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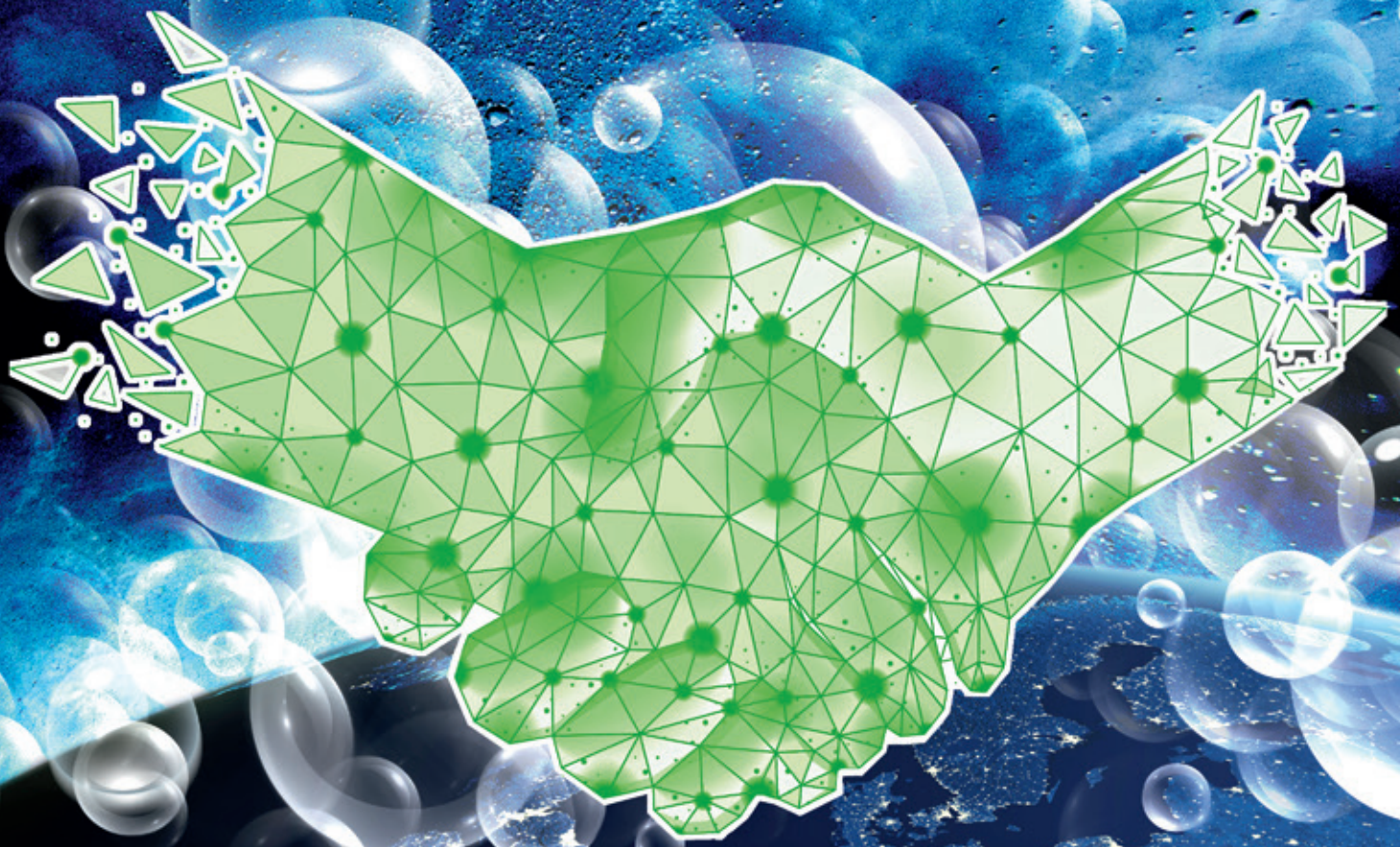
H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS



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Cover image: European Green Deal sparks off hydrogen economy [Sources: Europe © NicoElNino, Hands © macrovector/Freepik]

NATIONAL STRATEGY, GREEN DEAL AND COVID-19

Dear readers,

Now that's what you call luck. Right around the editorial deadline of our sister magazine HZwei, the German government debated, passed and presented its strategy to support the hydrogen and fuel cell industry.

