility and necessity of the project and the contribution it can make to an integrated energy transition. The company is therefore standing by Hybridge and remains at the ready to develop it further as soon as it is legally possible to do so." ||

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

THE INDUSTRIAL SECTOR HITS ON HYDROGEN

Digital Handelsblatt Energy Summit 2021

Global energy trends are clearly moving in the direction of hydrogen – and away from fossil fuels. That's the conclusion that can be drawn from the three-day digital energy summit staged by German business paper Handelsblatt which ran from Jan. 13 to Jan. 15, 2021. The energy sector as a whole faces enormous challenges as it continues along the path of decarbonization. Coal will be exhausted and demand for oil, too, will gradually decline in favor of hydrogen – with green hydrogen a credible prospect in the longer term given its renewable credentials. Natural gas must also become cleaner, though carbon capture and storage, CCS, remains a divisive issue. "Turquoise" hydrogen, meanwhile, can be viewed as a sensible option for applications associated with the production of green steel. No mention was made of yellow hydrogen produced from biogas, and was addressed instead in terms of hydrogen created using nuclear power.

Fig.: Hildegard Müller [Source: VDA]

The kaleidoscope of hydrogen, each color defined by the means and energy type used to create it, should not, however, be seen in fundamentalist terms: Instead of an "either... or" split as some politicians would have it, there should be more of a "this and that" approach. For the need is so immense that there is no way of bypassing blue hydrogen, which admittedly is a carbon dioxide emitter, though emissions are being significantly reduced. In fact there's talk of over 70 percent compared with coal.

The energy transition is beginning to gain traction – at an international level. And this transformation with all its dynamism should not be impinged upon by the conditions and regulations of policy. In this respect, the trade in carbon emissions offers a good alternative to Germany's previous renewable energy law. According to political and industrial thinkers, going forward the prices should rise to EUR 100 to EUR 200 compared with the current EUR 35 to EUR 50 per metric ton in order to massively incentivize investment in clean technologies.

DISRUPTIVE CHANGE IN THE ENERGY SUPPLY Several sectors, for instance cement and steel, currently find themselves on the cusp of major changes where carbon dioxide emissions present a real problem. The chemicals industry, too, intends to replace oil and natural gas with hydrogen, with EUR 0.04 per kWh potentially providing the basis for production. This change opens up possibilities for new business areas and new jobs – indeed ones that are in tune with climate objectives. The European Green Deal represents an opportunity for achieving this.

This requires a transnational approach to green hydrogen – not just within the European arena but also globally. While Germany does not have the underpinnings for a sufficient supply of renewables, it does have the capital. Therefore some large-scale thinking is required. For its 2,600 terrawatt-hours of annual consumption, Germany will be depending on imports of energy – despite around 600 terrawatts of domestic renewable production. It makes a lot of sense to utilize the favorable conditions in countries such as Spain, Portugal, Greece and many others for hydrogen production. Industry can channel investment into those locations and use its skills to provide assistance – in its own interest. Hydrogen, it is fair to say, is the oil of tomorrow. Sooner or later there will be a similar level of annual investment to that in global oil production: USD 2,000 billion.

For all these positive developments, it would be well if there weren't so many different independent hydrogen strategies, be it at an EU, national or local level. Instead a single holistic approach is called for. For this to happen, industrial policy must be linked pragmatically to climate objectives. After all, climate protection is a business model. The demands at the energy summit have therefore so far been: less regulation, more market and no climate alarmism, just technological openness.

The electric transportation sector is primarily ruled by battery-electric mobility. Tesla can be seen as a clear role model here. The company has managed to give a boost to the global automobile industry. German carmakers, however, need to stop hiding behind Tesla, according to VDA president Hildegard Müller. In the lobbyist's opinion, Germany and its business sector need to now pick up speed and confront the key challenge of digitalization – artificial intelligence systems in vehicles. What's more, the charging infrastructure, Müller says, must be made simpler to use with increased standardization and compatibility that is independent of the manufacturer or the electricity supplier. She also envisaged that in 10 years, around a third of vehicles will still be running on a combustion engine.

To sum up: Hydrogen has never before been the subject of so much discussion at the Handelsblatt Energy Summit. ||

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

COLORFUL PATH TO A GREEN FUTURE

Second round of HyLand competition kicks off

"We're not talking about Champagne, we're talking about table water." This was the pronouncement of Katherina Reiche, chairwoman of Germany's National Hydrogen Council, as she instigated proceedings at this year's H2Congress. On Jan. 26 and 27, 2021, over 3,000 attendees gathered online for a joint conference consolidating the NIP General Assembly and the German Hydrogen Congress. In among the discussions came the announcement that the second round of the HyLand competition would soon open.

Although some audience members had already anticipated this disclosure, news that the HyLand initiative would enter its second stage in spring 2021 still came as a surprise. This triggered a rush of meetings, both during and immediately after the conference, between the many potential partner organizations eager to be involved in this second part of Germany's hydrogen regions project.

So far, 25 areas nationwide have received grants to help with driving forward the integration of hydrogen as an energy carrier. The latest round now makes it possible for regions with HyStarter status to become HyExperts or for HyExperts to upgrade to the HyPerformer category. New regions that have not previously taken part are also invited to join. The intention is to encourage a wide range of applications from various hydrogen proponents, each with their own different focus. HyStarter applications can be submitted until the middle of May, while HyExpert proposals are welcomed through to May. A new HyPerformer round will open in early 2022.

Not just a diverse mix of attendees at the H2Congress. Both Katherina Reiche and Thomas Hüwener from Open Grid Europe referred to the "diverse colors" of hydrogen, thus sidestepping any mention of "blue" hydrogen – a variant which has drawn criticism from some stakeholders.

COMPETITION FOR SITE OF HYDROGEN CENTER In his keynote address, German transportation minister Andreas Scheuer appeared delighted that a total of 15 applications had been received for the hydrogen technology and innovation center, a facility previously announced by his department that would focus on mobility solutions. From these submissions, a shortlist of three candidates is due to be agreed before the next stage when the winner of the tender will be selected.

What may be interesting to see is whether the decision of the CSU-led transport ministry will favor the submission from its political home ground of Bavaria or whether the promising applications from Berlin-Brandenburg, Chemnitz or Duisburg, for example, get a genuine chance. The choice of location for the German battery research center, as decided by the federal research ministry, prompted a major row in summer 2020 when Ibbenbühren, a town in Minister Anja Karliczek's own electoral district, gained the advantage over Ulm (see H2-international, October 2020).

THREE GRANTS AWARDED At the event, Scheuer also took the opportunity to reveal the recipients of three grants for initiatives supporting the development of fuel cell-powered commercial vehicles. A figure of almost EUR 17 million was handed to Achim Kampker from the SeLv project. A collaboration between Quantron and AE Driven Solutions, SeLv is itself a spin-off from RWTH Aachen University with involvement also from the Neuman & Esser Group. The consortium is working jointly on the conversion of heavy trucks, regardless of make, to fuel cell powertrains through the development of a modular powertrain kit (see H2-international, October 2019).

Some participants were surprised to hear that Opel may still be continuing to work on fuel cells given the prolonged silence on the subject. Since January 2021, the German automotive manufacturer has been owned by Stellantis following the merger of its French parent PSA Group with Fiat Chrysler. Now Opel Automobile has announced its return to the fuel cell sector and is benefiting from around EUR 5.7 million for the development of a light commercial vehicle of up to 3.5 metric tons with a fuel cell power system and for the testing of five prototypes. Other partners in this HyLightCOM project are Faurecia, Michelin and Symbio Fuel Cell. According to current plans, this undertaking should pave the way for large-scale manufacturing of the Opel Vivaro-e from 2025. An initial B2B test fleet could go into operation in early 2022. According to Lars Peter Thiesen, who received news of the funding approval digitally, "it's not about showcasing the nth demo fleet."

The third award was bestowed on the University of Kassel, supported by the Kassel Mercedes-Benz plant, which received approximately EUR 1.8 million for the Scale-e-Drive project and for their work on commercial battery electric vehicles (3.5 to 7 metric tons).

Werner Diwald, chairman of the German Hydrogen and Fuel Cell Association that helped organize the event, voiced criticism during the congress that Germany's national hydrogen strategy does not go far enough. At the same time, he was also confident that the 21st century will enter "the history books as the century of hydrogen." His stated aim is to make "Europe the leading H_2 continent." ||

"The question is not if but when battery electric, hydrogen and fuel cell drives will become competitive for road freight transport. We are working proactively in this area, since around 90 percent of CO_2 emissions within the transport sector originate from road traffic, and a third of that comes from trucks. [...] Only if hydrogen becomes truly green can we convince people and make transportation more environmentally sound."

Andreas Scheuer, federal transport minister

Category: Energy storage | **Interview Partner:** Gerald Linke

THE TIME TO TRANSFORM THE GAS NETWORKS IS NOW

Interview with Gerald Linke, DVGW chairman

Fig.: Gerald Linke [Source: DVGW, Tatiana Back Kurda]

The German gas and water industries association DVGW has for some time been increasing its efforts in relation to hydrogen. In early 2018, it entered into initial negotiations with the German Hydrogen and Fuel Cell Association, DWV, with the aim of intensifying the cooperation between the two organizations. At the end of 2020, DWV members voted overwhelmingly in favor of the partnership proposed by the board. What unites these two associations and what could the gas industry look like in the future? Gerald Linke, DVGW chairman, shared his views with H2-international.

H2-international: Mr. Linke, the DVGW has for decades been synonymous with natural gas. Could you please tell me in your own words why it now also represents hydrogen.

Linke: One doesn't exclude the other. Natural gas is currently essential for the energy transition following the departure from nuclear power and coal. We need natural gas to partner renewable energy. It stabilizes our energy supply, for example, whenever wind or solar energy is not available. That's to say nothing of the existing gas infrastructure, which we need in any case for storing and conveying climate-neutral gases. Therefore if we want to create a reliable energy supply for the future – and the scientific expertise of the DVGW with its high-level research skills has an essential role to play in this process – there is no way of getting around gas. Hydrogen is quite clearly part of this, for the reason that gas as an energy carrier will become less and less carbon dioxide-intensive overall during the next phase as we move toward climate neutrality. Changing the gas content results in an increasing number of climate-neutral gases such as biomethane, hydrogen and synthetic methane shoring up our energy supply.

How long has the DVGW been involved with hydrogen?

We started researching hydrogen very early on. Our first study in 2005 entitled "Hydrogen in the natural gas system" was a strategic analysis, that is an overview that included hydrogen production pathways along with costs, technology screening, scaling potential and much more. In short: An overarching assessment of hydrogen in the natural gas system in which blending was already cited as a strategic option. From 2010 onward, we then intensified strategic research into hydrogen in the form of a special research program – the "Gas innovation initiative." Since 2013 we have been sketching out a power-to-gas map, for example in the Portal Green guide, and drawing up guidelines for the approvals process. So you see that the DVGW has already been focusing a great deal of scientific effort on the development of this groundbreaking energy carrier and its enormous potential at a time when hardly anyone in Germany, aside from experts, was talking about it. These days, this topic is on everyone's lips and is discussed widely in the political arena. The DVGW has played a pioneering role in Germany in the way that it has addressed the subject of hydrogen.

I can remember in the 2000s there were only a few isolated voices in your association that spoke out in favor of hydrogen. When did the change come about for you personally or at board level?

The 2000s can't be compared with the situation today. Since then, key political decisions have been taken on the energy supply in our country and at a European level. It's possible one could say that we were poorly positioned, adhering to the status quo and not taking account of fundamental developments in our decision-making. In other matters, we at the DVGW turned our attention toward hydrogen much earlier than others did; we carried out research and training and adjusted our policies. And this was all at a time when this was still not a popular subject, before it was filling newspaper pages and social media channels on a daily basis.

How does the DVGW intend to get the opponents of fossil fuels especially to accept this change? Ultimately, the association has represented a fossil fuel-based energy system for many people up until now.

Even those who fundamentally take a critical view of fossil fuels are increasingly aware that transforming the energy system in an industrial location such as Germany cannot happen by the use of renewable power alone – especially if the energy system of the future is to remain secure and af-

fordable. That's the DVGW's standpoint. Hydrogen is a core focus for the association because it has a pivotal role to play as we head toward climate neutrality. That's been the case at the DVGW since well before our cooperation with the DWV. And of course, in terms of the energy transition, hydrogen takes on quite a different significance to what it did previously. We are also taking account of this development through our innovation program by providing an additional 15 million euros over the next five years for investments and new appointments in all areas of the association.

There is, however, the suggestion that your corporate members in particular are advocating the initial use of blue hydrogen from natural gas reforming, a controversial subject not least due to carbon capture and storage, CCS, and a lack of experience. How do you respond to these critics?

We don't believe in discussing hydrogen colors as this risks excluding certain technologies. Such a discussion distracts us from the fact that climate-friendly hydrogen, whatever its provenance, has enormous potential to reduce greenhouse gas emissions in all energy-consuming sectors. In our view, it's unimportant whether hydrogen is produced via electrolysis, steam reforming with CCS or pyrolysis so long as it takes place in a climate-neutral manner. That's because it's not just green hydrogen but also blue and turquoise hydrogen, in which carbon dioxide is prevented from entering the atmosphere or can be reutilized as solid carbon, that can help us reduce carbon dioxide, but first and foremost they help us with the security of supply and social responsibility. Those are two other important elements in the energy transition.

At your events people talk openly about the fact that gas can become greener but that in other respects existing technology ought to be used for as long as possible. Volker Quaschning from the University of Applied Sciences in Berlin called this "green washing" and said that a transformation of the energy system looks different. How would you respond to him?

We're not saying these things to keep gas in the picture for longer and to keep the pipelines in use. We are in favor of continuing to use the infrastructure because it is absolutely predestined for conveying, distributing and storing climate-neutral gases such as biogas, biomethane and hydrogen. Not only does it not make economic sense to write off a network comprising more than 500,000 kilometers [310,000 miles] of pipeline, but it is the linchpin of the two-energy-source system of the future in which electricity and gas fulfill their respective roles in the best way possible.

If the proponents of an all-electric world had their way, then we'd need a seamless power grid but no longer require a gas network. That would spell the end for many of your corporate members. There is now a far-reaching consensus that we need an energy supply based on both electricity and gas. How much longer do we still need methane?

If you take a detailed look at the challenges facing the energy supply system, you'll soon see that a seamless power grid or electricity network, call it what you will, won't fix things by itself. Take the energy-intensive processes for example in the steel industry or in heavy haulage. How big and heavy would the battery be that the trucks would need to carry along with the goods they are transporting? In the energy system of the future there will definitely still be areas that rely fully on electrification. At the same time, gas is becoming ever more important. But even here there are differences in approach: There are concepts that focus on pure hydrogen; in addition we'll see blends with green methane in future – also based on hydrogen. The juxtaposition and coexistence of different approaches will produce the desired result: climate neutrality, and at the same time resilience, security of supply and social responsibility.

What are your aims? Do you want to turn, for example, the former L gas network into a pure hydrogen network?

The changeover from L gas to H gas is one of the largest infrastructure projects in the gas sector. It's needed because of the diminishing supplies of low calorific gas, in other words L gas, from the Netherlands and from production within Germany. The DVGW is in an influential position as a coordinator in this process, together with colleagues from the energy and water industries association BDEW. We are the link between the network operators, service providers, the Federal Network Agency and the German economy ministry as well as consumer watchdogs. This beneficial collaboration will play a significant part in ensuring security of supply in the gas sector. This year, around 570,000 appliance adjustments are due to be carried out on 40 switching dates – more than in any other year. Twenty-seven distribution network operators and five transmission system operators are involved in the project. Gas customers in northern Germany and parts of western Germany are affected. You have to bear in mind that the conversion from L gas to H gas will mean that roughly 5 million gas appliances such as boilers, cookers or water heaters in private households as well as in commercial and industrial properties will need to be modified by 2030. That's an enormous undertaking that we are managing very successfully. Despite COVID-19 restrictions, in the past year it was possible to carry out 99 percent of the roughly 400,000 conversions that had been planned. There is no automatic connection between the conversion of L gas networks and any development or conversion in relation to hydrogen networks.

So will the DVGW support or even push for the development of the proposed European hydrogen backbone?

We emphatically support the concept of the European hydrogen backbone, which some of our corporate members are involved in, and have already firmly embedded it into our projects. Likewise there are examples from H2vorOrt; in this project we have drawn up a concrete plan together with over 30 gas distribution network operators, setting out how the German distribution network can be converted to hydrogen and other climate-neutral gases by 2050. The way things look going forward, the distribution networks will need to be supplied via the backbone as well as through the decentralized local production of climate-neutral gases.

The German government now wants to invest billions in green hydrogen infrastructure. However, the injection of hydrogen into the natural gas network is not part of the proposals, even though the grid could take 10 to 20 percent in volume without requiring any significant conversion measures. Please could you briefly explain the government's plans.

L GAS AND H GAS

Natural gas can be divided into two types: low calorific gas and high calorific gas, otherwise known as L gas and H gas. L gas, which is still used in northern and western areas of Germany, is due to be exhausted by 2030 and then replaced by H gas.

In the national hydrogen strategy the government calls for the existing gas infrastructure to be made fit for the transport and distribution of hydrogen. We understand from this that injections of hydrogen into the natural gas networks will also become widespread. The current version of the Energy Industry Act amendment does not, however, sufficiently reflect this spirit of the government's underlying strategies.

What is your attitude toward it?

It's great that the government has addressed the issue of the hydrogen network and, as announced in the national hydrogen strategy, is creating a legal framework for the regulation of key infrastructure. That said, the necessary infrastructure development has sadly started at too slow a pace. To achieve climate neutrality, the gas network must be able to transport and distribute climate-neutral gases on a large scale in the medium term. This transformation of the gas networks needs to be started here and now. Instead of supporting this, the present draft legislation only regulates the financing of individual pure hydrogen pipelines. In our view, that does not make sense. What's important is that policy takes account of hydrogen injection in the natural gas network and the use of infrastructure in its entirety within a common market model.

Given that Uniper CEO Andreas Schierenbeck, the boss of a corporate gas group, is calling for blending not be ruled out, is that not then evidence that things are slipping out of the gas industry's reach?

No, it shows more that the industry is standing solidly behind the concept of blending. Not least because it would allow the large volumes of hydrogen needed to enter the energy system, something which is essential to bring down the costs of hydrogen production. Our H2vorOrt project shows that up to 20 percent hydrogen by volume is being injected into the gas distribution infrastructure right now, without huge costs being incurred. The DVGW supposes that nearly all gas heating appliances in existing buildings can operate on hydrogen blends of up to 20 percent volume without undergoing any conversion. After further verification checks with manufacturers, a blend of up to 30 percent hydrogen by volume will be possible. As a result, end customers are saved the costly expense of replacing their heating system. In addition, it gives a long-term boost to the national climate target for 2030 due to the cumulative emissions savings. The impending increase in the EU's climate target for 2030 means that early blending of hydrogen with natural gas takes on even more importance since it allows Germany to make a greater contribution toward meeting climate objectives. Efficiency increases in hydrogen-ready condensing boilers can achieve further emissions reductions and pave the way for the changeover to a 100 percent hydrogen supply. Blending hydrogen and natural gas doesn't create any lock-in effects but a cost-effective, resilient and socially responsible route to climate neutrality.

Fridays for Future is demanding a fossil-free world by 2040. How would you respond to them?

The great achievement of the Fridays for Future movement is that it has raised enormous international awareness of global climate problems within a very short space of time. I can't remember any other group of this kind that has done that until now. And of course a movement, particularly one that is primarily made up of people from the younger generation, has to overstate things. How else are you supposed to get widespread attention? The concepts of defossilization, decarbonization and climate neutrality are often merrily lumped together. Our goal in Germany and Europe is to further reduce carbon dioxide emissions as quickly as possible. We are committed to the government's objectives in terms of greenhouse gas reduction. Renewable gases, and hydrogen in particular, will play an essential part in this. When it comes to the heating sector especially, positive environmental results can be reached extremely quickly.

Your colleague Alfred Klees was elected to the DWV board as an assessor in May 2019. What role does he play in the DVGW?

Mr. Klees has been a member of the DVGW for many years and heads up our gas technologies and energy systems section.

Rumor has it that the atmosphere at the DWV has been pretty tense at times in the past few months. Yet the newly formed DWV executive committee, which Mr. Klees also moved over to in December, elected Mr. Diwald as chairman again. Was this a unanimous vote?

Werner Diwald was voted in unanimously as chairman.

The DVGW provides one of the three deputies to DWV president Oliver Weinmann: Uwe Ringel, director of Ontras Gastransport. What is his take on hydrogen?

Uwe Ringel is a strong proponent of hydrogen as a cutting-edge technology. Being an Ontras director means he is a recognized expert in this area and hence can give crucial impetus.

And who will the DVGW suggest for the DWV board?

We will shortly make a decision on the second appointment to the board and give due notice of this.

What do you hope to gain from the cooperation with the hydrogen association?

Our common aim in terms of the cooperation between the DVGW and the DWV is to help make hydrogen a success. Both organizations complement each other extremely well in this respect. We bring scientific research skills; the DWV has exceptional expertise in regulatory matters.

What shape will the continued partnership take? What specific courses of action is the DVGW planning in the hydrogen sector – potentially with the DWV – in 2021?

The DVGW has established an extensive hydrogen innovation program. This involves an investment of 15 million euros over the next five years and the employment of additional staff particularly in the research area. The partnership with the DWV also profits from this work. An important task for the DVGW will be the creation of a regulatory framework for the use of hydrogen. We also see the strengthening of hydrogen in the heating sector as another focal point of our work. The innovation program also provides a means to strengthen our alliance with the DWV.

Mr. Linke, thank you very much for answering my questions.

Fig. 1: Project leader Tom Lindemann (left) explains the mySMARTLife project in Bergedorf

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

HYDROGEN NEIGHBORHOODS IN THE MAKING

Supplying zero-carbon energy to entire districts

An increasing number of building projects are now incorporating an energy supply based on hydrogen and fuel cells. In light of the Paris agreement's climate targets, the current thinking is clearly to avoid designing new housing developments that are dependent on fossil fuels and instead switch entirely to renewables. However, due to the high expense that is often associated with innovative energy technology, it makes sense to maximize the number of users. For residential neighborhoods in particular, which may run from several dozen homes to a hundred properties, this is a worthwhile alternative approach.

Since early 2020, the city of Esslingen in Germany has been in the process of creating an urban district that will have virtually zero impact on the climate. Built on the 30-acre (12-hectare) site of a former freight station, Neue Weststadt will be the location for 450 residences as well as office and commercial buildings. A future-proof energy system has been developed especially for all properties in the development as well as for the new buildings that will form part of Esslingen university: Situated not far from the current railroad station, the new campus is due to be completed by 2025 and will incorporate lecture theaters, seminar rooms, offices, a canteen, a computer suite and a library.

The research project, dubbed the "climate-neutral quarter," should be finished in 2022. According to the proposals, excess power from the building's integrated photovoltaic system (1,700 kW_{peak}) will be used to generate green hydrogen on site via electrolysis. This can then be supplied to properties or made available for transportation or industrial applications. If required, hydrogen gas can also be converted back into electricity in the planned combined heat and power (CHP) plant or fed into the natural gas grid.

A notable feature of this project compared with other similar schemes is that, here, hydrogen production (400 kg_{H2} a day) will not take place on some industrial park or greenfield site, but right in the middle of this city quarter. This means that waste heat from the 1 MW electrolyzer can be utilized concurrently to heat surrounding buildings.

The hydrogen tank, weighing in at just under 9 metric tons, was delivered to site at the end of November 2020. Felix Mayer, project manager at the developer Green Hydrogen Esslingen, explained: "The weight is due, in particular, to the 1.2-cm [0.5-inch] thickness of the tank's stainless steel wall. The tank needs this in order to withstand the high number of load cycles as the pressure increases and decreases."

Mayer added: "The tank can hold 30 kg of hydrogen. That doesn't sound very much but the specific energy density of hydrogen is extremely high. For example, a full tank is equivalent to 1,000 kWh in terms of its heating value. The connected CHP plant can run for more than two hours on a full tank and this means, for instance, that the 167 housing units in Block D can be provided with energy, and a few more homes besides."

Because this initiative is being funded by the German economy and education ministries and the intention is to keep German taxpayers' money in the country, according to Norbert Fisch, a co-founder of Green Hydrogen Esslingen, the decision was taken in favor of an engine-driven CHP unit from Germany rather than a fuel cell power plant from Japan, whose power to heat ratio is reportedly around 10 percent higher than the German plant. >>

In summer 2019, operating company Green Hydrogen Esslingen, established in March 2019, received first prize in the startup category for its city quarter concept as part of the Sustainability Challenge run by the German Sustainable Building Council.

Fig. 2: Installation of the 32-foot-long (10-meter) hydrogen tank in Esslingen (Source: Neue Weststadt)

CREATING A HYDROGEN DISTRICT IN GÜTERSLOH A comparable project is taking shape in the German city of Gütersloh: Entrepreneur Dimitrios Tassikas is making plans for an entire hydrogen district named "H2-Revier." The Avenwedde area is the proposed location for a total of 120 housing units, divided into 10 single-family and multifamily homes, in addition to childcare facilities as well as a complex offering commercial premises and office space. The district will be supplied with clean energy through the use of fuel cells. The businessman founded a company specializing in property development back in 2019 – Tassikas Immobilien.

Joining the project is BEN-Tec from the city of Rheine, which is overseeing the technical aspects as well as project planning and finance. According to its calculations, roughly 370 kilograms of hydrogen will be required on a daily basis – 290 kilograms for the buildings and 80 kilograms for the refueling station. Sebastian Niehoff, director of BEN-Tec, informed H2-international that both the nursery and the business complex are to be supplied with 100 percent hydrogen. The company is reportedly already in contact with a heating appliance manufacturer that intends to provide a suitable heating unit by the end of the year.

The 7.9-acre (3.2-hectare) area of land on Avenwedder Straße, which is owned by the Tassikas family, will be supplied entirely by renewable energy, with biogas, solar power and wind power being sourced from plants nearby, according to the plans. Any excess capacity would be used to generate hydrogen by means of electrolysis, explained Ben Blomberg, spokesman for the project. The gas, which would be produced away from the residential area, will be stored on site, for example in several gas cylinder racks, and can be used in the planned hydrogen refueling station in order to "close the loop," in other words to tie in mobility applications as well as power and heat. And a buyer for the hydrogen gas has already been found.

Anke Buschmaas, director of logistics company Spedition Buschmaas which is located in the immediate vicinity of the development, told H2-international: "When I heard about the plans for H2-Revier, straight away I was interested in the filling station. I'm actually planning to include hydrogen-fueled trucks in my fleet as soon as possible. As my vehicles and I travel a lot across the region, and if the range is ad-

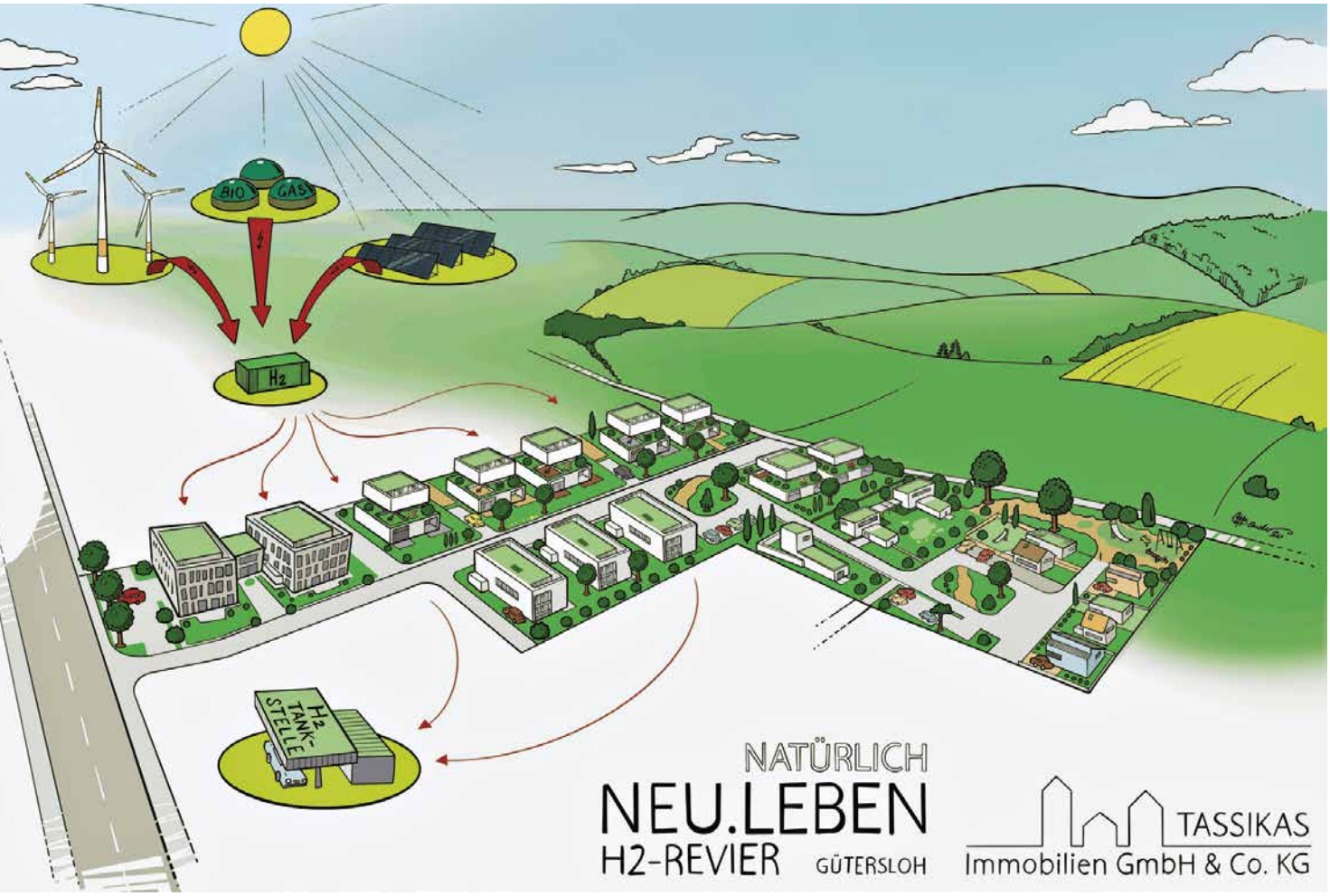


Fig. 3: Drawing of the proposed H2-Revier district

Fig. 4: The gas mixer is a rather inconspicuous piece of pipework

equate, I would always be able to rely on this filling station so the fact that there isn't an extensive supply network wouldn't be problem. I think hydrogen is the future and I'd like to make transport as environmentally friendly as possible."

Initial work on the first commercial premises is expected to start this April. As construction progresses, a grand total of EUR 40 million is due to be invested as part of the overall project, plus EUR 12.3 million for the hydrogen scheme. Building work is forecast to take five to seven years.

HYDROGEN COMMUNITY IN FRANKFURT There are also similar plans afoot for a housing project in the town of Aschaffenburg, situated close to Frankfurt in Germany. As part of the new Anwandeweg development, the Aschaffenburger Versorgungs-GmbH, AVG, intends to create a residential area with a pooled electricity supply under the banner "H2-Community." In a system similar to car sharing, residents would be able to share self-generated electrical power among themselves. According to plans, electrical energy would come from photovoltaic panels and fuel cell appliances. And the amount of power produced is expected to be so great that those partaking in the scheme would be self-sufficient. Any excess power can then either be used for electric transportation or by neighbors. To begin with, the fuel cells would be powered by natural gas and then in the longer term run on hydrogen as part of a second phase, resulting in a zero-carbon energy supply.

Roland Ebert, director of AVG, which belongs to the municipal Stadtwerke Aschaffenburger Group, told H2-international: "We are currently holding consultations with interested housebuilders. The hydrogen community concept was already taken into consideration at the site development stage and therefore supply lines have been sized appropriately and space has been earmarked for the area's storage facility/facilities as well as rapid charging points for electric vehicles." Ebert envisages a completion date around the early part of 2022.

On a smaller scale, and hence already in operation, is a Swiss project led by developer ecocoach. Since last year, three multifamily homes forming part of the Am Aawasser development in Buochs have been supplied with solar power (100 kW), hydropower, and heat from a ground source heat pump (100 kW). A methanol fuel cell with an output of 10 kW is installed as a backup system which will cut in if ever the PV module and the hydropower plant are not available.

BLENDING IN BERGEDORF AND ÖHRINGEN A different route was chosen in Hamburg-Bergedorf and Öhringen. Here, the project groups have created separate networks which will initially see a proportion of hydrogen being added to the gas mix.

The Öhringen initiative, located in the state of Baden-Württemberg, is still under construction. It is here that distribution network operator Netze BW intends to connect 25 homes to the standalone hydrogen network in Öhringen. This "hydrogen island" in Meisterhausstraße is a section of the normal gas grid in which the hydrogen level is due to be raised successively to 30 percent. According to plans, the necessary hydrogen will be produced by means of an on-site electrolyzer. Work to build the electrolyzer commenced in October 2020 at Netze BW's company premises.

In phase two, hydrogen will also be gradually added to the "island area" in the neighboring streets and increased up to 30 percent hydrogen. This project, which is estimated to reach completion in several years, aims to demonstrate that an environmentally responsible energy supply is possible using sustainably produced hydrogen while at the same time proving that the operation of this kind of system is both safe and reliable. Hydrogen could start being injected in the second half of 2021.

May 2020 heralded the start of initial construction work in Hamburg, Germany, for the mySMARTLife project. Since last fall, Gasnetz Hamburg has been carrying out testing in the city's Bergedorf district in a collaboration with enercity Contracting Nord and university renewables center CC4E. As part of the trial, housing in the Am Schilfpark residential area is being fed with natural gas enriched with up to 30 percent hydrogen. For this purpose the energy supplier has erected a small operations building (see fig. 1) to house the hydrogen blending facility.

From this location, the CH_4/H_2 mix is channeled to two CHP plants as well as two peak load boilers that have been optimized for this gas blend. This facility is then responsible for providing a total of 273 homes with heat for central heating and hot water. The proportion of hydrogen will be raised in stages, with the 30 percent mark likely to be reached in summer 2021. The required hydrogen is being supplied in cylinder racks by the gas producer. Udo Bottlaender, technical director of Gasnetz Hamburg, explained: "Our mySMARTLife project in Bergedorf provides a glimpse into the future supply of gas." ||

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

WAIT CONTINUES FOR HYDROGEN HEATING

Are fuel cell appliances fed by natural gas fit for the future?

Fuel cell heating appliances have now been on the market for several years. Nevertheless, this area of the market has yet to pick up, with the number of installations growing only slowly. This could be due to the limited choice of products and their continuing high price level. However, considering the generous funding currently available to homeowners if they switch to energy-efficient heating appliances, particularly when upgrading from an outdated oil-fired system, it appears that there are other reasons why potential buyers are being reticent. One such reason could be the fact that today's fuel cell heating units – just like condensing boilers – burn natural gas, thus making them a source of carbon dioxide emissions.

Fig. 1: Remeha hydrogen boiler [Source: BDR]

Modern fuel cell heating appliances share the same shortcoming as gas-fired boilers: their reliance on fossil fuels. For this reason, the installation of a fuel cell will in no way support efforts to meet the climate goals of the Paris Agreement. In 2015, the world entered a pact to limit global warming to well below 2 °C – or ideally 1.5 °C – compared to preindustrial levels. In order to meet the 2 °C target, global greenhouse gas emissions must be scaled back to zero by 2050 at the very latest. Any gas heating systems fitted today with an operational life of more than twenty years will doubtless be an improvement on oil-fired boilers, but their capacity for saving carbon will be limited due to the continued combustion of hydrocarbons and the significant quantities of carbon dioxide that they release into the atmosphere.

Previously, the only commercially available alternative to a condensing boiler for domestic heating had been a heat pump – that is apart from wood pellet or biomass heating systems which, as part of a continuous cycle, emit only the carbon dioxide that was formerly stored as a biological raw material. Heat pumps draw heat from their surroundings – in other words, the air, water or ground – and "pump" it indoors. If the necessary electrical energy is provided from solar or wind resources, either through an eco-tariff or a photovoltaic panel on the property itself, the amount of carbon dioxide emitted is negligible – not taking into account the materials and energy required to make the components.

Even so, fuel cell heating appliances have long been considered innovative, efficient pieces of equipment which could pave the way for a cleaner energy ecosystem in the future. Yet awareness is now growing that the environmental benefits are, in fact, modest. While fuel cell heating systems are proven to be highly efficient, condensing boilers have, for many years, yielded efficiencies of over 100 percent through the recovery of heat stored in the flue gases. In addition, the latter cost only a third of the price of fuel cell heating units and – assuming a preexisting connection to the gas grid – can be installed within one working day.

One advantage cited in relation to fuel cells is their ability to generate both heat and electricity. What this doesn't reflect is the overall worsening of the environmental footprint, as the following example illustrates: Suppose a homeowner heats their property with a condensing boiler and buys carbon neutral electricity from a green energy provider to power their home. If the owner then replaces the boiler with a fuel cell unit, which supplies the electrical and thermal energy needed for the property, it means that both electricity and heat are now generated from natural gas. All of a sudden, the homeowner's energy supply is no longer carbon neutral and in fact is causing more carbon dioxide emissions than was previously the case.

Fuel cell heating appliances consequently offer no real prospect of aiding the transition to a carbon-free world – at least while they are fueled by a fossil gas. It would appear that this is now the view taken by the German economy ministry which has recently stated that hydrogen will not be an option for the heating market before 2030.

It is therefore understandable that the gas sector is presently seeking its salvation in blue hydrogen. For example, the industry initiative Zukunft Gas, formerly Zukunft Erdgas, has hosted an online event examining the subject of "Climate neutral hydrogen from natural gas." At the meeting, which was also attended by representatives from Norway, the case was made for carbon capture and storage, otherwise known as CCS. Discussions focused predominantly on "climate neutral" hydrogen, since CCS and blue hydrogen both have an image problem in Germany – a fact that was conceded by the speakers themselves.

Singing the praises of this fossil fuel-based technology during this round of talks were also members of the German parliament such as Andreas Rimkus ("We need it in the transitional period."), Timo Gremmels ("We are open to blue, turquoise and green hydrogen. […] The Social Democratic Party is closed.") and Karl Holmeier ("You have us on your side.").

> "The German gas network is capable of conveying 100 percent hydrogen. This is due to polypropylene pipelines. [...] We need more than green hydrogen, otherwise we will not be able to ensure decarbonization. [...] We should also open up toward pyrolysis. Then we will have hydrogen that is carbon neutral."
>
> *Timm Kehler, Zukunft Gas chairman and IBZ spokesman*

An inquiry from H2-international as to how the IBZ fuel cell initiative assesses the carbon footprint of fuel cell heating appliances remained sadly unanswered. However, the IBZ did disclose that annual growth in the number of installed units in previous years was around the 50 percent mark. In absolute terms, that corresponds to a figure of around 6,000 appliances in 2020. It was also stated that the consortium is aiming to have half a million units in the field by 2030.

Meanwhile, 2020 proved a record-breaking year for the gas sector when it came to the heating market: Over 600,000 gas-fired heating systems were installed, quite a number of which will still be in operation beyond 2040 and will continue to emit carbon dioxide up until this point.

READY FOR HYDROGEN For some time now, heating system manufacturers have been busy making sure that their fuel cell appliances are hydrogen-ready. It has also become apparent that 100 percent hydrogen gas networks will be established in Europe sooner or later. It is expected that, at first, a small percentage of hydrogen by volume will be blended with natural gas. Mixing 10 to 20 percent is considered harmless for pipework and most consumers. The injection of amounts up to 30 percent is currently being tested (see p. 13).

In the medium term, it is envisaged that hydrogen supply systems will initially be created at a regional level. Looking further ahead, a "hydrogen backbone," in other words a European hydrogen pipeline system, has been proposed that would extend from Rotterdam across the whole of Europe.

Buderus, Viessmann and other manufacturers are already claiming that their fuel cell heating appliances are capable of accommodating 100 percent hydrogen. However, dedicated boilers that can run on pure hydrogen are still not ready for market. Furthest along in development is BDR Thermea Group which, since early 2020, has been producing hydrogen using electricity from its own photovoltaic array in Bassano del Grappa, Italy. Located at its largest manufacturing facility which serves as the headquarters for Italian subsidiary Baxi S.p.A., a 6,000-square-meter area of solar panels generates power for the operation of electrolyzers. The hydrogen gas produced is then used by Italian engineers to carry out tests on their hydrogen-ready prototypes. Bertrand Schmitt, CEO of BDR Thermea Group, explained: "At BDR Thermea, we are playing a part in the decarbonization of heat and facilitating the global transition to sustainable energy sources. That is why we are investing a great deal of effort in solutions such as hydrogen boilers and heat pumps."

Since June 2019, initial hydrogen modules have been examined under real-life conditions in Rozenburg, Netherlands (see fig. 1 and H2-international, October 2020 and October 2019). Talking to H2-international, Dennis Mikkelsen, spokesman for BDR Thermea Group B.V., stated: "These pure-hydrogen-ready boilers will be made available in selected markets in the 2023 timeframe, while of course in the meantime we ensure ample hydrogen boiler availability to participate in demo projects, field trials and validation projects together with utilities and grid companies." They can then be operated with natural gas at first, and later converted to pure hydrogen during their operating life.

If and when these modules go on sale at affordable prices, assuming a suitable supply of hydrogen is also readily available, then we could see a serious carbon neutral contender to rival heat pumps.

HYDROGEN-COMPATIBLE SOFC SYSTEMS FROM BOSCH This problem has not escaped the attention of Bosch which plans to offer pure-hydrogen systems on a commercial basis from 2024. In December 2020, the group announced it would be strengthening its alliance with Ceres Power and investing hundreds of millions of euros over the next four years in the further development of solid oxide fuel cells, or SOFCs. Bosch then plans to manufacture systems with a total annual output of around 200 MW at its German factories in Bamberg, Wernau and Homburg.

Fig. 2: Head-high fuel cell appliance from Bosch [Source: Bosch]

Christian Fischer, board member responsible for energy and building technology, described this area as a new line of business which pools the company's expertise "across multiple divisions." He went on to explain: "We see the highly efficient solid oxide fuel cell as a key element in creating a sustainable energy supply."

Bosch has been collaborating with Ceres Power since August 2018 and acquired a stake of around 18 percent in the UK business in January 2020. According to company information, the SOFC systems, which reportedly have an overall efficiency of more than 85 percent, are "already hydrogen compatible." A blend of 20 percent hydrogen is currently possible, it is claimed, with future generations of appliance also capable of tolerating 100 percent.

Another manufacturer of high-temperature fuel cells, SOLIDpower, is planning a pure-hydrogen version of BlueGen model BG-15 which is due to be unveiled in the first quarter of 2021 and tested in hydrogen pilot regions. The appliance would then come onto the market in 2022. Up until June 2020, the company had 1,600 natural gas systems operating in the field. Company projections foresee production of a total output of 50 MW a year, equivalent to 2,000 – 4,000 appliances annually. In addition, Andreas Uhlenhoff, key account manager at SOLIDpower, has revealed plans for a 6 kW unit. ||

"To use hydrogen in the building sector is an absolute waste. This is the very sector that should focus on saving energy – by improving the energy efficiency of existing buildings. Furthermore, decentralized production of green electricity via solar energy combined with a domestic power storage system or heat pumps is efficient."
Claudia Kemfert, German Institute for Economic Research

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

SELF-SUFFICIENCY SOLUTIONS GET READY FOR MARKET

Off-grid living in Germany and Australia

Fig.: The Australian LAVO™ module – head height [Source: Lavo]

Energy self-sufficiency, a dream for a number of homeowners, could soon become a reality. As isolated projects have already demonstrated, it is perfectly feasible to forgo a conventional grid connection and have a property's entire energy needs met by renewables alone. The technology that makes this possible is on the tipping point of serial production following years of development, a move that could also bring the price down to a more acceptable level in the not too distant future.

Although connection to mains gas and electricity is virtually a given across Germany, some homeowners aspire to a life of independence from their regional energy supplier. Successfully completed projects such as those in Brütten, Switzerland (see H2-international, July 2018) and in Zusmarshausen, Germany (see H2-international, May 2020) show that the interest is there and that off-grid living is indeed a viable option.

HPS BEGINS SERIAL MANUFACTURE Talking about his company's Picea system, Zeyad Abul-Ella, managing director of HPS, said: "With our system, PV units don't just get short-term energy storage in the form of a battery. The integrated production of green hydrogen and its use in the in-built fuel cell eliminate all the disadvantages associated thus far with photovoltaics." According to information provided by Chief Sales Officer Roland Doll, in summer 2020 there were "several dozen units in the field" that were built by the company as part of its own pilot production run.

In summer 2019, HPS had entered an agreement with Zandt-based Zollner Elektronik, allowing the 11,000-strong contract manufacturing company to make the Picea modules. As a result, Zollner began mass production of the energy storage system at the end of 2020. The Bavarian contractor expects there to be sufficient production capacity available initially for several hundred appliances a year, increasing later to several thousand. Johann Weber, chairman of Zollner Elektronik, said: "Picea has the potential to be a disruptive innovation for the fact that it makes it possible for single-family and two-family homes to be supplied from an entirely CO_2-neutral power source."

With a headcount that has since climbed to over 100 staff members, HPS has now formed a maintenance team with its own vehicles for the purposes of servicing its "innovative hardware product," as Managing Director Henrik Colell termed it. What's more, the Berlin-based technology business has already concluded initial distribution agreements

PICEA

According to company data, the Picea's fuel cell module, which is provided by Ballard, has an efficiency of 55 percent to 60 percent. The appliance, whose fuel cell stack requires replacement after around five years, is supplied, for instance, by 36 compressed hydrogen gas cylinders that store around 1,300 kWh in a 3-square-meter area. A proposed five-figure price tag in euros for the system would result in a payback period of 15 to 20 years, HPS claims.

with Berlin gas supplier GASAG and nearby company Energieinsel. HPS, which was founded in Adlershof in 2014 also received a further boost in June 2020 when EIT InnoEnergy, its partner since 2019, announced that it wanted to invest approximately EUR 3 million in the company. This came as part of a round of financing organized by HPS in 2019 which brought in funding exceeding EUR 12.5 million.

Upon receiving the grant from the European Institute of Innovation and Technology, Abul-Ella stated: "Thanks to this pioneering technology and the market access which has been made possible by EIT InnoEnergy and its network, we will soon be able to expand beyond our home market of Germany. […] Together we have succeeded in turning a mature prototype into a product that's ready for the mass market – and much more quickly than was planned."

COMPETITION FROM DOWN UNDER Until recently, HPS Home Power Solutions was one of the few companies in Germany and worldwide to put a complete holistic energy package to the test and also subsequently bring it to market. Now the Berlin-based enterprise is experiencing some competition from an Australian company that intends to start offering similar systems soon, namely: LAVO™ Hydrogen Technology Limited. The LAVO™ appliance is named after Antoine Lavoisier, the scientist who coined the term hydrogen from the Greek for "water-former." The system measures 67 x 50 x 16 inches (1,680 x 1,240 x 400 mm), weighs 714 pounds (324 kilograms) including its four tanks and has an output of up to 5 kW. A total usable capacity of 40 kWh is reportedly sufficient to supply an average household for two days.

Lavo counts the University of New South Wales, UNSW, among its collaborating partners and their joint efforts have resulted in a system that is intended to meet the energy needs of both domestic and commercial properties. The design also makes it suitable for off-grid and back-up applications as well as telecommunication masts. In terms of sourcing, information supplied by the company reveals that the electrolyzers are provided by Enapter and the fuel cells originate from Nedstack. In addition to an energy supply system, Lavo is also looking to bring a hydrogen-fueled barbecue and bicycle to the market.

The company, which was established in Sydney in 2020, uses metal hydride containers as a means for hydrogen storage. Kondo-Francois Aguey-Zinsou, executive director at Lavo and head of research at the hydrogen department at UNSW, calls metal hydride storage a "trusted and widespread technology," although until now commercial systems have been few and far between. In his opinion, however, hydride technology is "versatile, scalable, and reliable for consumer use."

From June 2021, a total of 2,500 models are due to come onto the Australian market, priced at around EUR 22,000 (not including the PV system). Preorders against an advance payment of EUR 160 are currently being taken. In fall 2022, it is expected that the price will drop to EUR 19,000. ||

Category: Policy | **Author:** Jan Michalski

HYDROGEN IN NATIONAL ENERGY AND CLIMATE PLANS

Opportunities from the inclusion of hydrogen in NECPs

Ambitious energy and climate policy requires a determined, holistic and coordinated approach and implementation. The National Energy and Climate Plans, NECPs, represent the key mechanism for reporting on future policy between European Union member states and the European Commission in a consistent way. They are used by the commission to monitor EU-wide progress in achieving the 2030 targets and to identify necessary actions. The latest reporting period considered a 10-year timespan between 2021 and 2030. The draft NECPs were submitted by EU countries at the end of 2018 whereas the final version was due by the end of 2019 after a detailed assessment by the commission. In the context of hydrogen all EU member states are encouraged to develop and implement their own strategies to enable hydrogen deployment taking the European framework and guidance into account.

In order to better include hydrogen in future national energy and climate plans and policies the Fuel Cells and Hydrogen Joint Undertaking, FCH JU, in consultation with the European Commission's department for energy, commissioned a study on the "Opportunities for Hydrogen Energy Technologies considering the National Energy & Climate Plans." The objective was to identify and evaluate national opportunities for hydrogen deployment and perform an analysis for two hydrogen deployment scenarios based on information in NECPs and other sources. The analysis at the member state level focused on renewable and low-carbon hydrogen until 2030 in the EU's 27 member states plus the United Kingdom. The results are presented and summarized in individual fiches per member state and a comprehensive main report including methodology, assumptions and member state comparison (see website). The study has been jointly conducted by the consultancies Trinomics and Ludwig-Bölkow-Systemtechnik.

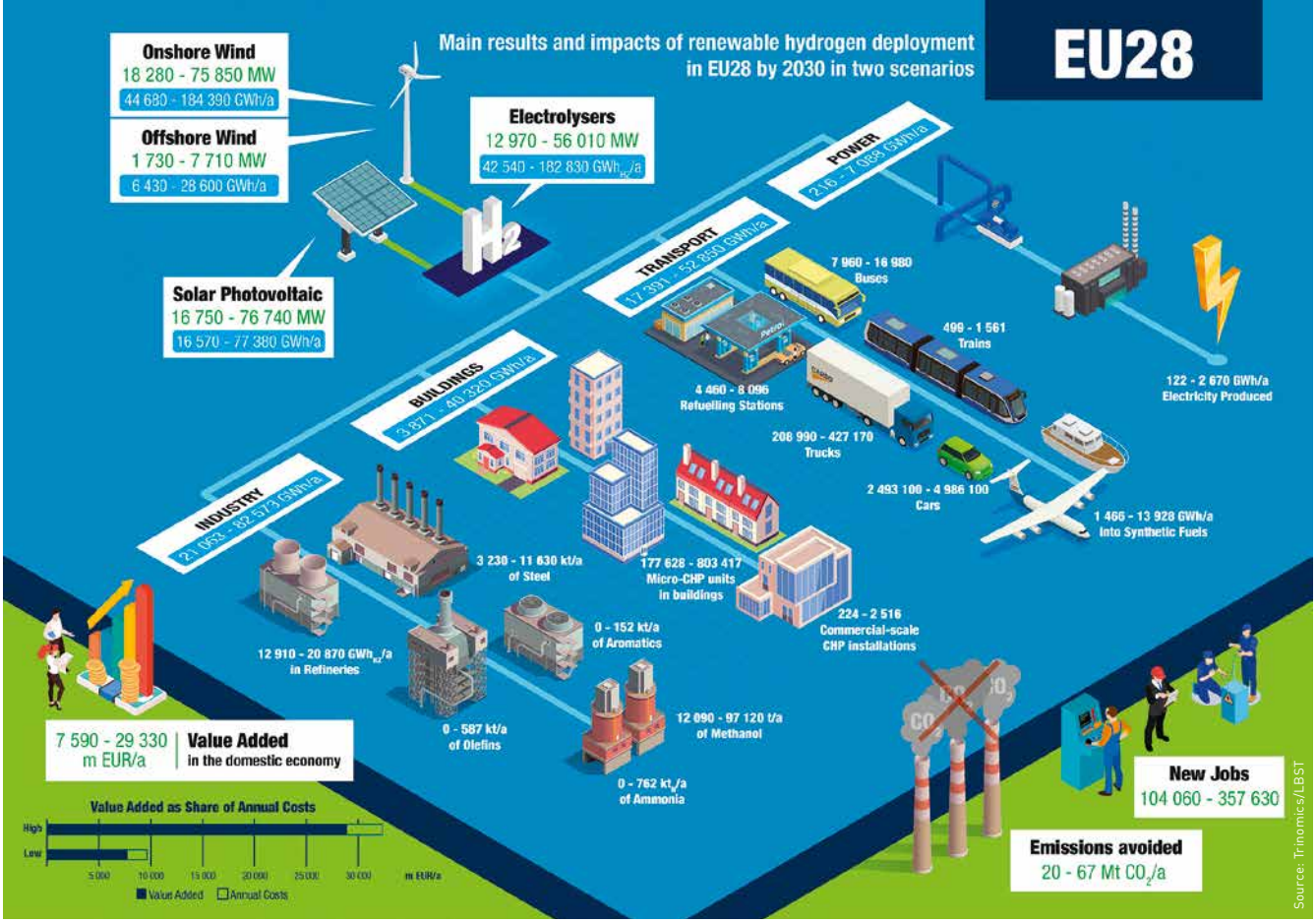
INCREASING AWARENESS OF HYDROGEN In the first step the analysis focuses on the extent to which hydrogen deployment is addressed by the NECPs and provides an overview of the related national targets, policies and initiatives. Nearly all member states mention hydrogen in their NECPs showing that it is broadly recognized as an important element of future energy and climate policy. Moreover, in comparison to the draft version the final NECPs pay much more attention to hydrogen which is gaining momentum in the debate on decarbonizing the EU economy. Due to the reporting structure defined in the EU's Energy Governance Regulation 2018/1999 the information regarding policies and measures that are directly or indirectly related to hydrogen is scattered across different parts of the respective document.

Hydrogen is mainly considered as a short-term and seasonal flexibility provider as well as a solution for greening fossil fuel use in hard-to-abate applications in industry and transport. The initiatives mentioned in NECPs focus on research, pilot and demonstration projects for hydrogen production, transport/distribution and storage, and end use, in particular for transport purposes. Several NECPs comprise expected or targeted hydrogen demand for 2030, while only a few also include targets for hydrogen production. The intended regulatory measures typically refer to renewable gases which include hydrogen and focus on financial or fiscal improvements that would help to facilitate their development. In most member states, a specific hydrogen association or working group has been established which serves as a useful instrument for exchanging information and initiating and coordinating projects.

Only some NECPs comprise concrete dedicated measures to facilitate hydrogen deployment and its integration into energy systems. The majority of the member states do not address how the national regulatory frameworks will actually be improved and provide limited information regarding measures to effectively address the barriers to hydrogen deployment. However, several NECPs refer to specific hydrogen roadmaps or strategies that have been or will be elaborated at national level. These documents provide more comprehensive approaches, covering the different components of the hydrogen value chain (see H2-international, February 2021).

POSITIVE IMPACT OF HYDROGEN DEPLOYMENT Most EU member states have technical potential for variable renewable electricity that, largely, exceeds their expected electricity demand in 2030. Building up additional renewable electricity generation capacity for hydrogen production using electrolysis would hence be technically possible in nearly all EU countries. This opportunity is reinforced by the increasing penetration of variable renewable electricity across the EU and the increasing need for system flexibility. Moreover, significant opportunity for hydrogen demand can be observed in most EU countries, in particular for hard-to-abate industrial processes and heavy-duty transport. Several NECPs refer to this "driver" for hydrogen deployment, which shows that member states are increasingly aware of this opportunity.