Five federal ministries were involved in drafting the strategy. Their compromise agreement sets a 2030 target of "only" 5 gigawatts in installed electrolyzer capacity, not 10, as the German science minister Anja Karliczek strongly proposed. However, the strategy does concede a note on adding another five by 2035 "if circumstances allow."

As anticipated, both the national hydrogen and fuel cell association DWV and the national gas and water industries association DVGW were not happy about the outcome. DWV chairman Werner Diwald and DVGW president Gerald Linke now hope that the "remaining five gigawatts" will be added by 2030, not by 2035 or even 2040.

Also as expected, political and business leaders initially tried to keep the focus on commercial and rail vehicles, as well as ships and airplanes, not on passenger cars. But the biggest consumer of hydrogen, to be mainly produced using clean energy sources, will most likely be the industrial sector, the steel, cement and refinery industries in particular.

What came as a bit of a surprise was the suggestion that the EEG surcharge on electrolyzer output be dropped altogether. Even though the proposal was introduced at a late stage in negotiations, it is nevertheless worth mentioning, as the federal economy ministry did everything it could to avoid the debate. Subsequent statements by the ministry's staff members fueled speculation that the new energy surcharge rules would be approved without changes. However, the consensus now seems to be: "We are planning to remove the EEG surcharge on hydrogen produced from clean energy sources." The government then pledged that the removal would not lead to an overall increase in EEG charges.

Even though some have criticized the strategy proposal, all in all the government agencies have struck a compromise people can live with. The most important thing about the deal is that it provides predictability and a stable environment for investing, regardless of the precise target for electrolyzer capacity.

You can read more about Germany's national hydrogen strategy, and the debates leading up to it, on pages 10 to 15 of this issue. And on page 18, you will find our interview with Frans Timmermans, who offers us a first glimpse of the EU's upcoming hydrogen agenda.

Other oft-discussed questions these days are what will happen to the energy market transformation and climate action programs now and post-Covid-19, and whether interest in hydrogen will continue to grow as much as it has in recent times. What will become of the FridaysForFuture movement? Will we ever see another climate summit? Will we compulsively fall back on old patterns, continuing to rely on fossil fuels? Or will the hydrogen and fuel cell industry emerge stronger from the crisis in the near future? Could a hydrogen economy help revive the concept of a European identity?

I believe the chance for a genuine European energy market transformation has never been as promising as it is today. But it all depends on how we deal with the current situation. Every one of us can make a lasting contribution by jumping into action and making their voice heard.

If we keep following yesterday's leaders, as we did pre-Covid-19, lamenting that ICE cars are not eligible for economic incentives, nothing much will change. No matter how efficient the latest gas or diesel engine, all of them use fossil fuels and compound pollution. Don't forget, we are talking about a 140-year-old technology. It is high time we come up with something new.

I think it laudable that the government sticks to its guns, deciding in favor of innovative and sustainable technologies and against ICE incentives. When it comes to electrification, China overtook Germany a long time ago. Volkswagen may have abruptly changed course at the twelfth hour, still, their focus is on batteries only. And where does that leave them? In hot water, apparently, after multiple issues with the software and delivery of the new VW ID.3. Though to be fair, not one German automaker has made much progress in producing a viable electric vehicle.