In order to quantify the impact of clean hydrogen deployment the study also provides analysis results for two scenarios for EU-wide hydrogen demand in 2030 based on different levels of ambition linked to the national context in each member state: approximately 40 terawatt-hours per year in the low-demand scenario and almost 200 TWh per year in the high-demand scenario. This translates into installed electrolysis capacity of 13 – 56 gigawatts with an average utilization of 4,800 hours a year consuming 70 – 300 TWh per year of renewable power in Europe. Domestic renewable and low-carbon hydrogen production until 2030 will enable the EU to reduce its dependence on fossil energy imports by up to 1.5 percent, thereby contributing to security of energy supply and energy independence. The scenario assessment also shows that hydrogen deployment can contribute up to 20 percent in individual member states as a means of bridging the gap in meeting the decarbonization targets for 2030 with a total greenhouse gas emission



reduction of 20 – 70 million metric tons of carbon dioxide across the whole EU. The investment required, including end-user applications, until 2030 would amount to EUR 10 – 33 billion per year and renewable hydrogen supply would cost less than EUR 5 per kilogram as an EU average. However, some parts of the aforementioned costs will occur also in a reference case without any renewable hydrogen use, as there is a general demand for energy and end-user applications. In this context, the EU can benefit from reduced fossil fuel costs by EUR 3 – 9 billion per year. Moreover, hydrogen technologies will increase the value added in the EU by EUR 7 – 30 billion per year and create 100,000 – 350,000 new direct and indirect jobs.

NATIONAL HYDROGEN STRATEGIES TO COMPLEMENT CURRENT NECPS The study shows that the deployment of hydrogen technologies can help to achieve the European and national energy and climate policy goals. In particular, hydrogen can contribute to a better use of renewable energy sources across the EU increasing security of supply and allows for further utilization of existing natural gas infrastructure, thereby avoiding stranded assets and reducing the investment needs for electricity transport and storage infrastructure. Its deployment generates economic growth and creates new jobs increasing the EU's wealth and prosperity.

The current NECPs provide a very useful overview of the different national energy and climate policies and measures and their contribution to the main policy objectives. They also take a first step by showing the political interest of most EU member states in integrating hydrogen into their energy system and end uses. However, with the current template imposed for the NECPs, hydrogen is addressed in different sections, and a consistent overview is hence not available. In addition, most member states might need to update their national decarbonization strategies in respect of the 2030 target to reduce greenhouse gas emissions by at least 50 to 55 percent compared with 1990 levels and the EU's aim to achieve climate neutrality by 2050, as outlined in the EU's Green Deal. This update may represent an opportunity for member states to also review their hydrogen policies and targets for 2030 and to determine how to enable hydrogen deployment with the right set of policy measures. Hence, a more comprehensive approach can possibly be expected in the next edition of the NECPs. In the meantime the member states should consider developing a dedicated policy document for hydrogen such as a strategy, plan or roadmap. A few member states have already published such a national document alongside their NECP and a number of other national strategies are expected to come in the near future (see H2-international, February 2021).

ACKNOWLEDGEMENT: The Fuel Cells and Hydrogen Joint Undertaking, FCH JU, in consultation with the European Commission – DG Energy, has commissioned a study on the "Opportunities for Hydrogen Energy Technologies considering the National Energy & Climate Plans," which has been conducted by the consultancies Trinomics and LBST. Part of the outcome of this study is presented in this article. The authors would like to thank the FCH JU project officer Nikolaos Lymperopoulos for his support. ||

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FROSTY RECEPTION FOR HYDROGEN GRID LEGISLATION

Two-pronged approach causes controversy

Fig. 1: Gas grid expansion. This infrastructure can also be later used for conveying hydrogen. [Source: OGE]

Draft legislation on the regulation of hydrogen networks, which was recently unveiled by the German government, has been met with little enthusiasm by the gas industry. In particular, criticism has focused on the distinction drawn between gas and hydrogen infrastructure. This two-pronged approach will prevent coordinated development, it has been claimed. However, there are also those who take a more favorable view and cite the positive effects the legislation will have in terms of clear cost allocation. Further questions remain over hydrogen blending and the kind of possibilities that will be opened up by truly comprehensive cross-sector regulation that also incorporates electricity.

At network operator Open Grid Europe, OGE, hydrogen which has been preferably produced from renewable sources is seen as a cornerstone of a successful energy transition alongside renewable electricity. Indeed the company has clearly signaled its intention to play a part in ensuring a "comprehensive and efficient" transformation of the energy system. To this end, OGE has been involving itself in a variety of projects, such as GET H2 Nukleus (see H2-international August 2020), Westküste100 (see H2-international October 2020) and H2morrow. The GET H2 Nukleus, for example, aims to create the building block for a nationwide publicly accessible hydrogen infrastructure. The plan envisages a network covering an approximately 81-mile (130-kilometer) stretch from Lingen to Gelsenkirchen that will connect the production of green hydrogen to industrial users in Lower Saxony and North Rhine-Westphalia.

"It's important to create build-out in the market. This will allow competitive, large-scale hydrogen production in the 2030s, without the need for subsidies, both within Europe and beyond," said Daniel Muthmann. The head of corporate development, communication and policy at OGE went on to outline three crucial areas that need to be addressed. Firstly, the entire value chain, including transport infrastructure, would need to be regarded as forming a link between production and deployment in order to get hydrogen off the ground.

The second issue mentioned by Muthmann in relation to the run-up phase is the need for quick political decision-making within the current legislative period – specifically on the regulation of publicly accessible hydrogen networks. In his opinion, the existing framework governing natural gas has proved itself to be a suitable starting point. Hence he believes that "This kind of framework provides a solid foundation from which to make appropriate decisions relating to investment in hydrogen production and deployment." Muthmann sees further advantages in this approach since, to his mind, such a framework can be dynamically adjusted to the needs of the hydrogen market through the means of adaptable legislation, taking into account all market participants.

Thirdly, Muthmann is calling for a clear statement on policy with regard to the commercial target model for hydrogen. He sees this as including liquid international trading markets, options for customers, security of supply – including over imports – and publicly accessible hydrogen grids.

CRITICISM FROM FOSSIL FUEL INDUSTRY So how does policy set about tackling these demands? The first tangible signs became apparent at the beginning of February when the German cabinet presented draft legislation on the implementation of European Union provisions and on the regulation of pure hydrogen grids in the Energy Industry Act – EnWG. The response from many of the associations affected within the energy sector has been far from glowing. Nevertheless, the energy and water industries association BDEW has welcomed the fact that the government is still pushing ahead with plans to enact legislation on hydrogen networks during the current parliamentary term i.e., before the next election in September. This positive reaction, however, was not reciprocated when it came to thoughts on the path chosen to achieve this. "Instead of integrating hydrogen grids into the established and well-understood regulatory framework for the gas grid, the draft legislation makes ar-

rangements for the separate regulation of gas and hydrogen grids," explained the BDEW. It added that the distinct control of these networks prevents coordinated development of gas and hydrogen infrastructure and fails to create a reliable framework for investors and market players.

Likewise the German association of local utilities VKU was less than satisfied with the draft proposals. The separate regulation of gas and hydrogen grids is, it believes, a step in the wrong direction, stating that: "Even if the specific regulation for pure hydrogen grids is supposed to be transitory, it would have made much more sense to take a holistic approach from the very beginning." For instance, the VKU sees the possibility of transposing the existing and, in its opinion, well-honed controls for the natural gas network onto hydrogen grids. This could be achieved, it thinks, with little regulatory effort. For legislative purposes, the public utilities organization suggests extending the definition of gas to include hydrogen and biogas. Taking this approach would, the VKU claims, give momentum to the transformation of the gas networks and propel the decarbonization of the gas supply as a whole.

For the German gas and water industries association DVGW, the rate of progress that is required is somewhat lacking. That was the complaint of the association president Michael Riechel who begrudges the slow pace of change when it comes to expanding the infrastructure. In his view, the gas network must be able to transport and distribute climate-neutral gases on a large scale in the medium term – and that now primarily means hydrogen. "This transformation of the gas networks needs to be started here and now," appealed Riechel, who in his main role chairs the municipal utilities group Thüga. He also asks that the mistakes that were made for electricity are not repeated as, in his view, expansion of the power grid is slowing down generation.

Dissatisfaction also abounds among hydrogen customers in the industrial sector. For example Holger Lösch, deputy director general at the federation of German industries BDI, would have welcomed "decisive action" from national policy. In his view, it's very much the case, particularly when seeking to transform the energy system, of exploiting existing sector interdependencies and unlocking potential efficiency gains.

Fig. 2: Daniel Muthmann [Source: OGE]

The strict separation of natural gas and hydrogen is also dismissed by transmission system operators. Germany's association of transmission system operators FNB Gas highlights that it would make economic sense in the longer term to have just one entity combining both the hydrogen and natural gas systems for the purposes of regulation, finance and network planning. In the eyes of FNB Gas, the goal must be to enable one network to evolve from the other. "The gas customer of today is the hydrogen customer of tomorrow" is the association's standpoint.

PRAISE: ENWG TO FAST-TRACK HYDROGEN GRIDS Despite the overwhelmingly negative reaction, the EnWG proposals have, however, drawn some favorable reviews. According to the opinion of Germany's federation for renewable energy associations BEE, the distinction between hydrogen and natural gas is highly significant. "It must be ensured that network operators do not break this clear separation between grid and generation/storage and allow themselves to operate power-to-gas plants such as electrolyzers," explained BEE President Simone Peter. She also added that this is the only way to effectively ramp up the German hydrogen industry while at the same time ensuring a broad spectrum of market participants. >>

Fig. 3: Michael Riechel [Source: DVGW]

Sebastian Bleschke, managing director of Ines, Germany's association of gas storage system operators, was almost euphoric in his reaction to the passing of the EnWG amendment by the cabinet, calling it a "fast track for hydrogen grids." He takes a favorable view, in particular, of the voluntary regulatory framework for hydrogen networks and its planned strict separation of gas and hydrogen grids. Ines finds the legislation's approach to cost especially compelling: "If natural gas sales fall in the future, the costs of the natural gas networks would be a considerable burden on the ramp-up of the hydrogen industry. This would not only be problematic in terms of meeting climate targets, but would also release natural gas network operators from the obligation to deal seriously with the decreasing use of the natural gas networks," he stated.

A fair allocation of cost is an aspect that the German government seems to value highly. The EnWG makes it clear that the cost of infrastructure expansion is not to be borne by all gas users, rather only those who are set to benefit from the rollout of hydrogen. Also the blending of hydrogen in the natural gas grid is not currently provided for in the EnWG amendment, with its inclusion unlikely before 2030.

PROJECTS TEST OUT HYDROGEN BLENDING On the subject of hydrogen blending, there are already several promising projects in the offing. One such example is the pilot project planned by the network operator Avacon, supported by the DVGW, which will see up to 20 percent hydrogen by volume being mixed with natural gas in one section of its gas grid – that's double the current blending threshold of 10 percent. The partnering organizations are well aware of the huge challenges ahead, since adding hydrogen to natural gas fundamentally changes the key data and combustion properties. The higher the proportion of hydrogen, the greater the difference in behavior to the natural gas presently used. According to Avacon, laboratory trials have shown, however, that a large number of different appliances can be run on a blend of up to 30 percent hydrogen by volume.

As part of the approvals process, all appliances are tested on 23 percent hydrogen by volume, which is why a 20 percent limit has been chosen for the field trial. Avacon is thus taking a similar approach to many other network operators in getting their gas grids ready for hydrogen with the overall aim of using the "green" gas to deliver a climate-neutral gas supply which will directly facilitate the decarbonization of heat, transport and industry (see further examples of blending projects on page 13).

INDUSTRIAL CENTERS MAKE IDEAL STARTING POINTS According to a study by energy policy organization Agora Energiewende, European industrial centers in particular are ideal starting points from which to plan the build-out of a pan-European hydrogen infrastructure network to meet the inescapable demand for hydrogen – while at the same time avoiding ruinous investment. Calculations carried out by the Berlin think tank show that the level of hydrogen needed by industrial plants located within the European Union's 27 member states will equal around 270 terawatt-hours by the year 2050. About half of the requirement will come from steel manufacturing. Experts from Agora have highlighted four corridors that are especially suitable for use as bases for hydrogen infrastructure development. One of the key factors that makes them prime locations is their favorable access to renewable energy. Potential sites include, on the one hand, sunny Spain and southern areas of Eastern Europe and, on the other hand, coastal locations between France, the Netherlands and Germany as well as in Eastern Europe.

German energy agency dena has also been turning its attention to this matter. For example, analyses performed as part of preparation for the forthcoming dena pilot study have shown that hydrogen imports from the EU could turn out to be much lower than previously hoped. The reason for this is that many EU countries have already started making their own arrangements or are planning to do so in the future. Head of dena Andreas Kuhlmann sees a difficult transitional phase ahead, particularly in the 10 years running up to 2030. After this point, low-cost green, blue and perhaps also turquoise hydrogen will potentially be available in sufficient quantities, he believes.

SYSTEM DEVELOPMENT PLAN PROVIDES ROUTE FORWARD The difficult issue of regulation is a subject that dena has recently addressed in its Grid Study III, taking into consideration all sectors involved. The draft system development plan presented in the report focuses on implementation and is designed to precede current planning processes such as the network development plans for electricity and gas. The Grid Study III is due for completion at the end of 2021 and includes the participation of 55 stakeholders from politics, the energy sector and non-governmental organizations. The role of this additional planning stage is to tackle fundamental questions surrounding the energy system, create a space for discussion, exploit the optimization potential of an integrated energy ecosystem, support political decision-making and provide a consistent foundation for further planning processes.

Kuhlmann makes the plea that: "Planning processes need to fit together better." The fundamental complaint of the dena chairman is that the current debate does not sufficiently take account of the important role played by gas in the transformation of the energy system. In this respect, many parties have taken "too little responsibility." The message he wants to send is clear: "Those who only ever contemplate the end point of the tough road ahead, disengage from the discussion itself and do the energy transition and climate action no favors." ||

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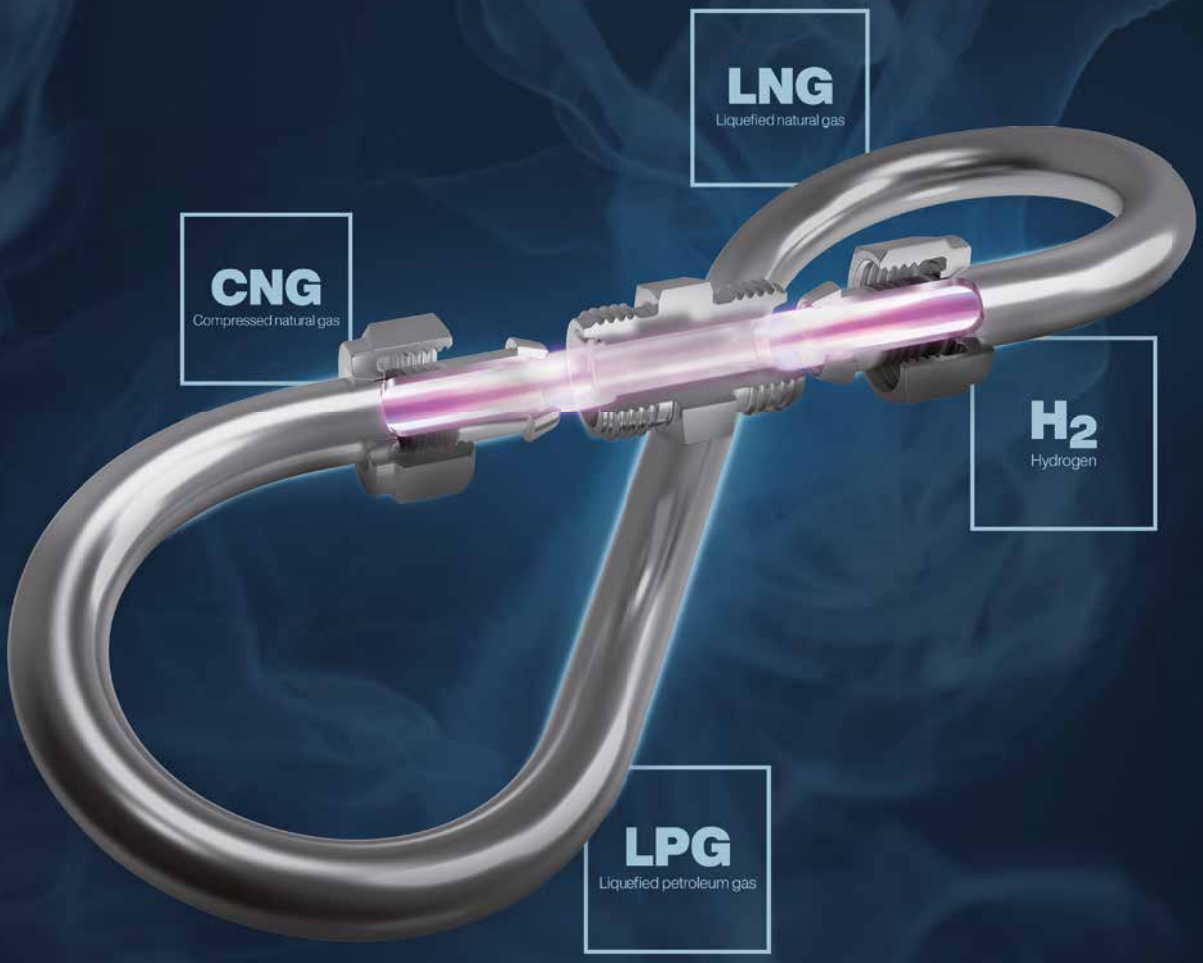

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Category: Energy storage | **Author:** Arthur Dornburg

HYDROGEN TO ENSURE CLEAN FUTURE AT LAKE CONSTANCE

Hydrogen Regions, Part IV: HyExpert project – HyAllgäu

Before the start of the HyExperts study, the plethora of ideas surrounding hydrogen development in the Allgäu region near Lake Constance resembled a thread with many loose ends. But now thanks to the HyExperts funding program, backed by the German transport ministry and overseen by NOW, it's been possible to quickly put forward concrete plans for a local field trial with the aim of producing and utilizing 1,000 metric tons of hydrogen a year in Allgäu. NOW's HyLand initiative for the development of hydrogen regions in Germany has therefore given crucial impetus to the transformation of this area into a hydrogen economy.

The outline submitted by the project team detailed tight constraints and high barriers for the efficient and profitable use of hydrogen in Allgäu. While many other plans call for a change in state rules, the HyAllgäu project concentrates on tackling any hindrances and finding appropriate solutions. Key performance indicators and strategic guidelines, such as the upper limit on production costs for "green regional hydrogen" from Allgäu of EUR 5 to EUR 6 per kilogram of hydrogen meant that the evaluation of suitable locations was a primary consideration. To keep within the limits imposed, green electricity would therefore have to be supplied to the electrolyzer at a maximum of EUR 0.05 per kilowatt-hour. Consequently, external power, power from plants which still receive government allowances or that have unfavorable production costs, and plants with insufficient hours of full utilization were deemed to be unsuitable in terms of meeting the above target price.

District climate officer Simon Steuer succeeded in initiating the feasibility study, a joint project by the Oberallgäu district and the town of Kempten, in record time. Engineering company bluemove consulting, BMC, was commissioned to carry out the research with director Arthur Dornburg at its helm. Scientific support is being provided to the project by the Kempten University of Applied Sciences under the direction of Werner Mehr.

SEWAGE PLANTS PROVIDE EXCELLENT FOUNDATION Given the numerous schemes to convert wastewater's energy potential into electrical power, the water treatment industry has long been considering the part that its plants could play in hydrogen production. The water treatment plant in Kempten, AVKE, together with its technical manager Franz Beer, was among the instigators of the HyAllgäu project. Since 2017, a continuous surplus of electrical power has been generated by regional wastewater treatment processes through the exploitation of sewage gas. This source of green electricity, which has a high number of full utilization hours, offers an ideal opportunity for the production of local green hydrogen at competitive prices. Therefore an initial quantity of around 50 metric tons of hydrogen a year was already considered a realistic volume at the time the project outline was submitted.

Water treatment plants also have the added advantage that the oxygen from the hydrogen production process can be used directly in biological cleaning, thus further optimizing the use of excess power. AVKE is planning to take further steps to increase the amount of sewage gas available for power generation. Alongside co-substrates e.g., from the region's dairy industry, feedstock is also expected in the form of excess

Fig. 1: 1,000 metric tons per year of green regional hydrogen from Allgäu

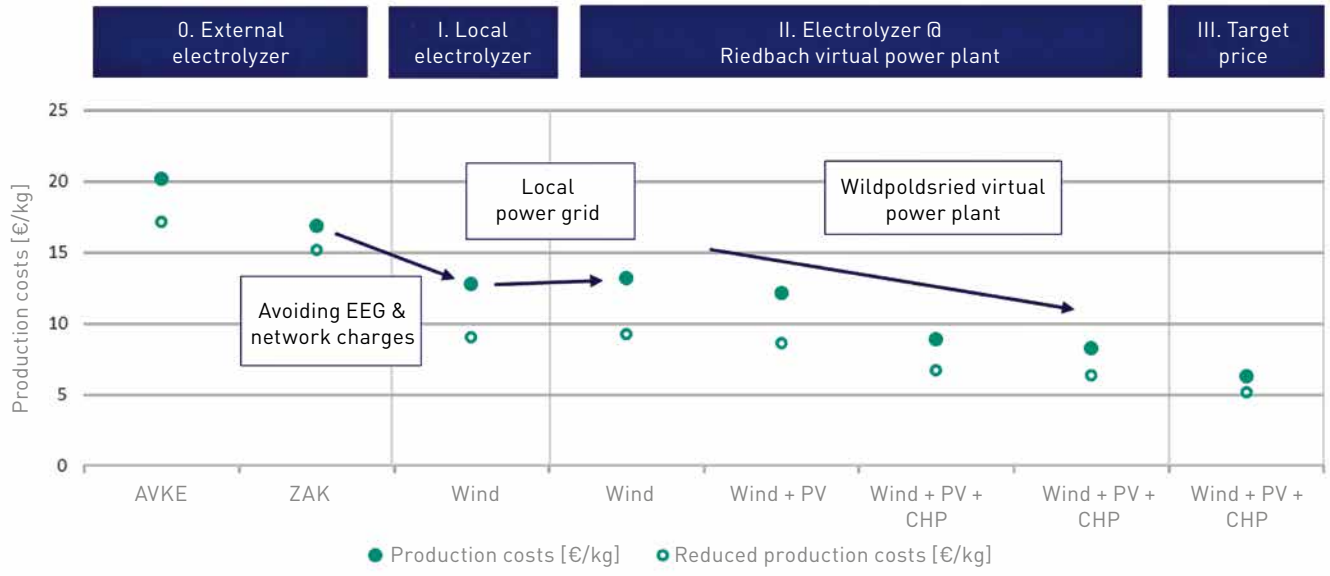

Fig. 2: Competitive hydrogen production costs through the intelligent combination of wind power, PV and biogas (BMC graphic)

methane-based biogas from the neighboring digestion plant, ZAK, making the facility an ideal partner. This contribution will allow annual hydrogen production at AVKE to increase to over 100 metric tons a year.

The HyAllgäu feasibility study also covers alternative means of hydrogen production, taking the AVKE facility as an example. In addition to the use of an electrolyzer, investigations have been made into steam reforming, wastewater and methane plasmalysis, pyrolysis and hydrolysis. However, it has already emerged that these alternative processes will not play a role in the upcoming HyAllgäu field trial. While electrolyzers are a mature technology that is already in use and the subject of funding appeals, the other techniques are largely processes that are still at the pilot or testing stage. In the future, though, it is perfectly possible that these could play a part and would have the added benefit of providing a further commercial outlet in addition to sewage treatment facilities with biogas plants.

REGIONAL ENERGY SECTOR Key to successfully putting together quick and profitable proposals for the future HyAllgäu trial were the excellent implementation skills and the high level of practical expertise brought by the engineering consultancy as well as early involvement of the regional energy sector as a partnership network. The plans detail hydrogen production of around 400 metric tons per year at the ZAK site, which is home to Kempten's waste- and wood-fueled cogeneration plant, and would be powered by green electricity that is certified using guarantees of origin. Furthermore, an additional 400 metric tons of green hydrogen can be produced annually at the Horn hydropower plant, operated by AÜW, located near Füssen in Allgäu. Once the period of government reimbursement under Germany's renewable energy law, EEG, has elapsed, hydrogen production will also become feasible at the region's wind farms.

CLEVER COMBINATION Volatile electricity supplies from regional wind power or photovoltaic (PV) plants are an issue that has been taken into consideration in devising future visions for green hydrogen. Obstacles such as time left to run under the EEG allowance scheme, network charges, insufficient full load hours, particularly if the number of hours for load shedding is low, have generally made a closer inspection of such options superfluous.

The Wildpoldsried energy village in Allgäu is a pioneer in terms of Germany's energy transition. In 2021, the EEG allowance lapsed for the first wind turbines, making them free from government subsidy. In addition to over 20 MW of wind generating capacity, Wildpoldsried also boasts numerous PV and biogas plants. By intelligently combining individual plants, the load profile available at the electrolyzer can be optimized to over 4,000 full load hours, resulting in a reduction in the production costs for green regional hydrogen from EUR 20 per kilogram to EUR 5 – EUR 6 per kilogram. Indeed biogas cogeneration plants are able to flexibly and effectively offset variable load profiles, allowing them to be operated in a way that benefits both the market and the network as a whole.

SECTOR COUPLING AS A SOLUTION The Allgäu region still has a large section of rail track that has not yet been >>

HYDROGEN REGION HYALLGÄU

As part of the proposed field trial in the Allgäu region, production of "green regional hydrogen" will begin in 2024. The volume of investment, not including vehicles, runs to roughly EUR 60 million and initial funding has been approved of around EUR 25 million. Production is to be spread across several sites and gradually stepped up according to demand, reaching 1,000 metric tons of hydrogen per year by 2030. The project is a collaboration between regional companies ZAK, Allgäuer Überlandwerk and Allgäuer Kraftwerke under the name Bioenergie Allgäu, otherwise known as BEA. In addition to hydrogen production, all regional distribution including hydrogen refueling stations will be coordinated, and also to a large extent operated, by BEA.

According to the plans, the use of pumped storage power plants in the neighboring Tyrol and Vorarlberg areas will in future be supplemented or replaced by hydrogen as a form of long-term energy storage. The Allgäuer Überlandwerk, or AÜW, is already successfully operating pioneering services on the flexibility markets. Consequently it is envisaged that the Allgäu electrolyzers will be integrated into a virtual power plant so they can be used in a way that is beneficial to both the grid and the market.

electrified. Many interested local parties are therefore hoping for the introduction of a hydrogen train. Even if this vision were to be followed up with feasibility studies and, assuming a favorable outcome, a pilot scheme, a hydrogen locomotive is unlikely to provide a reliable outlet for the hydrogen produced from the proposed HyAllgäu field trial over the next few years. Despite this, the mobility sector is still regarded as the principal buyer of hydrogen, potentially accounting for 80 percent of sales.

Potential users of hydrogen within the transport sector include local hydrogen buses in the towns of Kempten, Oberstdorf and Lindau, refuse trucks as well as regional logistics companies. While hydrogen-powered buses, which are especially suited to the rolling countryside of the Alpine foothills, are currently available on the market, a suitable supply of hydrogen-fueled trucks is yet to be forthcoming. Kempten university has a part to play in this respect through its collaboration with industrial partners on various projects relating to the development of powertrain technology.

The housing sector is another target market for hydrogen deployment in the region with a calculated 10 percent share. Indeed the use of hydrogen in combined heat and power (CHP) units represents a forward-looking alternative to natural gas. Furthermore, when these CHP systems form part of a hydrogen neighborhood, any surplus electricity that is generated can in turn be used to power all manner of private electric vehicles, thus relieving the burden on regional electricity networks.

A third area of hydrogen takeup, making up approximately 10 percent, is the industrial sector. Some industrial companies situated in the Allgäu region source large quantities of hydrogen which has to be transported over long distances. The market prices of industrial hydrogen and the price differential between those rates and the price of green regional hydrogen are certainly an obstacle to be overcome. Nevertheless, the blending of small amounts means a reliable outlet for the hydrogen produced in Allgäu and enables the region's industry to move toward carbon-free production. ||

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Category: Energy storage | **Authors:** Stefan Dohler, Michael Kröner

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FIRST UNDERGROUND HYDROGEN STORE TAKES SHAPE

Work on hydrogen test cavern gets underway in Rüdersdorf

Climate change is already in full swing, and it is this reality that makes innovative leaps forward in new technologies absolutely crucial. An important step toward creating a sustainable and environmentally responsible energy system is the development of a hydrogen economy. In the German municipality of Rüdersdorf, energy service provider EWE is currently building a cavern storage facility that will in future be capable of holding a large quantity of pure hydrogen that can then be called upon when required. The Hydrogen Cavern for Mobility project, or HyCAVmobil for short, is a collaboration between EWE and the German aerospace center DLR and sees the energy provider taking a leading role within Europe.

Transforming the energy system to meet European and German climate goals requires innovative leaps forward and appropriate action in order to translate technological advances into environmental progress. This is the reason why the European Commission and the German government have announced their intention to move rapidly into the development of a hydrogen economy. They share the understanding that necessary environmental progress can only be made if renewables-based gas, in other words hydrogen, plays a key role alongside electricity.

There is a general consensus that the green energy system of the future depends on the essential integrative properties of hydrogen. The gas is simple to store. It can be easily transported and imported over long distances. It's both an energy carrier and a feedstock. And it has the ability to link up different sectors in the economy (see fig. 2). Above all, hydrogen can overcome bottlenecks in the transmission of renewable power between northern and southern areas of Germany. This is possible through the conversion of electrical power into green gas which can then be delivered via existing pipelines to energy users in the south.

In addition, the interest in hydrogen is now growing among consumers and within the political sphere. Work is being carried out at speed to address legal issues, come up with a market design and devise a subsidy regime that will promote sector growth in the ramping-up phase. Specific projects are being drafted and some have already been rolled out.

PUTTING THEORY INTO PRACTICE EWE is one such organization that already has its first hydrogen projects in the planning and implementation stages. The supplier, which is headquartered in the city of Oldenburg in Lower Saxony, is convinced that a hydrogen-based system is technically and economically feasible and is prepared to invest heavily in the hydrogen economy. For this to happen, regulatory conditions will need to be optimized. In order to encourage market build-out, an equitable funding regime must also be put in place that takes into account climate protection goals and pays due consideration to capital outlay as well as transitional running costs.

The company's objective is to be the first integrated hydrogen provider in Germany to achieve a level of success across the entire value chain. This will be founded upon the practical experience gained through early initiatives. The company already has operations in the areas of production, large-scale storage and transport infrastructure and hydrogen sales, offering solutions that use a wide range of different technologies. For instance, EWE is carrying out a small tri-

Fig. 1: A cavern to store 100 percent hydrogen has been under construction since February 2021 in the Rüdersdorf area near Berlin [Source: EWE]

al in Huntorf, Lower Saxony, to investigate how a hydrogen economy could conceivably function.

The geographical and geological conditions in northwestern Germany make this an important region for the German hydrogen industry. Due to the plentiful offshore and onshore wind energy in the area surrounding the Ems, Weser and Elbe rivers, the company is aiming to produce green hydrogen in the future at the power plants and gas storage sites in this region. The seaports on the coast as well as the pipeline connections to the north and east also provide a logistical hub for handling most of the necessary hydrogen imports. According to the plan, EWE will store and transport its own self-produced hydrogen in addition to imported hydrogen via appropriate infrastructure and will facilitate the conversion of distribution networks from natural gas to hydrogen. For the conversion process, the company can rely on this region's unique technical expertise which has been acquired as a result of ongoing work to convert the area's natural gas grid from low calorific gas to high calorific gas.
Progress is also being made on the hydrogen storage front. At the moment, EWE stores hydrogen above ground but it is also exploring the use of caverns as another means of storing hydrogen.

BLAZING A TRAIL FOR HYDROGEN STORAGE In Rüdersdorf, in the state of Brandenburg, EWE is now taking action to test out this alternative hydrogen storage option. Over the past few weeks, EWE has begun constructing a cavern from aqueous rock with a depth of around 3,300 feet (1,000 meters) with a view to storing 100 percent hydrogen for the first time. The initiation of building work at EWE's gas storage facility signals the start of a research project that will look into the safe storage of hydrogen and will see the company taking a leading role in Europe.

The construction and test operation are due to take 18 months. When completed, the cavern will be able to hold 500 cubic meters of hydrogen, roughly equivalent to the volume of a single-family house. In the second half of 2022, EWE hopes to obtain knowledge in particular about the purity of hydrogen following its extraction from the cavern. This is something that is particularly important for the deployment of hydrogen in the mobility sector.

The DLR Institute of Networked Energy Systems in Oldenburg carries out research and assessment work into a number of related areas including the quality of hydrogen pre- and post-storage. Investigations begin in the laboratory and are followed up with trials at test caverns under controlled, real-world conditions. In carrying out its research, the DLR takes into consideration materials and components as well as user requirements. The institute also examines the >>

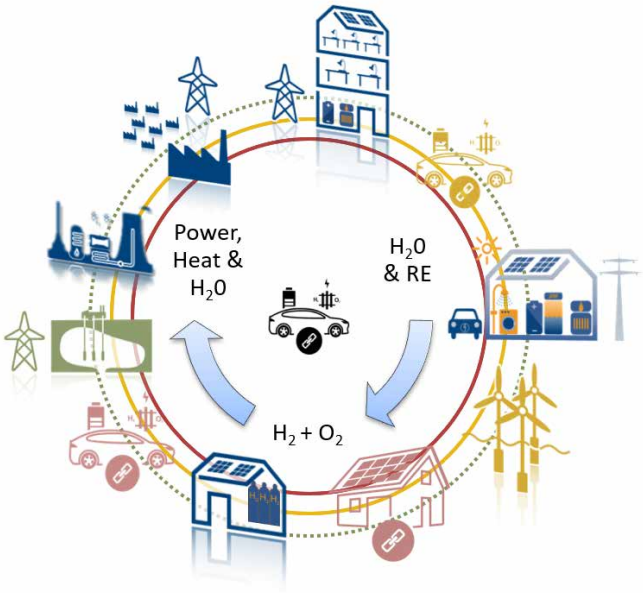

Fig. 2: Sector coupling with green hydrogen [Source: DLR]

Fig. 3: High-pressure test reactor with temperature control unit [Source: DLR]

workings of an example surface-level plant and optimizes its operation to manage its integration into the surrounding energy system.

The level of investment in the project runs to approximately EUR 10 million – EUR 4 million of which comes from EWE's own finances. The remaining sum is awarded by the German transportation ministry as part of its national innovation program for hydrogen and fuel cell technology.

HYDROGEN FOR E-MOBILITY Fuel cell powertrains represent a sustainable alternative for all transport that is presently powered by hydrocarbon-based fossil fuels. For hydrogen to be used in fuel cell power systems, the gas must be extremely pure. The combination of a highly pressurized cavern and the specific conditions of a salt cavern can have an effect on the materials deployed such as metals or sealing materials. If substances from these materials dissolve or react, they could contaminate the hydrogen that is stored. This is an issue that is currently being investigated by the DLR. As an initial step, the researchers are replicating the salt cavern in special reactors in the lab, making sure to recreate the pressure and temperature conditions under hydrogen atmosphere.

The lab setup has the advantage of allowing the hydrogen purity level before and after storage to be determined more precisely. The limits for contaminants in fuel cells are described in the standards EN 17124 and ISO 14687 which list maximum concentration levels for specific substances such as sulfur components in parts per billion. Even these extremely low concentrations, detectable only through trace gas analysis, can cause irrevocable fuel cell damage. In terms of repurposing natural gas caverns for hydrogen storage, contamination caused by methane, which is the main constituent of natural gas, needs to be taken into consideration; hydrogen with a methane impurity level in the parts per million range can also have a detrimental effect. The quality standards likewise recognize various salt ions as harmful substances. The DLR's high-pressure test reactors, together with gas analysis, are able to examine how a number of materials react with hydrogen and to detect a wide range of different contaminants.

In case the hydrogen, once retrieved from storage in the cavern, does not meet the high quality and purity requirements for fuel cell transport applications, the project team is also investigating various physical filtering processes at laboratory scale in order to reestablish the purity of the hydrogen in gas form.

Other issues to address include the type of plants and controls that are needed for the injection and withdrawal of hydrogen under pressure as well as the ability of renewables to meet demand despite their volatility of supply. Furthermore, it is also conceivable that sustainable hydrogen could be produced directly on site through electrolysis prior to storage. Against this backdrop, the DLR is modeling the upstream 110-kilovolt power networks in Brandenburg and at the cavern site in particular, calculating requirements and identifying operating concepts so as to find the best possible way to integrate hydrogen caverns into the existing energy system.

Detailed simulations of the electrical grid are produced that enable researchers to evaluate other suitable locations for hydrogen production and storage and to depict how these sites can give the power network useful flexibility. This flexibility can be exploited in the form of system services, such as primary balancing capacity. Scenarios are also possible in which targeted use is made of the cavern plant in order to avoid transmission bottlenecks.

LARGE-SCALE APPLICATION The expectation is that the research cavern findings will translate easily to caverns with 1,000 times the volume. The aim is to use caverns in future with a capacity of 500,000 cubic meters for large-scale hydrogen storage. EWE alone has 37 salt caverns, equivalent to over 15 percent of Germany's cavern stores, which could be suitable for storing hydrogen in the longer term. This would allow green, renewables-based hydrogen to be stored and supplied responsively on a terawatt-hour scale (TWh = 10^9 kWh). Such a capability would make hydrogen a critical component in the achievement of climate targets and the linking up of industry, mobility, heat and power sectors. ||

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Fig. 1: In future these tanks could hold carbon-neutral LPG instead of fossil-based propane and butane

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

BioLPG READY FOR THE OFF

Equal pegging for bioLPG and renewables in newbuilds

Liquefied petroleum gas derived from biomaterials has been legally recognized as a green compliance option in the German heating sector for over two years. Also known as biopropane, bioLPG could play a vital future role particularly in rural areas. What's more, there are also many pilot projects with synthetic LPG that can be manufactured using green hydrogen. This article provides an overview.

Uwe Thomsen, entrepreneur and director of family-run Propan Rheingas, can now see his name in print. Together with two co-authors, he has brought out a new book which is published in German by VDE VERLAG and entitled "LPG and BioLPG in the Energy Transition." In his view, LPG is a highly underrated fuel that is forever battling prejudices and lack of recognition, he commented when the book launched in May 2020.

BioLPG has been used in the German heating sector since 2018, Thomsen explained, where it can be deployed in energy-efficient heating appliances such as condensing boilers or combined heat and power CHP units. BioLPG can be made from biomass e.g., residual plant-based material and waste products, and reduces carbon dioxide emissions by up to 90 percent compared with conventional LPG. In addition, pilot projects examining the production of emission-free synthetic LPG which is made using green power, hydrogen and carbon dioxide, are ready for the off, Thomsen was pleased to announce. In his words, LPG is now getting green.

By contrast, propane and butane – the main constituents of fossil-based LPG – arise either as a byproduct from the crude oil or natural gas production process, or as a refinery gas. "From ecological and economic standpoints, it's worth not wasting these energy resources and instead refining them into high-value LPG," explained Markus Lau, head of the technical department at the German LPG association, DVFG. LPG is currently being used for heating and cooling purposes, as autogas, in industrial and agricultural applications, and in the leisure sector, according to Lau. An energy carrier which reduces carbon dioxide emissions and is low-polluting when burned could, in his opinion, be utilized in hard-to-abate sectors such as mobility and heat – if it becomes totally green in the future.

BIOLPG AS AUTOGAS? The German government's stated aim is to replace all fossil-based raw materials with renewable alternatives as far as possible by 2050. Carbon-based fuels are essential wherever storable energy is needed in decentralized applications, stressed Lau. "Renewable LPG will play a dominant role as a storable form of energy due to its essential properties, for example in the heating sector in those largely rural areas that are not supplied with natural gas – for the very reason that it is not tied to a pipeline. Furthermore, climate-neutral fuels generated using renewable power, or e-fuels – including renewable LPG serving as autogas – will in future complement the battery electric offering available," he predicted.

In many synthetic processes, such as the Fischer-Tropsch process, the synthetic manufacture of carbonaceous fuels using green hydrogen generates short-chain hydrocarbons that can then be supplied to the market as LPG, Lau expected. Here, it's impossible to estimate specific volumes, according to the DVFG, since the hydrogen-based industry is still in development and the legal framework for incentivizing hydrogen-based energy carriers is still being formulated. >>

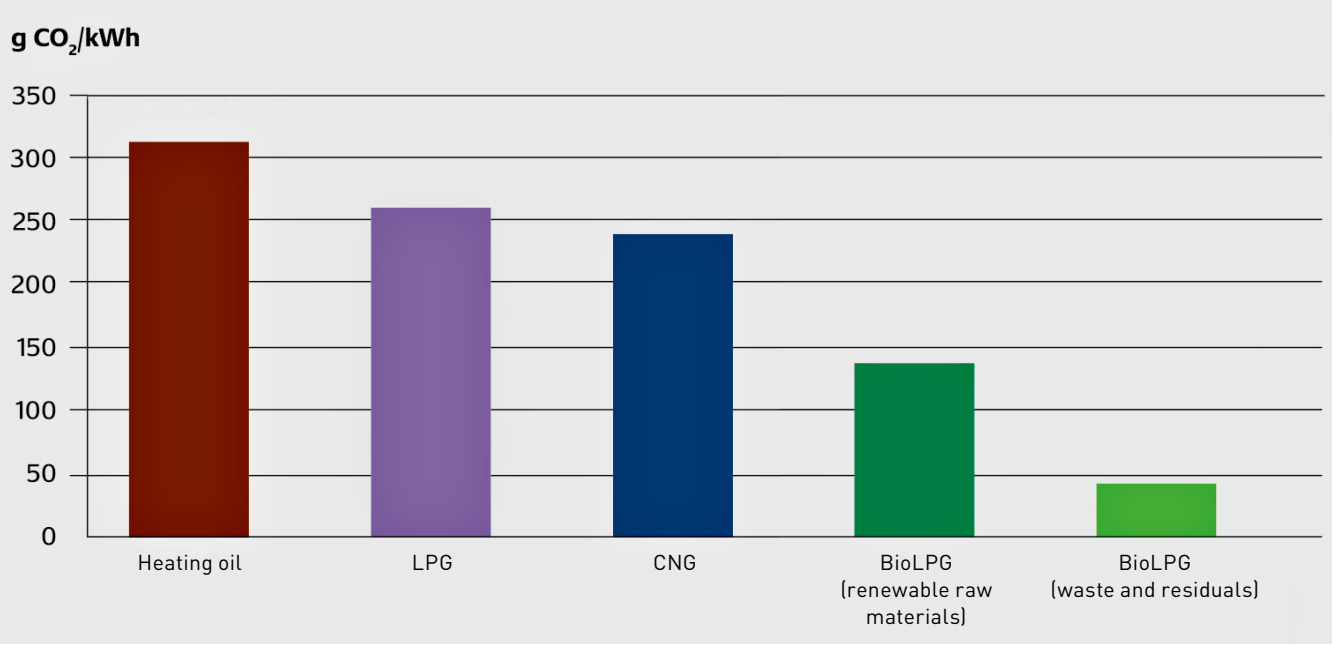

Fig. 2: Greenhouse gas emissions of different energy sources in carbon dioxide equivalent per kWh [Sources: IWU, GEMIS, Neste Oil, DECC, dena]

Propane and butane which have been produced in a synthetic process have identical chemical properties to their conventional counterparts. The gases have a high energy density, can be deployed in off-grid scenarios, are easy to transport and can be stored for long periods at low pressure. "The particular advantage of synthetic fuels and combustibles is that they can be used via existing systems, logistics and infrastructure," emphasized the department head and engineer. To generate heat in private households, for example, it's possible to use widespread technologies such as modern gas condensing heating systems. In the transport sector, e-fuels could be supplied via the existing network of refueling stations which currently comprise around 7,100 stations across Germany as a whole.

BIOLPG STILL NEW ON THE BLOCK "The fully synthetic, climate-neutral version produced using renewable power is undergoing tests and will take its place in the energy mix well before 2050. There are currently numerous pilot plants at which the power-to-X process is being continually refined. Right now, there aren't any relevant technical hurdles standing in the way of the market ramping up to an industrial level," said Lau, assessing the situation.

But what specific policy framework would synthetic LPG require? Similar to bioLPG, it would have to be legally recognized as a fully fledged renewable compliance option, emphasized the DVFG. In particular, the association explained, Germany's building energy law GEG, through the process of legal review described in Section 9, would need to set out a primary energy factor for synthetic LPG which corresponds to that outlined for bioLPG (GEG Sec. 22, para. 1 no. 3). BioLPG in this scenario is created from renewable raw materials as well as organic residual material and waste products. This includes, for example, edible fats from the food processing industry.

The new GEG has been in force since November 2020 and adopts bioLPG as an alternative energy for newbuilds. When combined with conventional condensing boiler technology, bioLPG now fulfills the obligation to use renewable energy which is mandatory for new properties. For DVFG chief Rainer Scharr, this is a historic step: "Incorporating bioLPG in the building energy law and making it an option for synthetic LPG via the innovation clause represents a milestone in the history of LPG fuel in Germany."

LPG GAINS MORE GROUND IN RURAL AREAS Likewise Jobst Diercks thinks it highly likely that bioLPG will be successful in the marketplace in the years ahead. Diercks is director of Primagas Energie in Krefeld, Germany, and it was his company that commissioned the German Energy Agency study "Liquefied petroleum gas and bioLPG" back in 2016. He believes that LPG will play a role in heating single-family and multifamily homes primarily in rural areas without a connection to the natural gas grid. The GEG already gives bioLPG as an option for newbuilds to meet the obligation to make use of renewables, he stated. "We presume that in the coming years the German states will also increasingly require the proportional use of renewable energy, including bioLPG, in the existing housing stock when converting or replacing the heating system," said Diercks.

The use of this option in existing buildings is financially the better alternative compared with the wholesale modification of the heating system, for example by converting to an air source heat pump, he maintained. "For existing housing, the use of bioLPG in combination with modern technology such as a CHP fuel cell or a gas heat pump is the clearly more affordable and environmentally friendly option," elaborated the Primagas boss. The market for bioLPG is indeed still small, Diercks also confirmed, but will grow significantly in the years ahead.

CONDITIONS FOR TRULY SUSTAINABLE BIOGAS By contrast Oliver Powalla, who works for the environmental action group BUND as a scientific advisor on the Kopernikus power-to-X project, takes the view that the regulations in the EU's renewable energy directive, RED II, rather let the use of conventional biofuels stagnate in future. He did confirm, however, that gas companies are currently concentrating on presenting natural gas as a more climate-friendly alternative to using coal. Furthermore, according to Powalla, a great deal of emphasis is being placed on presenting the

conversion of the natural gas network to hydrogen as a feasible prospect – without taking account of the costs and inefficiency of such a course of action or considering existing renewable alternatives.

The German automotive industry association VDA indicates that petroleum companies are now deploying biofuels in order to meet regulations imposed on the biofuel and oil industry that have been in force since Jan. 1, 2015, and which set out requirements in terms of climate protection quotas or greenhouse gas quotas. Ulrike Hinz, who is in charge of energy and climate policy at conservation group WWF, is nevertheless skeptical on this front: "We oppose increasing the proportion of biofuels based on cultivated biomass; there is still potential, though, for the use of so-called advanced biofuels from waste products and residues."

"If hydrogen is used as the basic substance, it must be ensured that the hydrogen is produced in a way that is beneficial to the energy transition," stressed Carolin Dähling, policy expert at Greenpeace Energy. In her view, "beneficial to the energy transition" means that electrolysis occurs during periods when there is an excess of renewable energy and a low level of electricity consumption. "Hydrogen which is produced using the normal power mix or from fossil-based raw materials is not a climate-neutral solution and is therefore not sustainable. If biogas acts as the energy carrier or as the basic substance for making a fuel, then particular consideration needs to be given to advanced technology without methane slip and to the substrate used," stressed Dähling. She added, biogas only makes sense if it yields a genuine greenhouse gas reduction and would not cause or exacerbate any other ecological problems. The graphic shows that bioLPG from waste and residual material especially, with carbon dioxide equivalents per kWh of below 50 g, cause fewer emissions; in the case of renewable raw materials they are around three times as high.

EKOBENZ FROM POLAND SUPPLIES FIRST COMMERCIAL BIOLPG Despite these criticisms, the market is beginning to develop for bioLPG: At the start of this year UGI Group along with SHV Energy, one of the largest international LPG corporations, concluded a deal on the supply of bioLPG with manufacturer Ekobenz from the Polish city of Lublin. In the eyes of Primagas boss Diercks, the company's production process is new yet relatively inexpensive. "The biomass products made by Ekobenz can be mixed with crude oil products without limitation," promised Stanisław Jabłoński, president of Ekobenz. As a result, bioLPG could gradually replace fossil fuels and bring carbon dioxide emissions right down to zero. For the time being biofuels or synthetic fuels are, nonetheless, more expensive than the fossil-based starting product, said Diercks, qualifying his view. Yet he is still certain that his company will have synthetic LPG in its portfolio within a few years.

The question of economy is rather less important in a direct product comparison, Diercks believed, since the economy of the chosen system overall is the crucial factor. A customer, he explained, can be financially better off with a fuel cell CHP unit that is supplied with a mix of 50 percent biofuel and 50 percent fossil fuel when viewed over an investment period of 10 years than if they go for an air source heat pump. The carbon footprint will be positively impacted in a way that fits with energy transition objectives, the DVFG deputy chair assured. In his words: "For there won't be one-size-fits-all solution in the heating sector." ||

LPG – A CAMPER'S BEST FRIEND

LPG bottles won't be dying out anytime soon according to the DVFG's opinion. The industry association sees a rising trend, particularly in the booming camping sector that took off again due to the pandemic. The reason: Methanol, which can be employed in direct methanol fuel cells for instance, can't replace LPG in a campervan because methanol can't be used for cooking. For peak-load applications, when the cooker is being used, it's even less suitable. Here's one example: An EFOY methanol cell has an output of 100 watts. An 11 kg bottle, on the other hand, can deliver a short-term output of around 25 kW. This is why even campervans which are already starting to come equipped with a fuel cell still have an LPG system on board.

It would seem that complete electrification with powerful batteries would be out of the question due to their weight, since in campervans there is a balance to be struck between payload and unladen weight, particularly for the 3.5 metric ton category.

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

FUEL CELL TRAINS ON THE MOVE

Electrification of rail transport

The evocatively named Heidekrautbahn, or heather railroad, has a long history: Since 1905 it's enabled city dwellers to escape from the German capital into the surrounding Schorfheide countryside to the north. However, efforts to resume the passenger service between Basdorf and Berlin-Gesundbrunnen, which was discontinued in 1983, have been drawn out over many years. On Dec. 14, 2020, a grant was due to be awarded that would make this rail link a vital part of a large-scale hydrogen project. According to the proposals, the trains would be powered by fuel cells using renewable energy supplied from regional sources and an electrolyzer would be acquired along with additional hydrogen vehicles. In spite of these preparations, the pandemic has, nevertheless, put the launch on hold.

Fig. 1: The Coradia iLint in Austria [Source: Alstom]

Plans started taking shape in October 2017 when the states of Berlin and Brandenburg, in collaboration with rail company DB Netze, initiated the i2030 infrastructure project. This then led to the signing of a planning agreement between the transport association Verkehrsverbund Berlin-Brandenburg and the rail company Niederbarnimer Eisenbahn-Aktiengesellschaft in January 2019. The arrangement set out proposals to reinstate the main line of the Heidekrautbahn for rail passenger usage. The kick-off event was due to take place at the end of 2020 with the German transport minister in attendance who was contributing a total of EUR 35 million to the project. Lockdown, however, necessitated a postponement.

The original intention was for the Heidekrautbahn's hydrogen operation to serve as a pilot scheme for hydrogen-powered trains. Yet, "lighthouse project" would no longer be a fitting description of the initiative due to the numerous delays. Consequently, the same consortium began a new initiative in early 2020 with new funding requests to the German transportation ministry, this time not as a flagship program but in the form of several standalone projects. Coordination of the project is being handled by Barnimer Energiegesellschaft, BEG.

One initial scheme proposes to extend the power-to-gas facility of project partner Enertrag in Prenzlau in order to ensure that the plant can provide sufficient gas for around five railcars, with the exact number still to be decided. The plan foresees the hybrid power plant supplying 450 kilograms of hydrogen a day to a hydrogen refueling station, which would be located in Basdorf, via multi-trailer trucks. In addition, six buses and two refuse trucks are envisaged, along with an electrolyzer near Wensickendorf.

The district of Barnim has been pursuing a zero-emissions strategy since 2008, for instance through the use of renewable energy and carbon-neutral transportation at both a municipal and regional level. It was therefore only appropriate that, as part of the retendering of this section of railroad, certain environmental conditions would be imposed. Accordingly, the tender to operate the line from 2024 to 2038, allocated through a direct bidding process, was made contingent on research and development plans for the use of hydrogen railcars. As part of a "German tour" back in February 2019, the Coradia iLint has already traveled along part of the Heidekrautbahn route (RB 27, see H2-international, January 2018 and July 2019) to Berlin-Gesundbrunnen.

H2RAIL.PRIGNITZ – POSSIBLE FIELD TRIAL Other sections of track in Brandenburg could also see the running of hydrogen trains in a few years: While seven rail links anticipate the use of battery electric railcars, as tendered out in May 2020 for Northeast Berlin, diesel or fuel cell trains could enter service on three stretches from 2024. Regine Günther, Berlin's transport senator, explained: "We are focusing on the most up-to-date methods for powering the Berlin metropolitan region – moving away from diesel and toward clean electric power with trains that can store electricity and cover sections of line that do not have overhead wires. We also promise that there will be a binding requirement in the follow-up contract for the continued operation of the vehicles and the workshop. Thus we are committed to an ecologically sustainable local public transport network in the longer term."

A little further west, the H2Rail.Prignitz program has been operating since 2016 in a similar scheme to the one in Barnim, which should give plenty of opportunities for accumulating practical experience on the ground. This project concerns the electrification of the Neustadt/Dosse – Meyenburg line, otherwise known as routes RB 73 and 74, for which the hydrogen could be sourced from the power-to-gas plant in Falkenhagen. The decision on the most appropriate drive system, however, has not yet been taken.

When considering this proposal, Ralf Böhme, chairman of Deutsche Eisenbahn Service, came to the conclusion that the use of batteries is only suitable for networks with a certain proportion of overhead line equipment so that the batteries can be recharged during stops. On the other hand, the use of compressed hydrogen in fuel cells would be severely limited, he thought, in terms of the overall financial and ecological impact since hydrogen logistics and storage vastly reduced the energy efficiency.