It is crucial that the German auto industry at least tries to keep up with the latest developments on the commercial vehicle market, or even sets new trends. In the market for passenger cars, Tesla upended the automakers' entire world view. Nikola Motors is now the next US-based startup (see p. 44) to try to do the same, this time for trucks. And how do German automakers respond? By announcing a plan to electrify the truck sector no earlier than the end of this decade and offer fuel cell buses in 2022, or later than that (see p. 34). I am sorry, but not only will the world look different in 10 years, we also need fuel cell buses within the next weeks or months, not in two years.

We have an enormous chance – let's use it – the potential is vast.

Best wishes,

Sven Geitmann
Editor of H2-international

HYSOLUTIONS CEO RETIRES

Fig. 1: Heinrich Klingenberg (left) and Peter Lindlahr

A champion of the hydrogen industry, Heinrich Klingenberg's defining influence extends from northern Germany throughout Europe. In early July, the hySolutions chief executive embarked on his well-deserved retirement.

Klingenberg was instrumental in setting up hySolutions in 2005. As CEO and spokesperson, he doubly served the company throughout his entire term of office (see interview in H2-international, April 2019). Before taking the helm at hySolutions, he sat on Hamburger Hochbahn's board, assuming responsibility for bus services. Employing his extensive political contacts as well as those with regional transit company HVV, Klingenberg successfully promoted hydrogen and fuel cell technology among the highest administrative echelons in and around Hamburg. As a NOW advisory board member and serving on multiple EU committees, he stimulated technological advances on the entire European continent.

Hamburger Hochbahn's chief executive, Henrik Falk, said: "Regarding zero-emission transportation services and local clean energy, Hamburg is one of the top-performing regions, both nationally and globally. And hySolutions and Heinrich Klingenberg have been major contributors to this success."

Christoph Steinkamp replaced Klingenberg on May 1, sharing duties with Peter Lindlahr, hySolution's other CEO since 2010. Together, they will continue to move forward the business's electric transportation projects. Prior to joining hySolutions in 2013 to lead its vehicle market division, the 37-year-old Steinkamp was long employed by Deloitte. Upon accepting his new position, he said: "I look forward to working hand in hand with all stakeholders, pursuing Hamburg's vision of a sustainable, zero-emission economy and transportation network. This calls for integrating the transportation and energy markets while ensuring that the projects we launch today are economically viable tomorrow. As we have the support of several Hamburg politicians, committed business partners and hySolutions experts, we are confident our collective efforts will be successful."

Lindlahr, originally responsible for the battery-electric market, now handles initiatives promoting hydrogen and fuel cells. He told H2-international that Klingenberg "left big shoes to fill," but he clearly upholds hySolutions' commitment to propagating hydrogen and fuel cell technology in northern Germany. ||

DUNCAN YELLEN APPOINTED ITM MOTIVE CEO

ITM Power is growing. In mid-May, the company introduced its subsidiary, ITM Motive, which will build and operate hydrogen gas stations in the UK. The role of chief executive went to Duncan Yellen, 54, a physicist and materials researcher by trade and former project development manager for Storengy, an Engie subsidiary. At present, ITM Motive runs eight public hydrogen fueling stations, a number expected to grow to 11 by the end of this year. All stations are equipped with ITM Power electrolyzers. Compressors are provided by Linde, a major shareholder and joint-venture partner. ||

Source: ITM Power

ENAPTER PROBES EQUITY CROWDFUNDING

Taking an innovative approach to raising fresh capital, Enapter, an electrolyzer manufacturer based in Pisa, Italy, has launched an equity crowdfunding campaign. In late March, it began offering shares for only a few hundred euros, promising investors dividend payments over a period of five years. Germany's financial services regulator BaFin greenlighted the investment strategy in spring, the company said.

Enapter, which also has an office in Germany's capital Berlin, said it required additional funds to augment its patented electrolyzer. The device includes an anion exchange membrane and "merges the benefits of competing technologies." The company added that a small-size version of its system has already entered the market. But a cash infusion would give Enapter the chance to expand to mass production of its product to generate "hydrogen at a price everyone can afford." The company's chief executive, Sebastian-Justus Schmidt, explained that "equity crowdfunding will allow us to create a mass market for our electrolyzer." Enapter has yet to reveal the location of its new research technology center.