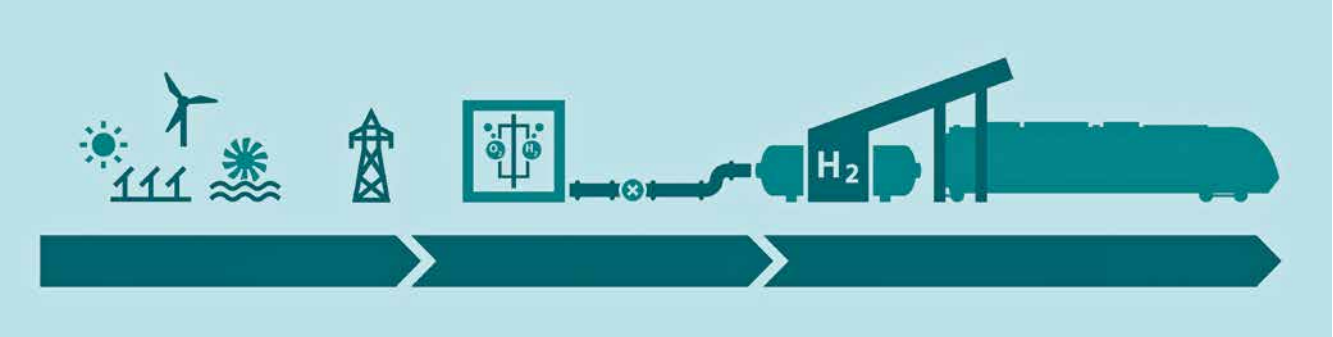

Fig. 2: Decarbonization of rail transportation [Source: Siemens]

WIDESPREAD INTEREST The first, and so far the only, fuel cell trains in service in Germany, two Coradia iLints from Alstom, completed in all 530 test days on the Weser-Elbe network through to February 2020 and traversed in excess of 112,000 miles (180,000 kilometers). From 2022, 14 series-produced fuel cell trains are due to supersede the diesel-powered models that have been in use to date. In March 2020, construction work began on the hydrogen refueling station situated at Bremervörde.

The Rhein-Main-Verkehrsverbund, RMV, which is one of Germany's largest transport associations, is also convinced by this technology: The Rhine-Main region is currently getting ready to build the necessary infrastructure to provide a supply of hydrogen to the world's biggest fuel cell train fleet for passenger transportation which is planned to start rolling out in December 2022. Fahrzeugmanagement Region Frankfurt RheinMain, known as fahma, is an RMV subsidiary that is preparing to construct an electrolyzer for fueling the planned 27 trains in a joint project with InfraServ Höchst, iGas energy and FEST. According to the proposals, the hydrogen refueling station will be sited in the Höchst industrial park and produce around 1,050 Nm^3 of hydrogen on an hourly basis.

Developments in the German state of Thuringia are not yet nearly so far advanced. There, Deutsche Bahn and state authorities initially signed a memorandum of understanding in October 2020 in which both parties declared their aspiration for a speedy deployment of hydrogen trains and an increase in the electrification of the region's railroads. The agreement sets out proposals for rolling stock powered by green hydrogen to enter service on the Schwarzatalbahn line in 2023. According to transport minister Benjamin-Immanuel Hoff (left), it is hoped that the redevelopment of rail transport in Thuringia in the run-up to 2050 will allow the state to become emission-free and climate-neutral in the future.

A tender for hydrogen trains is also in progress in the German state of Bavaria: In its plans for the area surrounding Mühldorf, Bavarian railroad company BEG envisages two sections of line in southeastern Bavaria that will run 10 emission-free trains with fuel cell power units from the end of 2024. The Zollernalbbahn line in the Swabian Jura should see one train entering trials from this May with the aim of throwing light on whether fuel cell trains are generally suitable for use in mountainous terrain.

> "Green hydrogen is an exciting opportunity for emission-free trains. Hydrogen is a particularly valuable energy carrier – it will be essential for us to use it in those locations where there is most urgent need."
>
> *Leonore Gewessler, Austrian climate action minister*

TESTS IN THE NETHERLANDS, AUSTRIA AND ITALY The Coradia iLint is not only enjoying some degree of popularity in Germany. In 2020, tests were also carried out in the Netherlands and Austria. In December 2020, Alstom was then granted official permission by railroad company ÖBB to instigate a regular passenger service on the Austrian rail network.

Italy is, likewise, showing interest: At the end of November 2020, Alstom announced that Ferrovie Nord Milano, the largest transportation company in Lombardy, has ordered six fuel cell trains based on the Coradia Stream with the option to add a further eight units in a deal worth EUR 160 million. Delivery is expected in the final part of 2023.

Austria, in the meantime, is drawing up its own plans which foresee the development and testing of a special hydrogen train as a part of the HyTrain research project. This would be a narrow-gauge train destined for operation on the Zillertalbahn railroad. This initiative, which has involvement from the Hydrogen Center Austria, is being supported by the Austrian climate action ministry to the tune of EUR 3.1 million.

SIEMENS PLAYS CATCH-UP There is potential for Siemens to become a second major German player in the field of fuel cell trains. However, up until September 2020, the focus had been on the separation of Siemens Energy from its parent company and its flotation on the stock exchange. As a result of this move, Siemens Energy is no longer part of the Siemens Group, although Siemens AG still holds the largest stake in Siemens Energy AG.

In October 2020, Siemens Mobility GmbH, which is owned by Siemens AG, and Siemens Energy entered into a collaborative research arrangement with the aim of driving forward hydrogen mobility and jointly offering fuel cell trains in the future. Albrecht Neumann, rolling stock director at Siemens Mobility, stated: "This enables us to support our customers in finding a lasting substitute for diesel-powered rolling stock on lines without overhead wires, through their replacement with zero-emission hydrogen vehicles. Working in partnership with Siemens Energy allows us to offer a 'hydrogen as a service' model over the service life of the vehicle."

STADLER PROFITS FROM BATTERY EXPERIENCE Another supplier from a German-speaking country is Stadler. At the end of 2019, the Swiss company announced it had sold its first hydrogen-powered Flirt H2 to San Bernardino County Transportation Authority in California. The Redlands Passenger Rail Project is due to launch its passenger service in 2024.

Stadler already has experience with battery-operated rail vehicles, having secured a number of commissions including an order for 55 commuter trains in 2019 from the German state of Schleswig-Holstein which should see the >>

Fig. 3: The HYBARI from JR East [Source: Toyota]

replacement of diesel railcars from the end of 2022. Transport company Nah.sh and state authorities had opted for Stadler's battery-powered Flirt Akku model as this type of train can be recharged at several stations via the existing overhead wires. Their range is approximately 93 miles (150 kilometers).

ASIAN COMPETITORS Things are also going full speed ahead outside of Europe: For example, East Japan Railway Co. is working in concert with Toyota and Hitachi on Japan's first hydrogen-powered train based on the FV-E991 series. In October 2020, the partnership announced that initial testing of the HYBARI, which stands for hydrogen-hybrid advanced rail vehicle for innovation, would begin near Tokyo in March 2022. According to the plans, Toyota is developing the fuel cell system complete with 20 tanks while Hitachi is designing the hybrid power system including converter and lithium ion battery with a 240 kWh capacity.

Asian competitor Hyundai is also making tracks. Rail industry manufacturer Hyundai Rotem signed an agreement in August 2020 with Korean city Ulsan for the development of a hydrogen-powered tram. Consistent with the Nexo model designed by its parent company, future rail vehicles are also planned to be fitted with special filters to improve air quality, it is claimed.

Fig. 4: VL-series PEM fuel cell powertrain [Source: Horizon]

South Korea is also home to Horizon Fuel Cell Technologies. The fuel cell manufacturer had previously revealed in early 2020 that it intends to incorporate 400 kW PEM fuel cell systems in rail vehicles as part of its collaboration with the Korean Railroad Research Institute.

UK: BREEZE AND HYDROFLEX In January 2019 – and therefore prior to Brexit – Alstom had been working on its own train design for the British market (see H2-international, July 2019). Dubbed Breeze and based on the Class 321 of Eversholt Rail, the train will bear the newly created Class 600 designation reserved for trains employing alternative traction methods and is targeted to enter service in 2024. As part of their joint enterprise, Eversholt Rail and Alstom intend to invest over EUR 1 million in this technology. According to plans, the non-polluting rail vehicles will then be built by Alstom at the Widnes Transport Technology Centre. It is also hoped that the Alstom facility in Widnes near Liverpool will become a globally linked center of excellence for hydrogen conversion.

Meanwhile, the Birmingham Centre for Railway Research and Education is also cooperating with leasing company Porterbrook to produce a fuel cell train. Over the past two years the University of Birmingham, with funding from the British transport department has been developing the HydroFLEX. Stephen Jarvis, head of the College of Engineering, indicated that the associated technology would be offered from 2023 as a retrofit solution.

VDE STUDY CONTRADICTORY Opinion remains split over whether overhead wires, batteries or hydrogen should be the powering solution of choice in particular circumstances. While one study by the German Aerospace Center, which was commissioned by NOW, sided in favor of hydrogen trains, the Association for Electrical, Electronic & Information Technologies, VDE, came to the conclusion – also in 2020 – that battery electric multiple units, referred to as BEMUs, are "significantly more economical" than hydrogen electric multiple units or HEMUs when seen over 30 years. Elaborating on this point, VDE explained: "The HEMU's main problems are the energy costs and the replacement costs for the fuel cell."

However, VDE conceded that: "In the case of lines with a special energy requirement, for example due to inclines that need to be negotiated or extreme climatic conditions, the BEMU concept is far less suitable than an EMU or HEMU since these have relatively limitless energy reserves available to them. […] The longer the stretches without overhead wires, […] the more disadvantageous the EMU and BEMU concepts become."

However, according to a report in German newspaper Handelsblatt, Alstom and Siemens have argued against this stance, saying that the Düren rail network, which was regarded as an exemplary model for the VDE study, was not representative. The verdict of the study's author, Wolfgang Klebsch, should nevertheless carry a certain weight. And indeed he concluded that "assuming an operational life of 30 years, from 2025 at the latest no more new diesel railcars" ought to be brought into service.

Enak Ferlemann, parliamentary state secretary at the German transportation ministry, stated that battery-powered trains definitely present advantages for distances up to 25 miles (40 kilometers). For longer stretches, however, the benefits clearly lie with hydrogen, he said. Addressing the issue in more specific terms, Ferlemann explained: "Hydrogen is a genuine low-emitting and efficient alternative to diesel. In particular for branch lines where overhead line equipment is uneconomical or not yet installed, these trains can run a clean and environmentally friendly service. We would hope for more applications of this kind." ||

"The current range of battery-supported hybrid railcars is up to 100 kilometers [62 miles], though this also depends on the operating conditions. […] Hybrid railcars with a battery back-up unit are therefore predominantly suited to lines that have at least some sections that are easy to electrify or already have segments of track with overhead wires. On lines with prolonged sections without overhead line equipment and for networks with only a few stretches with overhead wires, railcars with a fuel cell powertrain are the better option. This particularly applies to rail links in regions in which hydrogen generated from renewable sources is readily available."
NOW study "Market analysis of alternative power systems in local rail passenger transportation in Germany," 2020

FUEL CELL FUTURE FOR E.GO


Source: e.GO Moove

Thanks to new management and fresh financial backing, Günther Schuh is intending to push on with his plans for German-based e.GO Mobile – including the incorporation of fuel cells. At the end of February 2021, nd Industrial Investments B.V. reported the successful conclusion of a Series B financing round which brought in funds of EUR 30 million. The Dutch investment group nd Industrial B.V. had previously taken over e.GO Mobile AG on Sept. 1, 2020, and transferred it to Next.e.GO Mobile SE. The money should ensure that production of the e.GO Life goes ahead in June 2021. Among the investors are the once U.S. finance minister John Snow, Formula E chairman Alejandro Agag and the actor Edward Norton.

Schuh commented: "We are very grateful for the continued enthusiasm, commitment and patience of our customers and fans and are delighted to finally be able to accept orders again." Günther Schuh gained much attention in 2019 with the e.GO Mover commercial vehicle concept, explaining at the time that it was wrong to concentrate wholly on just battery or fuel cell power systems. The better approach, in his view, is to intelligently combine a comparably small rechargeable battery with a fuel cell as a range extender. He also remarked that car packaging is extremely difficult which is why it makes more sense to use these kinds of power units in buses, for example.

In 2018, Schuh had originally envisaged that e.GO REX GmbH, a joint venture with Proton Motor, would produce 30,000 units of the e.GO Mover within two years and kit out 5,000 models with fuel cell systems with a 30 kilowatt power output to extend their range. Proton Motor has since ceased to be a partner in the joint venture, according to e.GO, something which has neither been confirmed nor denied by Proton Motor. An e.GO spokeswoman, however, told H2-international: "Working in collaboration with a number of strategic partners, e.GO REX is pushing forward rapidly with the industrialization of fuel cells. The modular fuel cell range extender e.GO REX will be available on the market in 2024." ||

DAIMLER TRUCK + VOLVO = CELLCENTRIC

As previously announced (see H2-international, August 2020), Daimler Truck and the Volvo Group have embarked upon a joint venture in which each company holds a 50 percent ownership stake. At the beginning of March 2021, the two organizations announced that the company formerly trading as Daimler Truck Fuel Cell GmbH & Co. KG had been renamed cellcentric GmbH & Co. KG.

According to company reports, the new joint venture intends to develop, manufacture and commercialize production-ready fuel cell systems for heavy trucks. The stated aim is to become a "world-leading manufacturer of fuel cells" in order to ensure that transportation becomes climate neutral and sustainable by the year 2050. Initial customer trials of fuel cell trucks are forecast for 2024, with series production due to commence in the second half of the decade. ||

Category: Research & development | **Author:** Eva Augsten

GREEN FUTURE ENVISAGED FOR STEEL

ArcelorMittal plans to scrap the use of coke in steelmaking

Fig.: In the Midrex plant (left), ArcelorMittal obtains iron through direct reduction. Its successor is expected to one day use hydrogen instead of natural gas. [Image: Eva Augsten]

Steel group ArcelorMittal has plans to build a pilot plant in Hamburg that will use hydrogen in its ore reduction process to produce pure iron as part of a construction project that is due to get underway in the third quarter of this year. In future, some of the gas could be supplied by a new hydrogen network that is being set up especially for the industrial park at the port.

Between mountainous heaps and expansive production halls on ArcelorMittal's manufacturing site, situated on the industrial park south of the Port of Hamburg, lies the Midrex plant. All rusty-red towers and pipelines, the building is clearly the most photogenic feature in the complex – 1970s steampunk at its finest. But it's not just for looks that the German facility is now the center of attention. Its still unusual technological process is set to form the basis for carbon dioxide-free steelmaking – aided by green hydrogen.

This move toward hydrogen could potentially lead to large environmental gains since steel production in Germany and the European Union still accounts for around 7 percent to 9 percent of total carbon dioxide emissions. Of this, most of the carbon dioxide is released not as a result of the energy input required, but from material processes. Capturing and sequestering the carbon dioxide would be one way to "clean up" steel manufacturing. However, carbon capture and storage is a controversial subject due to the question marks remaining over storage location and the security of carbon dioxide containment.

If the intention is to prevent greenhouse gas from being created in the first place, and thus truly decarbonize the process, the one option still available is the use of hydrogen. Because of this, the hydrogen strategies of the EU, Germany and northern Germany rank the steel sector as a high-priority area of focus, along with the chemicals industry.

In Hamburg, the direct reduction process has been used as a means of converting iron ore to metallic iron for several decades. Yet in Germany as a whole, this method, which was developed by the company Midrex, has remained a rarity. In the ironworks of the Ruhr, Eisenhüttenstadt and Salzgitter, ore is still smelted in blast furnaces. But now that environmental concerns are starting to encroach on the industrial sector, the benefit of the direct reduction technique is coming to the fore. In comparison to a blast furnace which uses virtually pure carbon in the form of coke to draw out the oxygen from iron ore, leaving behind carbon dioxide and pig iron, direct reduction is much less carbon dioxide-intensive.

WHAT IS DIRECT REDUCTION? In this process, natural gas reacts with iron ore to produce water, carbon dioxide and pure iron. As a result, the pelletized ore is transformed into pure iron pellets with microscopic pores. The pellets look exactly the same as they did previously, just weigh slightly less. This is why they have earned themselves the name "sponge iron," also known by the technical term "directly reduced iron" or DRI. If methane is substituted for hydrogen, then the reduction process can occur with zero carbon dioxide emissions. This is precisely what ArcelorMittal wants to trial in Hamburg.

The projected cost for the pilot plant is EUR 100 million, with construction due to start in the third quarter of 2021 and last until 2024. The facility is then planned to go into operation in the course of 2025, with output provisionally pegged at 100,000 metric tons of DRI a year.

GOAL: CARBON NEUTRALITY BY 2050 ArcelorMittal's ambition is to achieve net-zero climate impact from carbon dioxide emissions by the year 2050. This is just one of several environmental milestones the company has put forward: By 2030 the company plans to reduce carbon dioxide emissions in Europe by 30 percent – no mean feat in itself considering the range of measures needed to make this a reality.

What is apparent is that achieving climate-neutral steel production will require hydrogen of the green variety – and for the moment that's a long way off. Therefore, initially, ArcelorMittal wants to fall back on the steam reforming of natural gas. This particular process is already incorporated into the plans for the new plant. That said, the company is also currently working in parallel on setting up its own electrolysis facility. Its technical stats: 50 megawatts of power input, 380 gigawatt-hours of annual electricity consumption for electrolysis, 310 gigawatt-hours of green hydrogen output.

In order to buy in the green electricity needed, ArcelorMittal would have to sign up a small offshore wind farm with 22 turbines, each with a 5 MW generating capacity. If the entire steelworks were to be converted, almost

2,000 GWh of green hydrogen would be required, in addition to the green electricity. This works out at around 870 MW of offshore wind capacity. According to ArcelorMittal, the German steel industry as a whole would need an offshore wind energy equivalent of 35 GW.

To date, an offshore wind capacity just shy of 8 GW has been installed and no new projects have been planned for 2021. By the mid-2020s, however, several large wind farms are expected to go online: Borkum Riffgrund 3 and He dreiht, both of which are located in the North Sea, and Gennaker in the Baltic Sea. Rough estimates show that any of these arrays could be sufficient to supply a steel factory. Ambitious climate action scenarios assume that offshore wind generation can be expanded up to 50 GW – 70 GW by 2050.

If you take into account the fact that the chemicals and cement industries, on top of steelmaking, are also relying on hydrogen, that doesn't leave much leftover for other applications. This calculation equally fails to consider the use of hydrogen as a long-term energy storage medium for the energy system. Therefore this projection will not stand the test of time without recourse to extensive imports. The infrastructure that would allow this to happen is already detailed in Germany's national hydrogen strategy. Not only that, specific plans are being forged for Hamburg.

As well as addressing the question of hydrogen procurement, ArcelorMittal is also putting together proposals for the conversion of its other industrial sites. The steel mill in Duisburg could, in future, be supplied with DRI from Hamburg which would then be refined into steel in an electric arc furnace. In Bremen and Eisenhüttenstadt, plants currently manufacture flat steel using the traditional blast furnace method. Group spokesman Arne Langner elaborated: "In the first step, the plan is to blow natural gas into the blast furnace in order to reduce carbon dioxide emissions. In theory, hydrogen could be blown in as well at a later date, but that is probably too expensive. What is more likely is that the site will be converted to direct reduction and an electric arc furnace."

While in Germany, at least, it seems that hydrogen technology is the only viable route, in Belgium, ArcelorMittal is also turning to carbon emission capture. Here, the aim is not to sequester the gas; instead the intention is to use it in the form of carbon monoxide to produce primary chemical products through carbon capture and usage or CCU. "A demonstration plant is being built in Ghent at the moment. It is possible that this process will become available more quickly than decarbonization using hydrogen," explained Langner.

VIABLE ROUTES FORWARD If the costs remain uncertain, one thing that is clear is that the use of hydrogen is not viable for the steel industry in the present circumstances. It's not just the required investment in new facilities that is crucial here, but also the price of hydrogen. Getting a handle on the price issue is a difficult task which is complicated by the fluctuating and interdependent nature of the figures involved. Some estimates for the additional cost of green steel are leveled at "35 to 100 percent"; others run to "150 to 200 euros per ton." Evidently the current price of EUR 3 to EUR 4 per kilogram of green hydrogen is too much. The price point at which the process would become viable depends on various factors including plant configuration. It would have to be "much lower," said Langner, "more like one to two euros."

As well as cost considerations, ArcelorMittal is also taking a look at market and revenue factors. "An awareness needs to be developed for the production and the additional costs. Here we are making what could be called bio-steel." Although green steel would have a much higher cost, at first sight this appears to have a negligible impact when it comes to the end product: A packet of 100 screws would be approximately EUR 0.50 more expensive; a small car manufactured from green steel would cost roughly EUR 500 extra. Yet, when compared to steel made using fossil fuels, green steel would be at a competitive disadvantage in the global marketplace. There are ways in which this discrepancy can be balanced out. ArcelorMittal has several ideas about how a new equilibrium could be brought:

- Automotive manufacturers could be given targets for carbon dioxide reduction at the production stage. This would create an incentive to pay a higher price for green steel.
- A global carbon dioxide price or alternatively a customs duty on carbon dioxide from outside the EU would ensure that European "green steel" could be put on a par with imported "gray steel" at least within the European single market.
- Under Carbon Contracts for Difference, as envisioned by both European and German hydrogen strategies, companies receive subsidies for lowering their carbon dioxide emissions, albeit not at a fixed level but in a style of bidding process. Whoever saves the most carbon dioxide for the smallest subsidy, is awarded the premium.

It shows that technology, economics and politics need to mesh together at an international level in order to achieve environmental progress.

INFRASTRUCTURE UNDER DEVELOPMENT Dovetailing with ArcelorMittal's plans is the initiative to create a new hydrogen hub in the industrial park to the south of the river Elbe. Here, Hamburg's trade and industry authority intends to build an alkaline electrolyzer with a 100 MW capacity at the site of the former Moorburg power plant. Exact details of where the green power for the electrolyzer will come from and how it will help stabilize the grid are yet to be made fully clear. There is potential, however, for Vattenfall's offshore wind farms to play a role.

In order to connect the electrolyzer to the industrial companies in the vicinity, the electrolyzer will be integrated into the Hamburg hydrogen industrial grid HH-WIN. The works located in this area, including – alongside ArcelorMittal – copper producer Aurubis and various petrochemical companies, consume around a third of all natural gas in Hamburg. The city's network operator Gasnetz therefore hopes to decarbonize a large proportion of the gas it sells within the next 10 years through the construction of a hydrogen pipeline reaching just 28 miles (45 kilometers).

Nevertheless, the 100 MW electrolyzer will only be able to supply a tiny portion of the hydrogen needed. Even if the electrolysis plant operated for 8,000 hours a year at full load – an impossible task if run on renewable energy – "only" around 0.2 billion cubic meters or 600 GWh of hydrogen would be produced annually. This represents roughly a third of the amount called for by ArcelorMittal if it is to succeed in fully converting its production.

For this reason, the hydrogen hub design makes provisions for an import terminal and a connection to the "hydrogen backbone," the planned pipeline which is due to stretch to the new import terminal in Rotterdam. ||

Category: Education | **Authors:** Lisa Lehmann, Winfried Wilke

NEW HYDROGEN TECHNOLOGY COURSE

Bavarian university gets hydrogen experts on board

The mechanical engineering faculty at the University of Applied Sciences Würzburg-Schweinfurt, FHWS, is taking action to address the energy transition by developing a new hydrogen technology course. The move comes amid Bavaria's drive to accelerate regional development through its High-tech Agenda program which is channeling investment into clean technologies. From October 2021, FHWS students should have the option to delve deeper into the subject of hydrogen, giving them the chance to pursue a career in this environmentally crucial area. The new course focuses particularly on the development and operation of hydrogen plants as well as plant and workplace safety. FHWS intends to shape the content of the course through continuous dialog with businesses and their specialist staff, with the expectation that this will lead to project collaborations at a later date.

Since 2017, the Faculty of Mechanical Engineering at FHWS, in southeastern Germany, has been investigating the skills that its future graduates will need and how these could be incorporated into its study programs. This research has enabled the faculty to develop an extensive skills profile for its mechanical engineering degree, covering specialist as well as interdisciplinary skills. The profile can also be modified for use by other technical courses. The adaptation process involves technical experts convening in guided workshops and adjusting the skills profile to suit their own specialist field.

On Nov. 27, 2020, discussions were held at a digital workshop entitled H_2-Forum on the creation of a promising new hydrogen technology course which aims to match the skills taught on the program to the needs of industry. The event was initiated by the BEST-FIT project team as part of the teaching quality program, a scheme supported by the German education ministry since 2017. Talks explored a number of topics, in particular the project- and competence-related entry phase of technical courses, and resulted in the creation of the above-mentioned skills profile.

Thanks to the university's long history of industry cooperation as well as the support of Stefan Dürr, head of innovation and technology at the Center Hydrogen.Bavaria – H2.B, over 40 top engineers and project planners in addition to management executives from relevant companies across Germany were able to participate in the workshop. Dürr explained: "We think that the FHWS approach is extremely valuable as it not only gives rise to partnerships and collaborations but it also allows us to generate results collectively, thus enabling us to shape the hydrogen technology course in a way that promises to benefit academic teaching and the business world in the future."

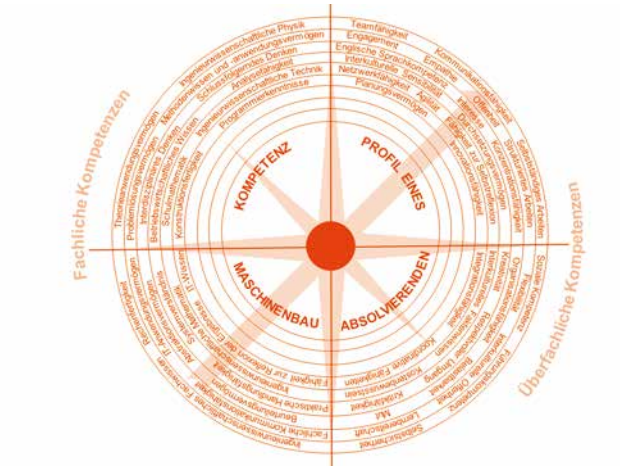

Fig. 1: Skills compass for the mechanical engineering bachelor's program at FHWS [Source: FHWS]

Views were sought primarily among technical experts who have developed hydrogen plants and who are responsible for maintaining their operation. Taking part in the workshop were a number of companies that have a business interest in hydrogen technology, including Airbus Operations, Linde, Thyssenkrupp Industrial Solutions, BMW, Schaeffler Technologies, H-Tec Systems, SL TecH2, ArianeGroup, Heitec Innovations, Green IT Concepts and Ferchau. These enterprises were joined by representatives from the Fraunhofer Institute for Machine Tools and Forming Technology and lecturers from various higher education establishments. Having been drawn from both academic and commercial spheres, the delegates were able to offer a broad range of perspectives when it came to collectively creating the skills profile for the new degree.

SKILLS RESEARCH FROM MECHANICAL ENGINEERING

But what precisely has gone into designing this skills profile? How was it developed? And what information is it founded upon? Even here, considerable emphasis was placed on the collaboration between the university and commercial organizations. For applied university education can only be suitably designed if future employers are engaged in the course planning process, inputting their essential requirements with regard to the specialist knowledge as well as interdisciplinary skills needed by their staff.

These requirements also formed the basis for the skills profile for the FHWS mechanical engineering degree. As part of the process, responses were gathered from 70 experts in their field from both academia and industry by means of a standardized interview questionnaire. A total of 19 companies, comprising 14 large corporations and five small- and medium-sized enterprises, took part in this research project. The process saw the application of tried-and-trusted surveying and assessment techniques, for example the systematic expert interview described in Bogner et al. (2014) and the qualitative content analysis outlined by Mayring and Fenzel (2010, 2016). Consequently, a comprehensive catalog of skills was compiled listing over 129 skills and qualities, along with their definitions.

To validate the research, the results gathered from the interviews were presented to experts in a workshop where the terms for specific skills, definitions and priorities were jointly discussed. A systematic ranking system made it possible to ascertain the most important skills in the following areas: specialist knowledge and application, working methods and cognitive skills, individual attributes, social and intercultural skills.

When the results were examined, the skills profiles compiled by teaching staff were at odds with the outlines given by

industry representatives. This comparison made clear once again the importance of developing the content of possible degree courses in concert with the future employers of those graduates. For while teaching focuses on imparting a broad range of useful knowledge, the labor market requires more than just technical know-how. Skills such as teamwork, ability to communicate, engagement, self-confidence and language skills are vital for our graduates in terms of ensuring success in a dynamically changing workplace (Lehmann & Wilke 2019).

As a result of this process, the mechanical engineering faculty has been able to further refine its skills- and project-based system of teaching so that its students cultivate far-reaching interdisciplinary skills. The skills profiles served as the basis for the creation of a skills compass which can be used for guidance purposes (see fig. 1).

ADAPTING TO A SKILLS PROFILE The aim is to now also put these valuable findings into practice for the new hydrogen technology course. A sound understanding of industry requirements, in addition to close communication with the German gas and water industries association, should provide a well-informed basis for the development of a bachelor's degree that places skills acquisition front and center. The FHWS has set itself the goal of designing the hydrogen technology course in such a way that it provides students with relevant, practical skills, with much key input coming directly from the November online workshop.

The mechanical engineering skills profile was adapted for hydrogen technology and the selected competencies were prioritized systematically. Starting in the top left-hand segment, the tables list the most popular skills selected in a particular area, with the bottom right-hand segments showing the least frequently selected skills.

At the workshop, the technical experts were unanimous in calling for the new course to focus on the safe handling of hydrogen since the particular physical and chemical properties of hydrogen mean a high safety standard is essential for the development and, moreover, the operational monitoring of those plants that will be responsible for producing, transporting, storing and deploying hydrogen now and in the future. Furthermore, as is the case for all technical engineering degree programs, a great deal of weight is placed on mathematical and scientific fundamentals, thus allowing students to gain a base level of knowledge that can then be widely applied.

In terms of development, the focus will be on equipment and plant engineering in addition to plant operation. Given the status of FHWS as a university of applied sciences, its teaching will also concentrate on providing a wide range of knowledge with a particular spotlight on IT and programming skills in order to prepare students for the digital transformation occurring in the workplace and the technical and organizational changes that it brings.

Under interdisciplinary competencies, commercial law is marked out as an area of popular interest, and again this was highlighted in conjunction with the high level of safety necessary when working with hydrogen. The independent acquisition of knowledge through research skills is also highly prioritized as well as management skills which will equip future graduates with the necessary tools to exercise management responsibilities in years to come. English language proficiency and project management capabilities are still a mainstay of an engineer's ideal skill set in the currently changing job market, accompanied by an understanding of environmental impact, knowledge of IT applications and the ability to optimize processes.

Among the social competencies named, as already established by Lehmann and Wilke (2019), are the as-ever indispensable teamworking and communications skills as well as the ability to demonstrate critical thinking and the intercultural understanding called for in an increasingly globalized labor market. New for the hydrogen technology profile is the greater need for commercial competencies, for instance awareness of technical-economic interdependencies and efficiency considerations, as befits the energy transition.

Because it remains the case that universities have little in the way of specialist knowledge relating to the development and operation of hydrogen plants, the virtual workshop, along with the resulting comprehensive skills profile co-developed by lecturers and industry experts, has an essential role to play in developing the new study program. The lack of specialist expertise in academia is understandable given that thus far there has been insufficient research into the broad, cross-sector application of hydrogen plants as a means to facilitate the transformation of the energy system. Practical experience in plant set-up and operation exists principally in individual sectors.

Summing up, Winfried Wilke, who will take on the role of course leader for the hydrogen technology program, stated: "By bringing together and encouraging the participation of all education and industry stakeholders in order to jointly push progress in hydrogen technology, together we can and will shape the future of the energy transition." ||

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A BUMPY RIDE

Sven Jösting's stock analysis

Fig. 1: Weichai mining truck complete with Ballard fuel cell [Source: Ballard]

The highs and lows of hydrogen and fuel cell stocks in recent weeks can be best described as a bumpy ride following a significant and rapid increase in prices. It seems to me that the market has entered a major consolidation phase. Yet this is no reason to lose faith, especially as the wild fluctuations that have been raging since early December 2020 – with some stocks climbing more than 50 percent inside a month – begged a correction. A process which is now in full swing. At the end of the day, it's the future of the industry that counts and so here I stand by the old stock market maxim: The trend is your friend.

One thing that's clear is that there's no getting around hydrogen – in all its colors – when it comes to the technology needed to tackle climate change at an international level. Indeed this is the approach that must be followed and supported by subsidy programs where necessary. Even electric transportation, which has so far been biased toward battery electric vehicles, could switch focus to fuel cells as time goes on – at least in my view. If you look at the plans of the automotive industry, and above all Tesla, the extraction of the necessary raw materials is very carbon heavy. What's more, the sheer quantities of metals such as nickel and lithium that are involved do not really lend themselves to sustainable mining. Where the power for electric vehicles actually comes from is another matter, as is the development of charging infrastructure and line capacity.

As I see it, there is a certain invisible rivalry with hydrogen – and by that I mean predominantly green hydrogen but also blue hydrogen as well as the biomass-derived yellow variety – which is entering the market in ever-greater quantities at ever-cheaper prices. The questions then arise of how best to deploy hydrogen, which could be used in the commercial vehicle sector to power buses and trucks, and what the most suitable applications are for fuel cells, for instance as a means to generate electricity and heat in power plants, ships or even rolling stock. Cars will enter the frame later, but that won't be for another three to five years.

Now the stock market is going through this aforementioned differentiation process. For me, this means that not every listed company in the sector (including fuel cell stacks, electrolysis, hydrogen production, logistics) will continue to experience rising prices if this is fundamentally at odds with the company's true value or if there are only slim chances for revenue growth in the longer term. Plus, any news of orders, joint ventures, technological breakthroughs, sales and revenue growth, will now drive prices on a more individualized basis rather than all industry stocks continuing to move up and down as one. And there are plenty of acquisitions, mergers and joint ventures still to come.

Likewise Big Oil is at the ready to start investing massively in renewable energy and hydrogen as a way of distancing itself from fossil fuels. Some degree of takeover activity could be productive here. And if this does happen in the future I'm convinced that this will follow a more differentiated path. Things will get interesting, too, if major players in the field decide to improve their positions by splashing their cash – in other words taking over several companies within the sector and buying up their stocks – or if businesses agree to merge in order to gain scaling advantages and build a stronger market position.

Cummins Inc. demonstrated this gameplay perfectly in its acquisition of Hydrogenics and is now partnering with Air Liquide and Daimler. Fuel cell companies such as Ballard and Bloom, which I'll be discussing in this article, and their stocks will go their own way – even if it is a bumpy ride. The tendency, however, will be for their stocks to rise, making for more severe price corrections for new and additional purchases as well as dramatic price hikes for the temporary realization of gains.

Anyone who is taking a middle- to long-term approach will be building up a portfolio of diverse companies so they can be in a position to weather the normal ups and downs of the stock market, with a crash always a real prospect of course, just in case increasing interest rates and rising inflation or some over-the-odds valuations make for an uncomfortable ride. Hold tight in the hydrogen and fuel cell saddle! The excessively high prices will now head back down but this should be seen only as a temporary blip and an indicator of the general mood in the market. Rest assured, this will in no way impact on the extremely positive trend in this sector. And now to the finer details:

BALLARD POWER – NEW BOUGHT DEAL GROSSES OVER USD 550 MILLION

Despite a sharp decline in price from over USD 40 to below USD 22, Ballard [Nasdaq: BLDP] still succeeded in closing another bought deal worth USD 550 million, or USD 528 million net, with a new issue of stocks priced at USD 37 each. This is a testament to the high level of confidence in the company which now boasts a well-stuffed war chest of over USD 1.3 billion and thus now has its own resources to fund corporate growth. Ballard is certainly going to do something with its kitty – that's my gut feeling – something in the electrolysis neck of the woods. The Canadian enterprise could go into electrolyzer manufacturing or straight into hydrogen production. The construction of a production facility in Europe is also highly likely – ideally in cooperation with a company from the automotive components industry, according to my analysis.

QUARTERLY FIGURES ARE BY THE BY Figures for the fourth quarter 2020, which saw revenue at USD 28.6 million and for 2020 as a whole reaching USD 103.9 million, are by the by. Annual loss is attributable to high research and development expenses and the costs of developing manufacturing capacity in locations including China. The focus is on the core markets of bus, truck, rail and shipping, with plans to lower stack costs by 70 percent by 2024. In geographical terms, markets in China, Europe and California are playing a principal role. The partnership with Audi is continuing, even though the VW chairman sounds a little restrained when talking of fuel cells.

NEW COLLABORATIONS AND JOINT VENTURES ABOUND Incidentally, one thing that's hard to miss at the moment is the increasingly frequent news reports about Ballard teaming up with large international corporations with a view to jointly exploring fuel cell markets. Its partnerships with Siemens and CRRC for rail applications and with ABB in the shipping industry have been widely publicized. The latest example is the linkup with Chart Industries, a gas compression specialist headquartered in the U.S. with operations around the world, and Australian enterprise Global Energy Ventures, with the intention of co-designing a ship for transporting hydrogen; dubbed C-H2 Ship, the vessel is due to carry 2,000 tons of compressed hydrogen when completed. In addition, an agreement has recently been concluded with railroad company Canadian Pacific with the aim of upgrading a diesel locomotive with a fuel cell system. A prototype that will surely form the basis for a large order at a later point in time.

In Scotland, Ballard has joined in on ScotRail's first hydrogen-powered passenger train which is being developed in cooperation with Arcola Energy and is due to be revealed in Glasgow in November 2021 (see also p. 34 for other fuel cell rolling stock). Other collaborations include a development project with automotive supplier Mahle as well as a joint effort with Weichai Power in China to produce fuel cell stacks.

These are only a few examples, yet they do show that Ballard is positioning itself perfectly in a wide range of markets and that prototypes can indeed lead to mass production. And the collaboration with its latest new bus customer, global bus manufacturer NFI, should be seen in this light. NFI, or rather its subsidiary Alexander Dennis Limited, ADL, is looking

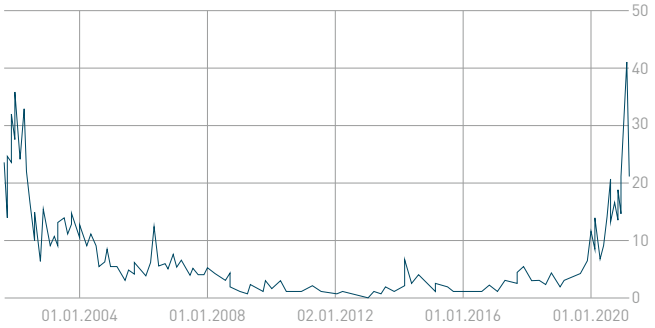

Fig. 2: Historical prices for Ballard since 1997
[Source: www.wallstreet-online.de] Retrieved March 15, 2021

to Ballard stacks to power its double decker buses. ADL, with its New Flyer brand, is one of the industry's heavyweights.

All this activity provides a solid foundation for high corporate growth and, at the end of the day, the necessary momentum when it comes to earnings. Of course Rome wasn't built in a day, that much is true, but it does give one the suspicion that things at Ballard are really going to take off in 2022. For instance, the company's order book for hydrogen buses is rapidly filling up, with recent commissions from the likes of Van Hool, Solaris and Wrightbus – the latter having placed an order for over 50 bus modules. It's my prediction that these one-off contracts for 10 to 20 bus modules will soon result in three-figure unit sales; orders from China are likely to be much larger still, with the potential for commissions to exceed 1,000, 2,000 or 3,000 modules.

To sum up, Ballard is quietly beating its path as a clear leader in the marketplace. As more good news stories unfold, the stronger the stock market's reaction will be. A USD 10 billion valuation was witnessed in 2001/2002 and again recently. Today, a market capitalization of that degree is only a step on the road to even higher worth. The seemingly low price level we are currently experiencing again during this correction phase makes things apt for investment. As I said before, if you trust that "the trend is your friend," you'll find yourself well prepared with a multibillion market opportunity. Sounds pretty good to me!

BLOOM – 25 PERCENT CORPORATE GROWTH IN SIGHT

Revenue in the fourth quarter of 2020 rose by 16.8 percent to USD 249.4 million, thus reaching USD 794.2 million for the year overall. Net loss was USD 0.16 per share and shows a marked loss for the year as a whole of USD 1.14 a share following a loss of USD 2.67 in 2019. The non-GAAP gross margin succeeded in rising by 11.3 percent to 27 percent. In the future Bloom [NYSE: BE] reckons on a profit margin on average of 25 percent per annum.

Orders on hand account for USD 4.4 billion. Of this, USD 3.4 billion can be attributed to service contracts and USD 1 billion is for systems. At the end of 2020, bank deposits totaled USD 416.7 million. What's more, it's now possible to generate electricity for USD 0.09 per kilowatt-hour, according to reports. A revenue of USD 1 billion is expected for 2021. What's interesting to note is that the loss-making service area could come back into profit this year – this had not been anticipated until 2022 at the earliest.

Electrolyzer capacity currently stands at 1 gigawatt. Bloom has plans itself to go into electrolysis, given its >>

Fig. 3: Historical prices for Bloom Energy since 2018
[Source: www.wallstreet-online.de] Retrieved March 15, 2021

excellent know-how in this field, with a view to producing hydrogen worth more than USD 0.75 billion per annum in a few years' time. A production price of USD 1 to USD 2 per kilogram is considered achievable. Expectations are riding high for the company's new energy platform Bloom 7.5 – which supersedes Energy Server™ 5 – and offers 75 kW per module instead of the previous 50 kW. With just USD 50 million to USD 75 million of investment, output here could purportedly be doubled.

The company views the infrastructure program of the new U.S. government under President Joe Biden as providing very welcome support; the president is proposing to funnel USD 2 trillion of investment into renewable energy, with hydrogen forming an explicit part of the current plans. Bloom has also now announced its own massive site expansion plans in which the business is considering new international markets for its fuel cell power plants as well as other U.S. states.

My conclusion: Following the fall from over USD 44 to USD 24, the stock is now once again at a very interesting price. It is entirely imaginable that Bloom will go down the same route as Plug Power and Ballard and issue shares in a bought deal so as to bring in the necessary capital for corporate growth. One of my industry top picks, this company has a bright future ahead of it.

PLUG POWER – POSITIONING UNDER WAY BUT ANALYSTS DISUNITED

Plug Power [Nasdaq: PLUG] has undergone one financing round after another, with a third bought deal sandwiched in between, this time to the tune of more than USD 1.7 billion. What's more, the South Korean SK Group has promised to put up USD 1.6 billion in return for a 9.9 percent ownership stake in the company, an investment that will also form a basis for a joint venture between the two corporations. And if that's not enough, Plug, which is headquartered in the U.S., intends to fit out delivery vehicles for France's Renault Group. Plus, the company has been busy buying in top talent for its management team. That's the good news.

My concerns are raised, however, when I look at insider transactions: The CEO himself cashed in at prices of USD 60 to over USD 70, which allowed him to transfer a sum of more than USD 35 million to his private account. Other board members and management executives did the same, with a total value of all transactions equaling more than USD 100 million. It's worth bearing in mind here that the business was worth around USD 700 million a year ago.

Now you could argue that the company has performed well, the coffers are brimming with a good USD 5 billion, the market value has exploded and the outlook could also not be better. That said, insider transactions should always give you some awareness of what the top brass think about the value of their own stock holdings. And we shouldn't forget that Plug still remains dependent on two large corporations in particular, and they themselves have also accumulated paper gains worth billions through the receipt of warrants.

The pursuit of its own hydrogen production strategy is, however, indicative of the company's goals. It'll be exciting to see what happens with the liquid assets i.e., acquisitions. A stock market valuation in excess of USD 30 billion, including allowances for Amazon's and Walmart's warrants, is, in my opinion, optimistic – possibly too optimistic? – even if the market price of sub-USD 50 means that the USD 70-plus peak has been left far behind.

As a side note, Plug has been doing great in terms of public and investor relations and has already made many allies among its investment clients, at least that's the impression you get from a quick delve into the forums. It would certainly seem that Plug is set to make strides in the fuel cell sector. In terms of valuation, I'm waiting to see what investment decisions are made further down the line as to how funds are used, and what the impact of that will be on revenue and the resulting margin.

WARRANT VALUE ADJUSTMENT I've written about this many times in the past: The two large customers Amazon and Walmart are in possession of warrants that they have received or will receive if a certain order volume has been or will be placed with Plug. In total we are talking over 110 million warrants which can be exercised at different prices – starting at USD 1.19 a share. Technically, Plug has only posted these in their accounts as non-cash charges: USD 456 million as an associated loss. Both corporations still have accounting profits in the region of more than USD 3 billion, which works out at more than USD 5 billion when Plug was listing at over USD 70 a share.

This chapter now seems to be at a close, of course bearing in mind that the number of underlying shares would equate to a considerable stock dilution should the warrants be exercised. On the other side of the coin, both customers are also good for new project business, since the two companies intend to invest massively in renewables, and hydrogen will surely have a role to play here – not just in forklifts.

PLUG POWER GETS INTO HYDROGEN PRODUCTION The most recent plans are highly ambitious and represent a step

Fig. 4: Historical prices for Plug Power since 2006
[Source: www.wallstreet-online.de] Retrieved March 15, 2021

in precisely the right direction. Given the copious funds available, the company is in a good position to finance its own independent hydrogen production. In New York state, a production facility for green hydrogen is slated for the sum of USD 290 million which will be capable of turning out 45 metric tons of hydrogen a day. Start-up is anticipated in 2022. Further hydrogen production plants are also planned at a total of five locations spread across the U.S. and should be completed by 2024. This year, investments are planned totaling USD 750 million – a very positive indication in my view.

The conclusion: Plug will cut its own path in the hydrogen and fuel cell sector and will end up taking a leading position. The company is well positioned valuation-wise and is planning to turn over USD 1.4 billion in 2024, bringing it well into the black. I'm using the latest analyst opinions as a basis for my own: Barclays thinks the stock is overpriced, giving it a sell rating, and is aiming for an upside target of USD 29. In its view, the company's value shows "a fundamental disconnect," with much haze apparently surrounding the contracts for forklift conversion. On the other side, J.P. Morgan, whose analyst raised the upside target to USD 65, rated the stock as overweight. Here he reasons that Plug is a story stock, with the expectation that a new pedestal customer could come from Europe in 2021.

I have a vision that goes even further: Plug should take a stake in Nikola Motors and leverage the synergies since its business model, to my mind, has many similarities to Plug's. It ranges from hydrogen production through to the new, strong growth market of hydrogen-powered commercial vehicles. The pair could form a very complementary partnership. But that's just my take on it. For me personally, Plug is adequately valued but that is something that all investors must decide for themselves. And given the generally good trading environment for fuel cells and hydrogen, it stands to reason that Plug will naturally be swept along with the current.

FUELCELL ENERGY – BUSINESS VALUED TOO HIGH

There has been a stark rise in the valuation of the business from around USD 100 million to now over USD 9 billion, with the stock price increasing from USD 1 – USD 2 to USD 29. I would go so far as to call it totally excessive. I got early wind of FuelCell Energy [Nasdaq: FCEL] as a turnaround after a management consultancy had "cleaned it up" and after the company had undergone a period of refinancing and restructuring and happily onboarded Orion Energy Partners as a key investor.

The current figures do not bear out this valuation: In the fourth quarter of the fiscal year 2020, as at Jan. 31, 2021, revenue increased to USD 17 million, a rise of 54 percent, yet there was a loss on shares of USD 0.08 apiece. Orders on hand dropped slightly by 2.9 percent to USD 1.39 billion.

TRADERS FUEL STOCK PRICE FLUCTUATIONS With daily volumes of traded stocks frequently exceeding 100 million, it's got me thinking. And it leads me to conclude that this activity is due to a mixture of day and momentum traders as well as the swarm-like behavior of "neo-brokers." Purely from a valuation standpoint, its competitor Bloom Energy looks more interesting, in my subjective view. A rethink would, however, be valid if FuelCell Energy generates significant new orders for its fuel cell power plants in addition to its proprietary carbon capture technology. Until that happens a new investment does not make sense, unless you consider yourself a day trader since there is still considerable volatility in prices. For those who know how to skillfully leverage this there is some money to be made – and on a daily basis.

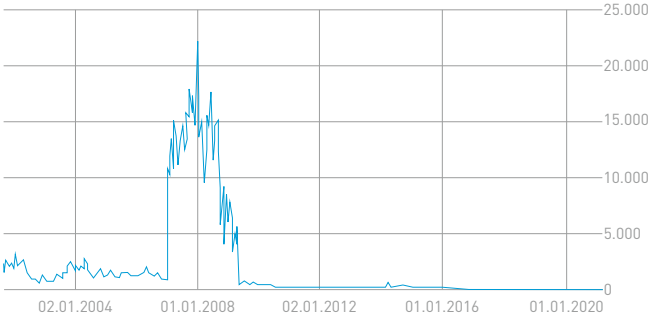

Fig. 5: Historical prices for FuelCell Energy since 2008 [Source: www.wallstreet-online.de] Retrieved March 15, 2021

Rounding up, if the company can noticeably increase its orders on hand and has the skills to broaden the reach of its own carbon capture technology, for instance through license agreements, then a rethink will be called for. A merger or takeover of the business is quite possible too, since there is no anchor shareholder yet; also should Orion Energy Partners withdraw from the partnership then the investor will be reeling in its credit line. A "strategic investor" could change the landscape but in valuation terms Bloom Energy is, for me, better positioned. An analysts' event held by U.S. broker Canaccord with representatives from Bloom Energy and FuelCell Energy will supply more information on the differentiation between the two companies. I'll report back.

NIKOLA MOTORS – UNCERTAINTY IS WANING

There are two sides to every story. And that's very much the case with the planned cooperation with General Motors, GM, and the cancellation of 2,500 battery electric refuse trucks for Republic Services which turned out to be rather fortuitous in retrospect. In the GM scenario, Nikola would itself have had to spend over USD 700 million on tools, among other things. The participation of GM with USD 2 billion as a "valuable consideration" would have resulted in a dilution of the number of issued stocks.

Now Nikola has a new agreement under which GM will supply fuel cell systems, and as such gives the company another key supplier alongside Bosch, with the upshot being much more security and independence. The Badger pickup is, however, history. As for the refuse trucks for Republic Industries – 2,500 units – Nikola would have borne costs of over USD 200 million. Reportedly delivery dates were pushed back by 12 to 24 months and in the end the decision to terminate the contract was mutual. Otherwise everything is ticking along nicely. This was evident at the fourth-quarter press conference where it was clear that Nikola [Nasdaq: NKLA] is once again fully focused on its business plan and driving forward its implementation.

Losses for the fourth quarter amounted to USD 147.1 million which also comprises over USD 67.5 million in expenditure on research and development. The company now employs 450 members of staff and this figure is due to reach >>

the 1,000 mark as the year closes out. The automaker expects to ship 50 to 100 Nikola Tre semitrucks this year, a figure that is targeted for the fourth quarter.

The prospect of Nikola producing its own hydrogen is cause for excitement. The company has managed to get a really competitive electricity deal with supplier APS which puts the price of green hydrogen on a par with diesel. As part of the tariff agreement, surplus renewable power will be converted at times when the electricity demand is low, with hydrogen providing an ideal means of storage. The company is looking to produce 8 tons of hydrogen a day. Nikola will build hydrogen production facilities which it hopes to use to supply its hydrogen fueling stations going forward. What's important to realize is that Nikola is not just exploring the fuel cell truck market; it also has its eye on the consumables sector and sees that as a way to monetize the hydrogen it produces.

In terms of shipments – production is being developed gradually and then ramped up – which means that over 1,200 trucks are due to roll off the assembly line in 2022, increasing to over 3,500 in 2023. The long-haul version Nikola Two, with a range of over 900 miles (1,450 km), will launch on the market by 2024.

On a separate point, the legal dispute with the short-seller Hindenburg Research ended up costing the company the princely sum of USD 19.5 million in lawyers and legal fees. There was certainly a degree of truth in some of the criticisms. An early customer, brewery group Anheuser-Busch, however, remained committed to seeing through its truck purchase obligation.

My conclusion: As the company has itself admitted, further corporate action is inevitable in order to be in a position to deliver on its business plan. There is still about USD 841 million in the bank. My bet's on either another at-the-money, or ATM, program, in which shares are drip-fed directly onto the stock market, or possibly that the company will be approached with a bought deal, which could bring home up to USD 1 billion. Likewise another logical option, in my view, would be for a strategic partner specialized in truck construction to step in. An increase in the shareholding of CNH should also not be ruled out.

If and when additional corporate partners are revealed, and by that I mean oil and gas groups in a tie-up with hydrogen filling stations for example, this will have a very positive effect on the stock price. If I were Plug Power, I would join Nikola as a "strategic investor," but then that's just a thought from me. Whoever invests in Nikola will be calmly relying on the follow-through of the business plan and that requires patience. One thing for certain is that the first really big fuel cell and hydrogen market for commercial vehicles is starting to get underway.

Fig. 6: Historical prices for Nikola Motors since 2020
[Source: www.wallstreet-online.de] Retrieved March 15, 2021

WEICHAI POWER – CHINA'S LARGEST DIESEL ENGINE MANUFACTURER ON THE FUEL CELL HIGHWAY

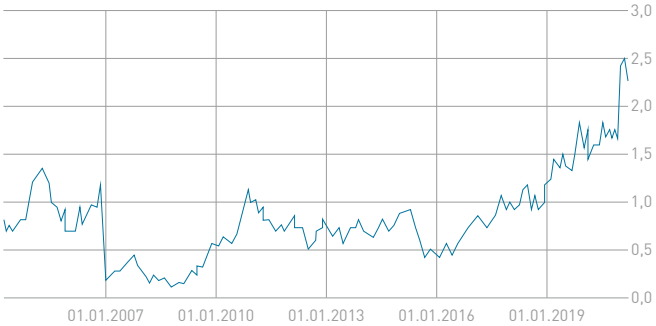

Fig. 7: Historical prices for Ballard since 1997
[Source: www.wallstreet-online.de] Retrieved March 15, 2021

The company Weichai Power, which I've so far only mentioned in this column as partnering Ballard, has a revenue around the EUR 20 billion mark and a stock market valuation of the same order. In 2020, a good EUR 1 billion was marked up as profit, with dividends also paid out. Weichai Power has several bus brands to its name and is the nation's largest diesel engine manufacturer; it has clearly recognized the potential offered by fuel cells in the commercial vehicle sector and, in its own words, is intent on becoming the market leader.

Weichai is the biggest single shareholder in Ballard Power, despite the fact that it now no longer holds a 19.9 percent stake due to the various corporate actions taken by Ballard and the accompanying release of shares. The Chinese company also has a stack factory in China as part of a joint venture with Ballard, with an ownership split of 51/49 percent. The joint venture company could also find its way onto the stock market at some point in the future in the shape of an initial public offering – but that's pure speculation on my part.

Weichai owns shares in several companies in the industry, Cerus among them. Added to that, the group is planning to single-handedly produce and install the necessary hydrogen infrastructure, i.e., hydrogen refueling stations. This is where Ballard could conceivably get a look in again, since it wants to bring its electrolyzer technology into the market.

One exciting prospect is China's plan to have a total of 100,000 fuel cell-powered commercial vehicles on the road by 2024. By 2030, 1 million vehicles of all types should be running on hydrogen. As it stands, there are at least 6,700 fuel cell commercial vehicles driving around China, and many of those are kitted out with a Ballard stack.

Weichai owns a 45 percent stake in forklift manufacturer Kion, number two in the world with brands such as Still and Linde. So in a sense Kion is indirectly Ballard's "sister" and perhaps this will translate into a collaboration on fuel cell forklifts. That would keep everything nicely in the family.

All in all, formidable growth is in the offing. Weichai as well as Ballard will be there out in front even if the competition increases massively, which is to be expected if you've been keeping an eye what Toyota, Hyundai and also Hyzon have been doing.

WIKIFOLIO

The value of the BZVision Wikifolio has naturally been at the mercy of the general, recently weak trend in hydrogen and fuel cell stocks. So while there was a price explosion from early December 2020 through to the end of January 2021 and the portfolio value shot up by over 600 percent within two years, it's now gone downhill. So even here, things remain bumpy.

Parallel to this, the investment in put options in Tesla – to shore up the portfolio as well as speculation on declining Tesla prices – turned out to be a good bet as the stock fell from over USD 800 to USD 540. Of course, there is quite a lot of price leveraging at play here, but liquidating and reinvesting in existing fuel cell positions is out of the question for me, even if the stocks for Bloom, Ballard and Nikola are once again listing at an enticing buying price. I've sold 55,000 put options and reinvested in the three fuel cell stocks.