By the end of May, the crowdfunding effort had raised a bit over EUR 80,000. Responsible for this comparatively lukewarm response were both investors' financial restraints due to the global Covid-19 pandemic and Enapter's own minimum of promotional activities. In late May, Schmidt told H2-international that Enapter "does not intend to pour more resources into advancing the crowdfunding campaign, at least not at this time." Instead, he said he will focus on raising cash through a series B funding round. ||

OGE CO-FOUNDS EVETY

In late May, transmission network operator Open Grid Europe (OGE) formed a joint venture with TÜV Süd and Horváth & Partners to "provide a path to a hydrogen economy." During the startup online video call, the united front of chief executives confirmed their intention to explore new markets and bring their expert knowledge in hydrogen technology >>

to industrial, logistics and transportation companies to allow them to draw on this valuable resource. Similar to Apex, the newly launched venture called evety will develop and implement plans and projects in support of a hydrogen economy (see p. 26).

The e in evety represents energy, while vety is Finnish for hydrogen. The company's main office is located in Essen, Germany, at OGE's headquarters. Prior to becoming evety's chief executive, Klaus Altfeld (see photo) was OGE's head of IT strategy, having served in that role since 2012. Altfeld is currently backed by a staff of three but will take on additional employees as demand increases. Further plans include a branch office in Munich by the end of the year. The partners' primary intention with evety is to pool their expertise, offering hydrogen solutions for a wide variety of uses. Sales will initially be limited to Germany and Europe.

Altfeld announced his task is to "create new ecosystems by merging cross-industry infrastructures." When he was asked by H2-international what this means for the economy, he said: "Ecosystems are a good foundation for starting small before scaling up." He explained that an ecosystem forms when several organizations unite to set up a regional project that can later be integrated into a larger whole. For example, should an ecosystem generate an abundant supply of hydrogen, the surplus could first be transferred to supply nodes. These nodes could then store, and possibly convert, the gas before transporting it to ecosystems where demand outstrips supply. Jörg Bergmann, OGE's chief executive, added that an increasing number of natural gas pipelines will be used to deliver the renewable product in the near future, eliminating much of today's need for road-bound transportation.

When H2-international asked, Reiner Block, the director of TÜV Süd's Industry Service division, conceded that in the last years, his company received few requests for hydrogen solutions. Nevertheless, he noted that interest has grown in the past 12 to 24 months. He added that thanks to the living labs and the HyLand project, it now feels is as if "money were falling from the sky." He also expects the European Green Deal to give the industry another "big boost." ||

ECOSYSTEM
A common word in biological contexts, ecosystem often suggests something environmental, not economic. Typically, it relates to a habitat and its inhabitants and describes the relation of microorganisms, plants, fungi, animals and humans to each other (biocenosis) and their environment (biotope).

N2TELLIGENCE TURNS JAPANESE

At the onset of 2016, N2telligence was renamed Fuji N2telligence. But it was not until early this year that Fuji Electric Europe, headquartered in Offenbach, Germany, acquired all of the company's assets. Before the deal went through, the number of staff members on N2telligence's payroll had shrunk to four. Lars Frahm and Andreas Exler, its founders and former chief executives, left at the turn of this year.

Frahm and Exler launched the fire safety specialist business in 2006. Over the years, they installed more than a dozen fuel cell systems that generated not only electricity and heat (or cold) but also air low in oxygen. One example of their work is the large fuel cell system put up at Nordfrost in Herne. The company catered mainly to the refrigeration market. For example, German food processing giant Dr. Oetker purchased three N2telligence systems for its factory halls. Nearly all projects were completed without the aid of public funds.