In any case, if Tesla drops below USD 500 – and some chartists are predicting exactly that – then the put options will list 100 to 300 percent higher. This is certainly highly speculative, yet not unrealistic if you take into account the 400 percent rise in just 12 months to a current adjusted pre-split level of USD 3,500 per share, or USD 700 following the 5:1 stock split. The extraordinary profit made through the trading of bitcoins is no use to Tesla here if the company cannot realize any long-term profit through the sale of its vehicles and software in order to justify its stock market valuation of over USD 800 billion.

Given that the stock market valuation can fluctuate daily by up to USD 100 billion, I interpret this as a highly risky development that can suggest great uncertainty on the part of investors. Should Tesla options become highly profitable one day, I'll use the proceeds to buy more of the shares already in the portfolio as well as make new investments, such as in Weichai Power and Burckhardt Compression, the former Sulzer subsidiary from Switzerland specializing in compressors – but that day is yet to come.

TESLA IN GRIP OF BITCOIN FEVER

That Tesla chief Elon Musk would, one way or another, place his trust in Bitcoin was to be expected. He had already stated his interest and his enthusiasm for the cryptocurrency many times in the past and had previously considered switching the whole of his corporate financing to this digital money format. Words turned to action, with Tesla investing USD 1.5 billion in bitcoins.

Although the value per unit at the time of investment was still under USD 37,000, the value jumped to over USD 50,000, allowing the total valuation to grow meanwhile to over USD 1 trillion. U.S. treasury secretary Yellen is not so convinced. Her lack of approval points toward some form of regulation in the future. I mention all this because it shows the kind of influence that Elon Musk exerts on his millions of fans and followers on Twitter and the like, and the consequences that his behavior can have. It's not a healthy situation in my opinion, since he is the only person who is capable of influencing the progression of this cryptocurrency at the moment.

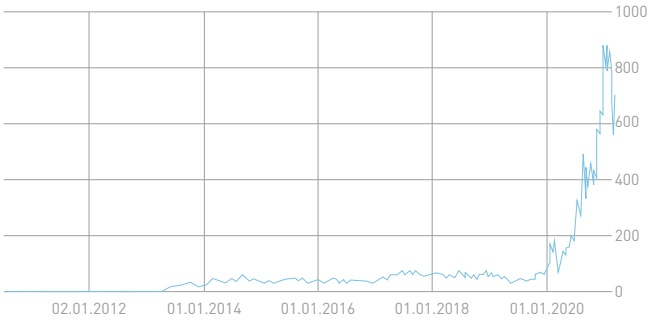

Fig. 8: Historical prices for Tesla since 2010
[Source: www.wallstreet-online.de] Retrieved March 15, 2021

Another point to mention is that the trading and creation of bitcoins require enormous amounts of energy, as is true for all other cryptocurrencies, and with Tesla's production of battery-powered automobiles it begs the question whether all of that is actually sensible and sustainable in the long run or if indeed it is a contradiction in terms.

I'd like to highlight something else, though: Tesla has so far been making profits primarily from selling regulatory credits for zero-emission vehicles – around USD 1.4 billion alone in 2020. A total of USD 1.1 billion is still expected to be generated in this way for 2021. This leaves me wondering whether bitcoin trading and the trading profits that result will now give Tesla a second revenue stream instead of relying on the sale of vehicles and artificial intelligence software to generate profit.

Taking a wander through the chat rooms, Elon Musk devotees are now mostly bent on bitcoin profits which could theoretically be in excess of USD 1 billion in just the first quarter of 2021. In some discussions on U.S. television, e.g. MSNBC and Bloomberg, irritation has already been spreading among analysts and fund managers whose share purchases or placements are supplying Tesla with the capital for growth, not for stock market speculation. That's what Elon Musk can do with his own private capital but not with his company's cash, was one of many assertions heard on TV.

It's worth bearing in mind that the new factory in Austin, Texas, costs money. The gigafactory in Grünheide near Berlin also still needs a great deal of investment. And not forgetting the planned construction of a manufacturing operation in India which will consume further billions. According to Tesla's own estimates, investment over the next two years is likely to be over USD 10 billion. That being the case, the hitherto USD 19 billion in liquid assets doesn't now seem all that much. Will the stock market simply continue putting up with additional share placements via ATM programs?

In addition to all of this comes the enormously high number of obligations, in my opinion, that result from the investment in raw materials for battery production, be it purchase obligations, the direct participation in mines or the forward purchase of large quantities of batteries from companies such as Panasonic, CATL and LG. What happens if these commitments can't be met because the demand isn't there? Penalties?

I have vivid memories of Solarworld which thought it was being really clever by securing large volumes of silicon for the production of photovoltaic cells on a forward basis but then was unable to pay. And we know how that tale >>

ends: bankruptcy. In my view, the procurement of raw materials for battery manufacturing, regardless of automaker, gets problematic if you include the carbon dioxide emissions generated by the material's extraction, by the logistics involved as well as by the value and delivery chain as a whole. And that's where hydrogen increasingly pitches up as a competing technology, assuming that the hydrogen is green, available in sufficient quantities and priced attractively, that is.

PROFIT VERSUS SALES FIGURES In the press conference on financial year 2020 i.e., the fourth quarter, CEO Musk admitted that the number of vehicle units sold is more important to him than making money from their sale – or words to that effect. By way of explanation it should be pointed out that the company is reaching this goal, with just shy of 500,000 units sold in 2020 – the exact figure was around 499,600 – albeit helped by discounting. And now sales are rapidly heading toward the 1 million threshold and it's predicted that as many as 20 million units will retail in 2030.

However, the numbers for the fourth quarter were not convincing despite revenue rising to USD 10.7 billion. That gives a below-the-line profit of USD 0.80 per share whereas USD 1.03 per share had been anticipated. It was only this quarter's USD 401 million in regulatory credits that saw the company into profit.

I remain extremely skeptical as the competition is certainly not resting on its laurels. 2021 should see over 250 battery models coming onto the market in Europe alone. And startups such as Fisker, Lucid and NIO are doing all they can to rival Tesla. Apple Inc. also springs to mind; I wouldn't put it past them to develop their own fuel cell hybrid vehicle. Last but not least, the Chinese group Huawei has signaled its intention to enter the electric car business, and this is one of the market leaders in 5G. Two words for you: autonomous vehicles.

While all the major carmakers are busy working on autopiloting solutions, Google's Waymo, Mobileye, Apple and the like are grappling with artificial intelligence. As such, Tesla's unique selling points are dwindling. Then there are the recalls relating to the large touchscreen, for example, in some of its luxury cars. Plus, the expiry date on the 8-year battery warranty for certain Tesla vehicles is drawing ever closer.

The market is getting increasingly jittery, as evidenced by the daily fluctuations (see Feb. 23, 2021, and March 9, 2021) in stock price of over USD 100, which works out at over USD 100 billion on just one day's trading. Die-hard Tesla fans, like ARK Invest, are continuing to buy and are not shy to admit it. For me this is the first sign of a changing price trend and a turnaround in the valuation of the business.

Chartists are seeing the danger of a major price slump after the stock price broke downward through important support lines. Think back to February 2020 when the price fell from USD 800 to below USD 400. At the moment the stock is resting at nearly USD 700, which following the 5:1 split works out at USD 3,500. It would then follow that the price ought to shift to USD 350, or USD 1,750 respectively, if 2020 is anything to go by. All purely theoretical – for now. ||

RISK WARNING

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

Category: International | **Authors:** David Hart, Stuart Jones

FUEL CELL INDUSTRY GROWS DESPITE COVID-19

E4tech Fuel Cell Industry Review

In March 2021, the new Fuel Cell Industry Review 2020 was published, complete with market data and detailed analysis. Since 2014, the team led by E4tech has been contacting fuel cell companies from across the globe, aggregating their shipment figures and producing an independent report each year on the current state of the fuel cell sector. Several extracts are provided here.

2020 was not the year many of us expected. But despite the very difficult situation brought about by COVID-19, fuel cell shipments continued to rise. The increase was much less than we anticipated at the end of 2019, both because of supply chain disruption and local economic slowdown, but is a very encouraging sign.

The leading applications remain passenger cars, combined heat and power (CHP), and prime power, and the same companies are dominant as in previous years. At nearly 82,500 units, 2020's fuel cell shipments are up significantly on 2019's 72,600. Megawatts shipped went up from nearly 1,200 MW to just over 1,300 MW. Asia continues to lead the unit shipments, and Hyundai again shipped most MW. For unit numbers, micro-CHP is the main contributor, with over 47,000 units expected to have been delivered for Ene-Farm in Japan and another 5,000 to the KfW 433 initiative in Germany, with about 1,000 going to the pan-European PACE program. The roughly 50 percent of Ene-Farm units that are proton exchange membrane, PEM, are not subsidized, and the remaining SOFC units only receive a small contribution, showing that these markets are starting to stabilize and commercialize. And many of the units installed in Europe are Panasonic technology, licensed and developed for the European market by Viessmann, enabled through the improvements engendered by Ene-Farm. SOLIDpower is another steady presence in that market.

Vehicles are another major contributor. Toyota and – mainly – Hyundai shipped over 8,500 cars in 2020. But cars are even more important for the contribution they make to power, over 850 MW globally, or nearly two thirds of the shipped capacity for all applications. Bus and truck shipments are particularly significant in China, at over 1,400 units shipped in 2020, a combined capacity of nearly 90 MW. This represented a significant decline from 2019, caused partly by policy uncertainty. Previous blanket subsidies are being replaced by targeted measures to support regions and supply chain players, and manufacturers paused their roll-out efforts until they knew funding could be available. That now looks assured, with further focus on the local policy and institutional environment, and on reducing costs and creating economies of scale, and not just on making running vehicles. This all links to China's longer-term policy goal of developing the indigenous capability for putting 50,000 vehicles on the road by 2025.

Materials handling stays strong, with Plug Power reports indicating shipments up from over 6,000 units in 2019 to perhaps 10,000 units over 2020 – despite COVID. Other materials handling providers are becoming more active too, with Hyster-Yale's Nuvera business aiming also at larger lift trucks, for example at shipping ports, and Toyota Industries and Linde also increasing their interest.

Stationary markets other than small CHP grew too, with large CHP and prime power units together contributing over 270 MW new capacity in 2020, 40 MW more than 2019 – and around 400 units globally. Fittingly, smaller fuel cells for grid support and off-grid power contributed smaller unit and power numbers – about 2,200 units and around 8 MW of capacity. Portable fuel cell units, at around 4,000 shipped, were similar to 2020. SFC Energy remains the consistent sector player, with a mix of recreational battery extenders, remote monitoring and remote power units. Unmanned aerial vehicles still await lift-off, with only a small uptick in numbers in 2020. Offerings included those from Plug Power (former Energy OR), Intelligent Energy, Doosan Mobility Innovation and HES Energy Systems.

ASIA LEADS THE MARKET Regionally, Ene-Farm shipments, larger CHP and prime power shipments (chiefly from Doosan Fuel Cell and Bloom Energy), and NEXOs drove annual Asian shipments up from 740+ MW in 2019 to 900+ MW in 2020 – nearly 70 percent of the global MW shipped. Asia's lead in both units shipped and power results from strong policy instruments. China's New Energy Vehicles support is increasingly influential, but Korea's policy support for its Hydrogen Economy Roadmap and Renewables Portfolio Standard means it accounts for about >>

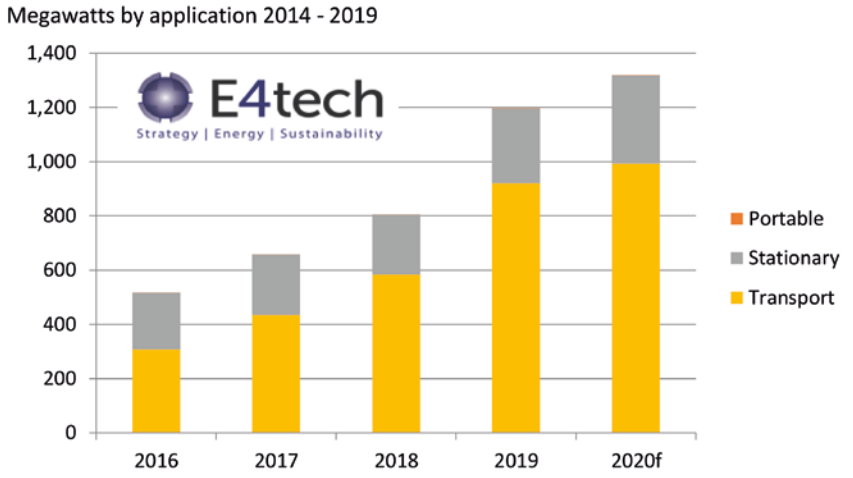

Fig. 1: Megawatts by application 2014 – 2019
f: 2020 contains a projection for the fourth quarter (forecast)

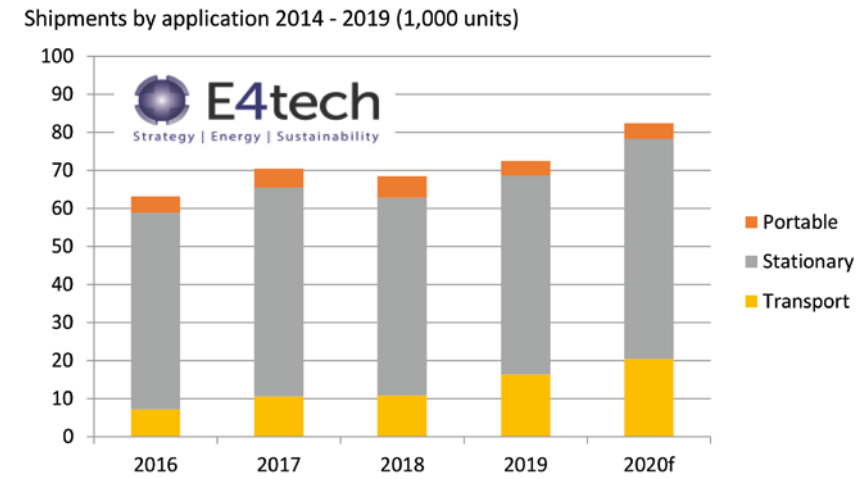

Fig. 2: Shipments by application 2014 – 2019 (1,000 units)
f: 2020 contains a projection for the fourth quarter (forecast)

35 percent of installed utility-scale fuel cells globally, and now around 60 percent of cars. Because vehicle fuel cells are relatively large – from tens to even hundreds of kW, the large but fluctuating numbers fielded in China mean significant volatility in industry numbers. 2019 was a bumper year, with our initial forecast of over 1,600 units some way under the actual final total of more than 2,700. But then the continued growth we expected in 2020 was hit by the changes to subsidy policy, as well as COVID-19. With policy now becoming clearer, we expect a return to growth in 2021.

Japan's Ene-Farm program has underpinned technology development and roll-out in micro-CHP for over a decade. While new European country strategies may result in stronger policy instruments in Europe, Asia is likely to stay well in the lead for fuel cell shipments globally. That is illustrated by Hyundai's new focus on Korean NEXO deployment. Around 6,000 local units in 2020 represent nearly 600 MW of power, close to 50 percent of total global deployment. Europe's annual shipments did grow though, by 17 percent in MW terms (ironically mainly NEXOs), from about 130 MW to over 153 MW. They also grew in number, led by micro-CHP units for the German KfW 433 initiative, from about 10,500 units in 2019 to just over 12,500 units in 2020. As with other regions, fewer Mirais were shipped to Europe as Toyota prepared for the global release of the new model Mirai in December 2020.

Unit shipments to North America rose too: 10,500 units were deployed in 2020 versus 8,000 in 2019, mainly materials handling. Megawatts shipped went down slightly though, from an adjusted total of 339 MW in 2019 (less than our forecast of 384 MW) to 253 MW in 2020. Much of that was stationary fuel cells, in 2020 led by Bloom Energy, as FuelCell Energy is still ramping back up after its difficult 2019. Annual stationary fuel cell shipments in North America grew from about 105 MW in 2019 to 115 MW in 2020. The gain is offset by the reduction in Mirais, down by about 1,000 units, nearly 120 MW.

PEM fuel cells continue to dominate, both in number and in capacity led by passenger cars and micro-CHP shipments. Over 53,600 units were shipped in 2020, or over 1 GW – up from just over 45,700 units or nearly 950 MW shipped in 2019. The range includes direct hydrogen units in vehicles to reformer-based fuel cells in micro-CHP, fueled by natural gas and LPG.

Solid oxide fuel cells, SOFCs, remain second in terms of unit numbers. The nearly 25,000 units shipped in 2020, or close to 150 MW capacity, was up from nearly 22,000 units and almost 110 MW capacity in 2019. This growth comes largely from an overall rise in Ene-Farm shipments, coupled with a slight shift from PEM-based units towards SOFC. The next largest shipments, by capacity, are phosphoric acid fuel cells, PAFCs, mainly from Doosan Fuel Cell but with smaller stacks also from Fuji Electric. Doosan's reported shipments remain well over 100 MW, and their Q4 report suggests sales of PAFCs in Korea may quadruple by 2024, buoyed by a near tripling of manufacturing capacity to 260 MW/year in 2021. Molten carbonate fuel cell, MCFC, remains the exclusive domain of FuelCell Energy, but production remained low in 2020, at less than 10 MW per year, with only one new shipment reported.

Other fuel cell types remain relevant, though with small numbers. Alkaline fuel cells, AFCs, hardly figure in the count, though GenCell Energy successfully went public in 2020. And AFC Energy is partnering with ABB to bring a DC Fast Charging system for electric vehicles to Europe and the U.S. in 2021. Bosch plans a similar (SOFC) offering in conjunction with Ceres. Direct methanol fuel cells, DMFCs, remain the mainstay of portable systems below 100 W, and continue to ship in the low thousands (nearly 4,000 in 2020). As the required power approaches 1 kW or more, PEM fuel cells start to be favored, exemplified by SFC Energy's links to and use of adKor PEM technology in delivering power supplies for BOS digital radio towers in Germany. We consider polybenzimidazole, PBI, fuel cells as a PEM variant, and SerEnergy continues to

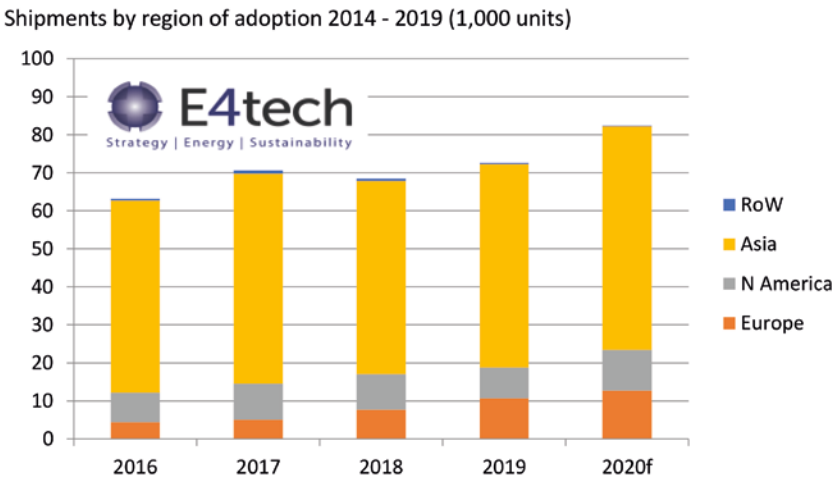

Fig. 3: Shipments by region of adoption 2014 – 2019 (1,000 units)
f: 2020 contains a projection for the fourth quarter (forecast)

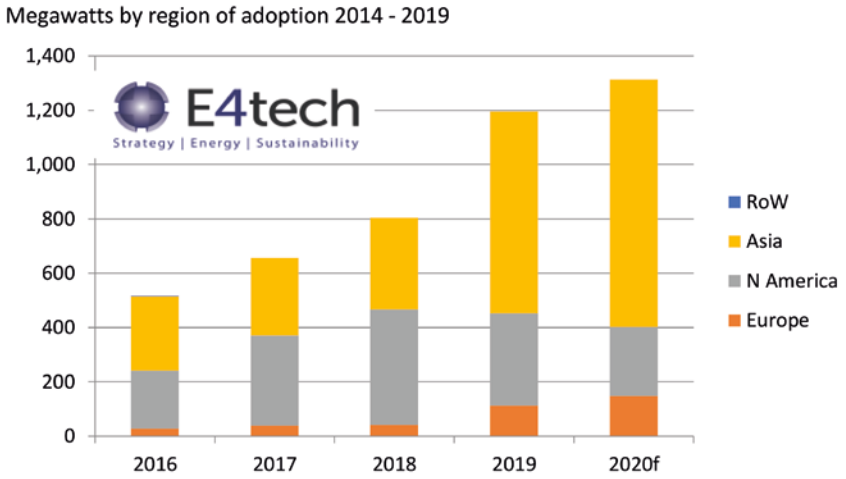

Fig. 4: Megawatts by region of adoption 2014 – 2019
f: 2020 contains a projection for the fourth quarter (forecast)

ship them for backup power, while Blue World Technologies has begun limited production of units for Gumpert Aiways' high end Nathalie passenger car. Numbers could increase soon, with 5,000 units or 50 MW of capacity planned by Blue World. ||

The complete review, including shipment figures, data tables, analysis and commentaries on specific company trends is available as a free download: www.FuelCellIndustryReview.com

Reference:

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

HYDROGEN FROM OFFSHORE WIND

Hydrogen production in the Polish Baltic Sea

On Jan. 15, 2021, the second chamber of the Polish Senate passed a bill designed to facilitate the development of offshore wind power in the Polish area of the Baltic Sea. Once the bill is signed by the president of Poland it will be able to enter the statute book. In the proposed legislation the Polish government intends to offer exceptionally generous support to the offshore energy sector, with grants of up to EUR 25 billion.

Several projects with a total capacity of between 6 and 8 gigawatts have already been completed or are under construction. Of these, the largest single venture, with a capacity of nearly 1.6 GW, comes under the ownership of Polenergia and Equinor. Taken together, these two companies alone will push forward the development of wind farm projects in the Polish Baltic Sea with a total capacity just shy of 3 GW. Also involved are large Polish energy groups such as Polska Grupa Energetyczna, or PGE, and Orlen. As it currently stands, PGE's offshore projects have the highest capacity in the region, exceeding 3.5 GW in total. Alongside these schemes, PGE is also piloting initial power-to-gas projects.

For Orlen, too, investment in offshore wind with a view to establishing itself as a hydrogen producer is of particular significance and represents an essential part of its corporate strategy. Both companies will therefore be at pains to participate extensively in the award rounds that will get underway as part of measures to support offshore energy generation in the Baltic Sea. Potentially up to 12 GW of capacity could be installed in this geographical area.

LITHUANIA PLANS 700 MEGAWATTS In 2020, offshore wind energy was also a major topic for discussion in the three Baltic states of Lithuania, Estonia and Latvia. While the amount of electricity expected to be produced by these countries is no match for Poland's power generation, the growth in capacity relative to the energy consumption of these small nations is considerable. Lithuania's plans to de-

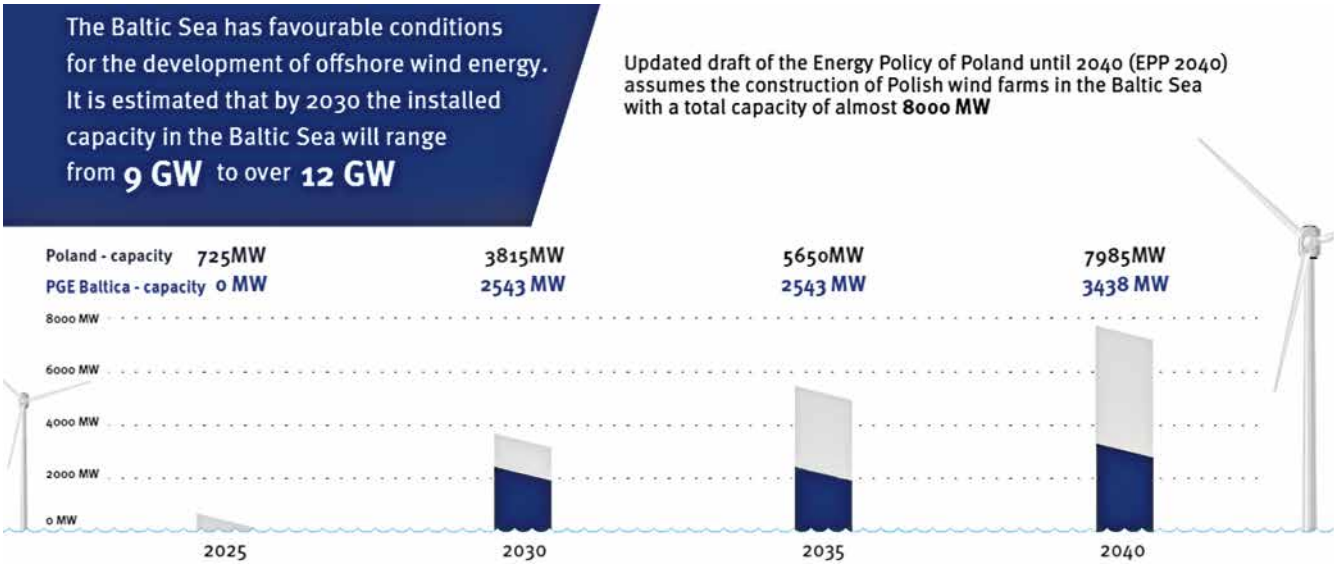


Fig.: Targets for wind capacity in Poland [Source: PGEB]

velop 700 MW of offshore capacity equates to around 2.4 to 3 terawatt-hours, in other words a quarter of the nation's electricity consumption. Leading the way in offshore development is the Lithuanian energy company Ignitis Group. Ignitis also plays an active role in the Polish energy market, as is the case for most large energy companies from the Baltic states since their own markets often leave little room for growth.

Ignitis Group is already investing in the hydrogen development of Israeli startup H2Pro. H2Pro is a company focused on increasing the efficiency of green hydrogen production and promises 30 percent more hydrogen per kilowatt-hour than is possible through conventional electrolysis. Use of its technology could see production costs falling on a continual basis resulting in parity with fossil fuel production in around five years.

"Hydrogen is often dubbed the fuel of the future. The technology developed by H2Pro to produce green hydrogen could lower air pollution and reduce the dependency on fossil fuels across the world," claimed Darius Maikstenas, chairman of the Lithuanian company.

Ignitis has found an excellent partner for offshore wind projects in the form of the joint venture Ocean Winds. However, the Lithuanian company will retain the 51 percent majority stake in the joint undertaking. Ocean Winds is owned by Portuguese company EDPR and French energy concern Engie. EDPR has also realized its own small offshore project in an area of the Baltic Sea off the Polish coast.

Helping to steer the Ocean Winds project is Polish manager and offshore expert Grzegorz Górski. In the Polish media Górski has been quoted as saying he is continuously monitoring developments in the region and intends to explore any opportunities that arise in the offshore arena in order to grow the Ocean Winds venture.

COOPERATION BETWEEN ESTONIA AND LATVIA Estonia and Latvia will in future be working in partnership on the expansion of offshore wind power. That's the agreement reached, at least, by the nations' governments in summer 2020. Among the plans is the installation of wind turbines in the Gulf of Riga with a total capacity of 1 GW which is due for completion by 2030. The turbines will generate an estimated 3.5 TWh, corresponding to approximately 40 percent of Estonia's electricity requirement. In this development, the project is also being managed by a state-owned company in the guise of Eesti Energia. Eesti Energia is the leading energy company in the Baltic region with substantial business interests in Finland as well as Poland.

In terms of funding, a degree of financial support for the project is expected to come from the European Union which should also enable the creation of additional infrastructure for the generation of electrical power from wind resources.

The future potential offered by Lithuania, as well as the other two Baltic states, for the development of offshore wind arrays is much greater still. Klaipėda University produced a report on this subject in 2019 which concluded that up to 3.5 GW could be installed in just the Lithuanian area of the Baltic Sea alone. In the years ahead, the seaport of Klaipėda is set to become a logistics hub for the wind industry. But even at the moment the site is of enormous importance in terms of energy policy since it handles most of the liquefied natural gas for the region. Facilities are therefore already in place that will also allow the transportation and storage of hydrogen at a later date.

In seeking an organizational model for the facilitation of offshore wind power projects in the region, industry players have taken inspiration from the North Seas Energy Cooperation and are now aiming to synchronize their respective plans so that they can exploit their synergies. The result has been the Baltic Energy Interconnection Plan which came into being via an initiative led by a joint working group comprising regional representatives and the Polish climate minister Michał Kurtyka. The plan aspires to pool resources in order to drive forward further development in the region with its main areas of focus being the coordination of investment and the tapping of technological, logistical and financial synergies.

One of the major challenges common to all offshore wind energy developments is the electrical connection. Poland, at least, already has offshore cabling for up to 7 GW but this is yet to be put in place in the Baltic countries. In recent years the three Baltic states have had to rise to the enormous challenge of severing ties with the former Soviet BRELL electrical grid and taking the necessary steps to integrate into the European system. This changeover, however, is due to be completed in the next few years and will pave the way for further investment in the power infrastructure. ||

Category: International | **Author:** Ken Silverstein

THIS IS THE CURE, NOT THE TREATMENT

"Who cares if H_2 production is inefficient? Free is still free!"

Fig. 1: Strizki with his Toyota Mirai in front of his hydrogen house

Mike Strizki is more than infatuated with hydrogen. He's dedicated to it, saying he has a lifelong commitment to the most plentiful element on Earth – that it is essential to bringing about zero emissions. And allowing his eight grandchildren to live healthier and more productive lives.

Before it was cool, Strizki started fiddling with cars that burn hydrogen as a fuel. But in 2006, he added a new layer of complexity to his eccentric life: He built a hydrogen-powered home in New Jersey, U.S. And then he built a second. And now he constructs them for celebrities, one of whom is Johnny Depp. Before he was the founder of the Hydrogen House Project, he served for years as a government engineer developing renewable energy technologies.

"I'm into the entire hydrogen industry," Strizki told H2-international, which is everything "from political lobbying to building prototype systems and refueling stations." As far as the Hydrogen House, "in three months – April, May and June – we make all the energy we need from solar." The hydrogen and oxygen are stored in tanks before it is run through a fuel cell.

"The whole purpose of the Hydrogen House is to educate the public that we have something else on the menu," he adds. "If people do not know something about it, they can't order it. This technology is real. The world's largest companies have adopted it: Amazon distribution centers have 300 forklifts powered by hydrogen. And Walmart has them too."

To say that Strizki is passionate is an understatement – driven to make the world a better place for his grandchildren. And he sees hydrogen reaching its potential by 2030. The building blocks are in place. Toyota is all in. Even Exxon Mobil has said it is in. And the oil and gas companies are saying that their pipeline infrastructure is capable of carrying hydrogen along with their products.

Pure hydrogen is stored in a tank before it is piped to a fuel cell to create clean electricity. Fuel cells will be cheaper than a Toyota Corolla engine, he says, because they will no longer need platinum. And that makes the electrolyzer cheaper – the key device that creates an electric current to split apart the hydrogen and oxygen from the water where it is found. While Strizki is upbeat about falling costs, others say it will make take time and that the cost of an electrolyzer has to fall from USD 840 per kilowatt to USD 420 per kilowatt. That could happen in 2040, not 2030.

BUT WHAT ABOUT EFFICIENCY? Even hydrogen's most ardent advocates acknowledge that significant energy losses occur when hydrogen is produced and transported: As much as 70 percent of the energy content may get lost. But Strizki says that all this is irrelevant if the price of hydrogen becomes cheaper than a gallon of gasoline and if the hydrogen is produced from renewable sources that are free.

"With so much renewable energy, who cares if hydrogen production is inefficient," he says. "Free is still free. We can do seasonable storage of energy and pump the hydrogen into the existing pipelines – as much as 20 percent. This is the cure, not the treatment. Once the infrastructure gets in place, we will be hard pressed to resume burning carbon."

If all the pieces are in place, what's the holdup? The U.S. American blames vested economic interest. But he goes on to say that if you are an energy company then you don't want to be an oil company: It is tantamount to landline phones, Blockbuster video rentals and Kodak film. Would you rather be a mobile carrier, Netflix and digital film in today's economy? he asks. And mass production is coming – just like it has for big-screen TVs, which were once price-exorbitant but that are now cheap. When all the major carmakers start producing hydrogen cars, the cost will keep falling – now around USD 40,000 for Toyotas.

To reach critical mass by 2030, Strizki argues that government incentives must be in place and particularly a carbon tax. Fossil fuel companies, meanwhile, must be stripped of subsidies. That will help expand the renewable energy network – powering as much as a quarter of the cars now on the road. He emphasizes that one hydrogen filling station can service 400 cars a day and that it only takes three minutes to fill up a car. And for this reason, he says that electric vehicles with costly batteries that are difficult to dispose of will lose ground.

"The obstacles are the politics and the education," says Strizki. "People think of hydrogen as the atom bomb. But it is using a gas – like natural gas. You can't get hydrogen to explode. It is safer than any other fuel; it gets to a 'non-flammatory' state in seconds." The 64-year-old says that "we will see a hydrogen economy before I die – so we can give our children and our >>

Fig. 2: Strizki with his own hydrogen fueling station [Sources: Hydrogen House Project]

grandchildren a healthier planet. It will come from powering the transport sector, along with housing and buildings, with hydrogen. It will not take years."

"This is coming. It has reached a critical mass," Strizki intones. "Pretty soon we will be able to tell that the emperor – the fossil fuel companies – has no clothes. Their product has an expiration date."

Strizki's single-minded approach is impressive. But as he readily acknowledges, the laws of physics do not apply when politics and money are involved – especially when industries that employ tens of thousands of people have a say. More likely than not, all energy forms will continue to participate, although renewable energy and hydrogen production will get more respect. ||

Category: International | **Author:** Uta Mummert

FRANCO-GERMAN HYDROGEN COOPERATION

Similarities, differences and future prospects

Fig.: Philippe Boucly, president of France Hydrogène, formerly known as AFHYPAC [Source: France Hydrogène]

By the time of the next presidential election in 2022, France hopes to have regained the economic growth it last experienced in 2019. In order to stimulate the economy following the COVID-19 lockdown, the French government is rolling out a EUR 100 billion recovery program named France Relance. EUR 2 billion of the funds will be released over the next couple of years to support hydrogen projects. In total, the French government plans to channel EUR 7 billion of investment into this energy carrier in the runup to 2030. Meanwhile over the border, Germany has earmarked funds of EUR 9 billion to bolster its hydrogen sector. These financial stimulus packages and, moreover, the ambitions of these two countries to adopt a leadership stance in the future hydrogen economy, are also resulting in increasing efforts of French and German companies to work together.

In 2018, then French environment minister Nicolas Hulot pledged EUR 100 million in finance for the hydrogen industry to be released over three years. In September 2020, current environment minister Barbara Pompili, along with the French economy minister Bruno Le Maire and Philippe Boucly, president of French hydrogen association France Hydrogène, presented the National Strategy for the Development of Zero-carbon Hydrogen (Stratégie nationale pour le développement de l'hydrogène décarboné).

The starting sum of EUR 2 billion reserved for the next two years is drawn from the France Relance economic recovery program and is designed to drive forward industrial decarbonization. A further EUR 5 billion is then due to be invested in the French hydrogen economy by 2030 with the aim of developing 6.5 gigawatts of electrolyzer capacity over the coming decade which will allow the production of 600,000 metric tons of green hydrogen.

Three priority areas are outlined in the French hydrogen strategy, the first of these being the decarbonization of industry through the construction of electrolyzers which can be then run on renewables at a later date. According to the environment ministry, 20,000 of the 145,000 metric tons of hydrogen currently used by industry is due to be produced by means of electrolysis by 2023.

The second priority is the development of clean mobility using zero-carbon hydrogen. Here, the emphasis is on the development of hydrogen-fueled commercial vehicles, such as delivery vans, trucks and refuse vehicles, as well as hydrogen-powered rolling stock for use on sections of track that have not been electrified. Almost EUR 1 billion has been set aside for clean transportation until 2023.

The third area of focus for support is research, innovation, business development and skills acquisition, with a particular emphasis on an "in-country" approach. So as to avoid dependency on foreign countries and to prevent the subsidizing of Chinese manufacturers – as has been the case with photovoltaic modules – France intends to encourage the creation of a value chain on home soil.

To make this happen, the government's hydrogen strategy can build upon the many large industrial enterprises, energy providers, interested regions and innovative startups that are all keen to promote the commercial development of hydrogen production and deployment. Similar to the situation in Germany, there are already numerous parts of France in which hydrogen is seen as a source of hope for regional economic development: Auvergne-Rhône-Alpes (Zero Emission Valley), Brittany, Bourgogne-Franche-Comté, Grand Est, Hauts-de-France, Occitanie, Provence-Alpes-Côte d'Azur to name but a few.

October 2020 witnessed the publication of two initial tenders: "Technical building blocks and demonstrators" (Briques technologiques et démonstrateurs) and "Territorial hydrogen ecosystems" (Ecosystèmes territoriaux hydrogène).

Funding applications for these schemes can now be submitted to the French environment and energy agency ADEME. The second tender, especially, targets the formation of consortia that bring together industry players and local authorities in a particular area.

FRENCH HYDROGEN COMMITTEE Similar to the hydrogen council which was formed in Germany in summer 2020, France has had its own hydrogen committee since early January 2021. This body is made up – aside from France Hydrogène president Philippe Boucly – almost exclusively of industry representatives who each sit on the relevant strategic committee for their particular sector. Members include Philippe Darmayan of Arcelor Mittal who represents the mining and metallurgy sector, Frédéric Chalmin of KemOne on behalf of the chemical sector, Jean-Brice Dumont of Airbus for the aerospace sector, Hervé Guillou for the marine industry, Patrick Koller of Faurecia for the automotive sector, Henri Poupart-Lafarge of Alstom for the rail industry and Guy Sidos of Vicat who represents construction.

The committee, which is overseen by interministerial coordinator Hoang Bui, is due to convene as part of the National Industry Council and later also involve the regions. The CEA is the only (state) research facility to take a place on the committee. Universities, other research facilities, "genuine" small- and medium-sized enterprises and environmental organizations (as represented on the German hydrogen council) are entirely absent. Nevertheless, two women have made it into the 16-member group.

The extent to which, in particular, small- and medium-sized businesses or regional initiatives are able to find a place in the hydrogen arena and, moreover, the hydrogen marketplace and are able to benefit from the finance available remains to be seen. The same can be said when it comes to how much sway environmental organizations, local action groups or other critical voices may be able to exercise. At the moment, the large players and their subsidiaries are predominantly shaping the future of the hydrogen market.

If France's climate targets are to be met, there is certainly no getting around hydrogen. What's more, hydrogen brings great benefits in terms of the environmental credentials of any corporation that seeks to get involved with the technology. Yet a vague sense remains that for many, rather than being a means of tackling environmental issues, the main attraction lies in getting the biggest possible slice of the pie.

FRANCO-GERMAN COOPERATION Likewise Germany has a similarly ambitious hydrogen strategy to that of France's hydrogen program. German economy minister Peter Altmaier has announced the intention to grow electrolyzer capacity to 5 GW by 2030 and 10 GW by 2040. Thus Germany is setting itself a somewhat lower production target than France but – in contrast to its neighbor – is instead forming import partnerships with countries that have plentiful solar resources. As such, EUR 2 billion from the total EUR 9 billion hydrogen pot is budgeted for imports of green hydrogen from nations such as Morocco.

Above all, Germany and France are planning to work collaboratively in order to drive forward the growth of the European hydrogen economy. Hence both the German energy agency dena and its French counterpart ADEME have plainly expressed their support for the creation of a Franco-German hydrogen alliance. >>

For the large corporates on the scene, however, this kind of strategic positioning is nothing new. The Coradia iLint hydrogen train developed by French manufacturer Alstom, for example, is already in operation in Germany, with a further 14 trains in this series due to be delivered to a German transport authority in 2022. A truly international undertaking, the manufacture of this train model is also carried out in Alstom's Salzgitter factory in northern Germany (see also p. 34).

In 2019, energy concern EDF founded a hydrogen subsidiary – Hynamics – and also owns a 22 percent share of French electrolyzer manufacturer McPhy. German branches of Hynamics and McPhy have been in existence for many years. Additionally Covalion, headquartered in Bavaria, comes under the umbrella of EDF Group. What's more, the French corporation has shares in the company Hypion, based in Heide in Germany, as well as part-ownership of the Eifer energy research institute in the German city of Karlsruhe. Total and AirLiquide, too, have long been involved in the German hydrogen market. In fall 2020, the two automotive suppliers Plastic Omnium, from France, and ElringKlinger, from Germany, signed a joint venture deal that brought about the formation of EKPO Fuel Cell Technologies which plans to develop and mass produce fuel cell stacks. These are just a few examples of cross-border collaboration between the two countries.

DECARBONIZATION WITH NUCLEAR POWER To become a global market leader in the hydrogen sector requires large-scale production in order to reduce manufacturing costs through economies of scale. It also needs investment and, more to the point, enormous state subsidies. That's why the European Union is planning a demonstration project that has been designated an Important Project of European Interest or IPCEI. A total of 22 member states and Norway have contributed to this European funding pot, with Germany and France each investing billions of euros. Both countries have applied to the scheme with a joint project which intends to create a hydrogen gigafactory.

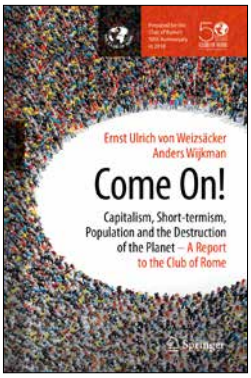
Discord exists, however, when it comes to the sensitive subject of nuclear power: In 2019 around 71 percent of France's electricity was generated from nuclear sources. According to government proposals, this proportion should drop to 50 percent by 2035. Against this background, it's clear to see why the French hydrogen strategy places emphasis on the production of "decarbonized" hydrogen as this wording also allows for hydrogen production using nuclear power.

The French, German and European targets aiming to bring about a reduction in carbon dioxide emissions are ambitious: By 2024, the EU hopes to have an electrolyzer capacity of 6 GW that will enable the production of 1 million metric tons of green hydrogen. By 2030, this quantity is set to be raised to 10 million tons, with an electrolysis capacity of 40 GW. In Germany, hydrogen production currently stands at around 20 billion cubic meters and globally at roughly 500 billion cubic meters which equates to approximately 50 million metric tons. The amount of hydrogen produced today in Germany covers just 2 percent of the world's primary energy requirement. Only 7 percent of this hydrogen is obtained from electrolysis.

All in all, the national hydrogen strategies that have been introduced are indeed a promising start. The amount of hydrogen that can actually be produced and utilized in Europe and how much of that will be genuinely "green" will only become apparent in the next few years. ||

FRANCE HYDROGÈNE
The French organization Association Française pour l'Hydrogène et les Piles à Combustible, or AFHYPAC, was renamed France Hydrogène following a unanimous vote by its members in October 2020.

COME ON!



When the Club of Rome's first book was published in 1972 it caused quite a stir. A report on the state of humanity, "The Limits to Growth" was penned by Donella and Dennis Meadows, two scientists from the Massachusetts Institute of Technology MIT in the U.S. Even back then, the two authors were able to demonstrate that each person's individual, localized behavior not only has an impact locally but has global repercussions and that these repercussions extend beyond an individual person's time frame and sphere of activity. Since then it's become clear that the excuse of "what I do here doesn't bother anyone" no longer stands up to scrutiny.

This subject is taken up by Ernst Ullrich von Weizsäcker and Anders Wijkman in their report "Come on! Capitalism, Short-termism, Population and the Destruction of the Planet." It explains in striking terms that virtually nothing has been done in the last fifty years despite all the necessary information being available and widely known. Using scientific yet readily understandable arguments, they put forward that population growth, food production, industrial production, resource depletion and environmental pollution still remain the five most important problem areas and that further challenges have come along since, such as species extinction and climate change.

In collaboration with their colleagues from the Club of Rome, the two authors have compiled a study with countless valuable and well-researched facts without drifting too far into the science. They set out the many challenges that today's society has to face but avoid whitewashing the subject or falling into fatalism. Instead, they use a wide range of good examples and requests to appeal to the good in human beings and to show that there is still hope. However, Wijkman and von Weizsäcker concede that achieving the Paris climate targets is becoming harder with every passing day. But in their view, a change in philosophy could still make this possible.

A definite must-read, this book sets out to persuade all readers that a wait-and-see approach and a business-as-usual strategy are no longer an option. ||

von Weizsäcker, Ernst Ullrich; Wijkman, Anders (2018): Come On!, Springer-Verlag New York

BUSINESS DIRECTORY

COATING

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

COMMUNICATION & MARKETING

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

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

COMPRESSORS

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

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

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

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Areva H2Gen GmbH, Eupener Strasse 165, 50933 Köln, Germany, Phone +49-(0)221- 2919073-0, Fax -9, *www.arevah2gen.com*

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

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

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

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

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

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ELECTRONICS

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INTEGRATION

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

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MEASUREMENT AND CONTROL TECHNOLOGY

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

MEASUREMENT DATA MANAGEMENT AND MONITORING

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

MEMBRANES AND SEPARATORS

Agfa-Gevaert NV, Zirfon – separator membranes for alkaline water electrolysis, Septestraat 27, 2640 Mortsel, Belgium, Phone +32-3444-8004, *www.agfa.com*

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

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

ORGANIZATIONS

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

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

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

ORGANIZERS (EVENTS)

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

Peter Sauber Agentur Messen und Kongresse GmbH, f-cell, September 29 to 30, 2020, Haus der Wirtschaft, Willi-Bleicher-Str. 19, 70174 Stuttgart, Germany, Phone +49-(0)711-656960-55, Fax -9055, *www.f-cell.de*

Peter Sauber Agentur Messen und Kongresse GmbH, f-cell + HFC, The Hydrogen and Fuel Cell Event, September 9 to 10, 2020, Vancouver Convention Centre, Canada, *www.hyfcell.com*

REFORMERS

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

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

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www.h2-ise.de

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Phone +49-(0)9645-884-30, Fax -90, *www.kerafol.com/sofc*

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

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

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

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TEST STANDS

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

EVENTS

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

MAY

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

Hydrogen 2021
Hydrogen Fuelling the Net Zero Economy,
May 20 to 21, 2021,
digital conference and exhibition
www.reutersevents.com/events/hydrogen/

Compressor Day
goes virtual
May 27, 2021, online
www.neuman-esser.de

JUNE

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

International Hydrogen Symposium
June 15, 2021, online
www.h2symposium.de

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

ZEROEMISSION 2021
together with H2 HYDROGEN & FUEL CELLS
June 23 to 24, 2021,
Piacenza Expo, Italy
www.zeroemission.show

JULY

Connecting Green Hydrogen APAC
July 19 to 20, 2021,
in Melbourne, Australia
www.greenhydrogenevents.com

OCTOBER

EES Europe Restart
electrical energy storage – with Power2Drive
October 6 to 8
www.ees-europe.com,
www.powertodrive.de

Hydrogen Online Conference
24-h-Conference by Mission Hydrogen
October 8, 2021
www.hydrogen-online-conference.com

The Hydrogen Technology Conference & Expo
co-located with Carbon Capture Conference
October 20 to 21, 2021, in Bremen, Germany
www.hydrogen-worldexpo.com

HyVolution
Hydrogen event for energy, industry and mobility
October 27 to 28, 2021, in Paris, France
www.hyvolution-event.com

NOVEMBER

Hypothesis XVI
HYdrogen POwer THeoretical & Engineering Solution International Symposium
November 8 to 10, 2021,
Muscat, Oman
www.hypothesis.ws

European Zero Emission Bus Conference (ZEB)
Learn what is next in clean transport
November 17 to 18, 2021,
Paris, France
www.zeroemissionbusconference.eu

2022

MARCH

Hydrogen & Fuel Cells Energy Summit
March, 2022, in Porto, Portugal
www.wplgroup.com

JUNE

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

Who are we?

Established in September 2020, *Ecogenium* is a student team and non-for-profit organization with members from **RWTH Aachen University** and **FH Aachen** who put theory into practice to build a **hydrogen fuel cell vehicle prototype.**

We aim to be a long-term sustainable organization that provides students the opportunity of doing hands-on work with hydrogen technology.

ECOGENIUM

Not-for-profit association

50

Active members

Hydrogen technology

Our Team's Goals:

Ecogenium aims to put our prototype to the test by participating in the annual *Shell Eco-marathon* - a worldwide mileage competition focused on **energy efficiency**. There we hope to have the most fuel efficient hydrogen vehicle!

Our team also **strives to be an active part** of the hydrogen movement. Our plan is to increase our engagement with the community through outreach events to promote hydrogen technology in the local community.

How can you support us?

In-kind donations in form of raw material, tooling, or vehicle parts to build the prototype;

Monetary donation to provide us with the financial stability to maintain the team and build the vehicle;

By being a **partner** in our growing network of students, professionals, and the community at large!

Our Achievements So Far...

Shortly after establishing our organization, we successfully achieved **1st place in Europe and Africa region** at the Shell #PitchtheFuture competition in the "Electric and long-distance travel vehicles" category by presenting a **unique idea** for a **route planning app** with potential applicability to both electric and even hydrogen vehicles!

In addition to that, we were awarded **2nd place** for the Southwest Research Institute **Technical Innovation Award** in April 2021. This award for technical innovation recognizes outstanding ingenuity through the optimal use of new materials, components, and inventions in the drive train, chassis, body, instrumentation, and tires of vehicles. Our innovation was the design of a **liquid cooling system** which we developed for our fuel cell vehicle.

Invest in a better future. Sponsor us!

Charlemagne's Characteristics

Novel Carbon Fibre-Sandwich Chassis Design

3D Printed Steering Wheel and Driver Control Panel

High Sensitivity Hydrogen Safety System

3 kW Liquid Colled Fuel- Cell System

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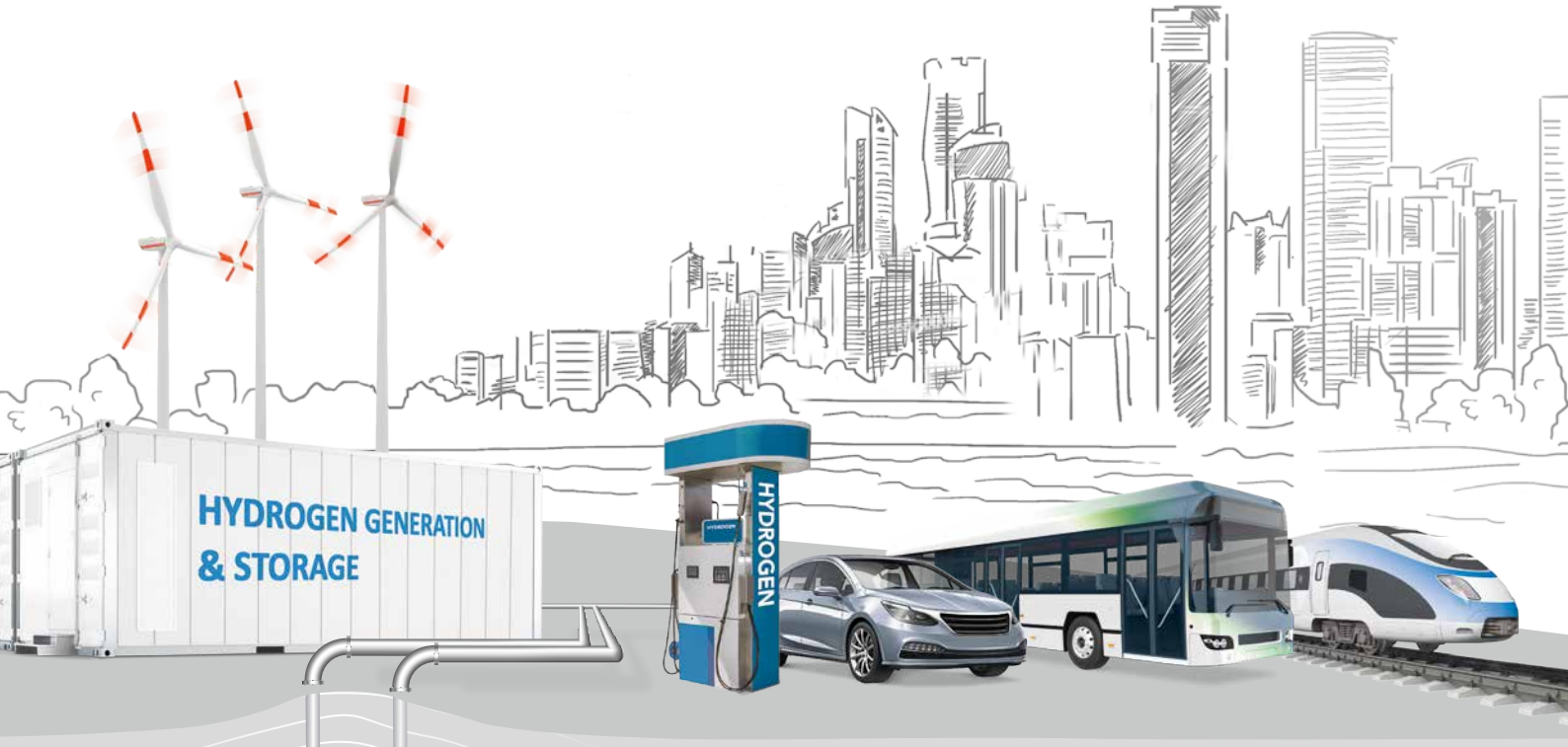

Energy transition with compressors

For 80+ years NEUMAN & ESSER have been serving processes in refineries, the petrochemical and chemical industries according to API 618. This is why NEA has a profound know-how in the compression of all process gases, especially of hydrogen and hydrogen mix gases. NEA GROUP has broadened its portfolio of applications by supporting the transformation from the fossil fuel based oil & gas sector to an H_2 Economy with green hydrogen from renewable energy. This is where the proven compressor technologies from NEA and HOFER come into play. The conversion of the energy system with Power to Gas needs energy-efficient piston and diaphragm compressors. They are the perfect match to ensure both the flexibility of demand and energy security with green gases.

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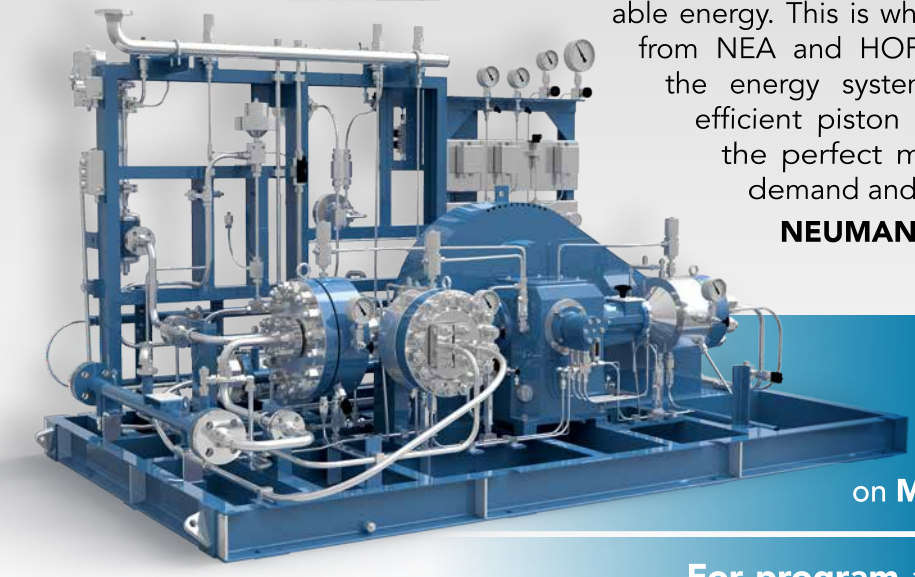

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COMPRESSOR DAY 2021 goes virtual

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For program and free registration:
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