Frahm, who once worked at Airbus, said N2telligence systems were originally intended for server rooms as well. But the company abandoned its plans after it became clear that far too many people would be entering and leaving these facilities regularly. By contrast, their devices are ideal for sites storing frozen goods, since water does not extinguish fires at subzero temperatures and some facilities are too large to allow the use of inert gases, such as argon or nitrogen, to control the flames.

A difficult time for business, Frahm said, was 2016, after the German government revised the CHP act. The new rules made funding unavailable to large stationary fuel cell power plants with more than 5 kilowatts of capacity. Had Fuji not intervened shortly thereafter, the company would have surely gone under that year.

Fig. 1: Andreas Exler and Lars Frahm (right) [Source: Lars Frahm]

Fuji N2telligence's new chief executives are Tai Sakata and Yoichiro Yamamoto, who flew in from Japan to take over the business. Its other two employees will remain to answer technical and administrative questions. Frahm and Exler continue on as advisers to Fuji as well as Fuji N2telligence (FN2). In late January, they founded their new business, N-zwo, which offers development, consultancy and promotional services to clients applying stationary fuel cell systems to energy generation and oxygen reduction. ||

Thema: Advertorial | **Authors:** Matthias Authenrieth, Karl-Heinz Lentz

IGAS ENERGY GMBH AND FEST GMBH COOPERATE

Exclusive cooperation in the field of hydrogen technology

The business area of hydrogen technology will be further developed and established in the Schmidt Kranz Group's corporate environment. In April this year, iGas energy GmbH and FEST GmbH launched an exclusive cooperation in the field of hydrogen electrolysis with consultation, marketing, production and the associated services.

Green hydrogen, generated from CO_2-neutral energy such as wind, water, solar and heat, will play an essential role as an energy source and storage in the future energy industry in Germany and globally.

iGas energy GmbH developed the 'green electrolyzer' for PEM-based hydrogen electrolysis in a modular and transportable design, as well as in the range of 50 kW to 20 MW electrical energy. iGas energy GmbH also develops and implements process systems such as the processing of biogenic residues under recovering valuable raw materials.

Already today, the FEST Group, as an industrial experienced and globally acting partner will offer, under the 'green-h2-systems' business unit, the conception, engineering and production of turnkey construction, services and operation of such systems in a close technological network with iGas energy GmbH and other specialized partner companies.

Based on the knowledge and experience of these companies, total energy systems about connecting renewable energy sources, H_2-generation, -transport and -storage, up to commercial refueling systems for vehicles are offered, implemented and maintained.

iGas energy GmbH and FEST GmbH have already successfully sold and implemented H_2 electrolysis systems abroad and in Germany's most important hydrogen market.

The current megawatt projects are under contracted progress:

GAS GRID SUPPLY, BERLIN REGION:

Production of green hydrogen and the proportional utilization of hydrogen in the public gas network.

According to the approval process, a PEM-based H_2 electrolysis with a volume of 200 Nm^3 corresponding to 1 MW electrical energy will be delivered after the engineering phase.

ENERGY SUPPLY, FRANKFURT REGION:

Production and utilization of green hydrogen to fuel new hydrogen-based regional trains of the Rhein-Main transportation association. A PEM-based H_2 electrolysis with a volume of 1,000 Nm^3 corresponding to 5 MW electrical energy will be delivered. ||

→ www.fest-group.de
→ www.igas-energy.de
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GERMANY'S NGO HYDROGEN CHAMPIONS

Non-profit organizations aiming to establish a hydrogen economy are sprouting up all over Germany. The first was founded in Hamburg in 1989. HyCologne in the Rhineland region followed in 2007, and H2BX in Bremerhaven in 2016. Newcomers are the Wasserstoffenergiecluster Mecklenburg-Vorpommern (see p. 26) and H2 Süd in southern Germany.

H2 Süd
DIE WASSERSTOFF INITIATIVE
BAYERN & BADEN-WÜRTTEMBERG

H2 Süd is a collective of businesses based in Bavaria and Baden-Württemberg. Founded in October 2019 by Andreas Seebach, the group is gradually stepping up operations. Seebach, the alliance's president, told H2-international he has mapped out several projects that he intends to launch in both states. In contrast to the H2.B hydrogen center of excellence set up by Bavarian administrators and supported by universities, he defined his organization as a group of independent voices, especially those of small and medium businesses, whose primary interest is the exchange of information on and experiences with promoting a hydrogen economy. ||

FAST FORWARD TO 2021

HANNOVER MESSE
HYDROGEN
FUEL CELLS
EUROPE

Although Covid-19 forced the cancellation of Hannover Messe, not to mention all other shows and conferences scheduled in the last months, there is no doubt how crucial the first is to the energy industry. The world's premier industrial show has now been rescheduled to take place between April 12 and 16, 2021, more or less as originally planned.

Deutsche Messe and Tobias Renz, organizer of the show's Hydrogen + Fuel Cells Europe exhibition, are confident that interest in the show will not wane. Renz told H2-international: "At the end of March, immediately after the news broke that Hannover Messe 2020 would be cancelled, we began planning for next year's event. […] Even we were surprised with how well things went. Except for a few organizations that had reserved comparatively small display spaces, we managed to convince all of this year's exhibitors to get back on board in 2021. This, I believe, speaks volumes for the hydrogen and fuel cell industry and, of course, for Hannover Messe." ||

HEXIS RESCUED, AGAIN

On June 1, Swiss fuel cell manufacturer Hexis was rescued once more from the brink of disaster. A Viessmann spokesperson said Dresden-based mPower purchased its stake in the company. The new owner is a subsidiary of h2e Power Systems, a high-tech business headquartered in Pune, India.


Source: h2e

Fig. 1: Siddharth R. Mayur

Siddharth R. Mayur, h2e Power Systems' founder and chief executive and mPower's CEO, said: "The acquisition of Hexis provides us not only with a great team but also with a very strong foundation to develop world-class products at competitive prices." Aside from real estate and green hydrogen, the business intends "to expand the Hexis product portfolio to include agricultural, oil, gas, and telecoms applications," while its vision is to fuse "German and Swiss engineering skills with Indian entrepreneurship," making it "the first truly global SOFC company." Alexander Dauensteiner, Viessmann's fuel cell division head, is certain that h2e will be "the perfect investor and partner to carry on with Hexis' work." Viessmann will maintain collaboration with Hexis to deliver SOFC modules.

Viessmann announced on March 19 that it intended to sell Winterthur-based Hexis (see H2-international, May 2020). A Swiss investor was the first to save the fuel cell manufacturer from shutdown in 2005 and in fall 2012, Viessmann had their turn (see HZwei, January 2013 and April 2006). ||

NEW NOW LEADER

On April 23, NOW's supervisory board announced its new director in Berlin. Starting on May 15, Kurt-Christoph von Knobelsdorff, formerly a department head at Brandenburg's economy and energy ministry, will lead the German national hydrogen and fuel cell organization.

Knobelsdorff, 52, is also spokesperson for the executive board. He replaces Klaus Bonhoff, who left for the German federal transportation ministry in summer 2019. Responsibilities are shared with Wolfgang Axthammer, NOW's other chief executive, who has managed the business alone over the months following Bonhoff's exit. Before serving the Brandenburg economy ministry, Knobelsdorff held similar posts in Schleswig-Holstein and Berlin, as well as management positions at Familienunternehmer and DIHK, associations representing German businesses at home and abroad.

Having worked on a statewide strategy alongside Brandenburg economy minister and hydrogen advocate Jörg Steinbach (see interview in H2-international, April 2019), the new NOW boss has become intimately familiar with the hydrogen and fuel cell market. Right up until his last days at Brandenburg's ministry, he was busy promoting a new hydrogen initiative in the region, making many new friends in the hydrogen and fuel cell community.

H2-international can confirm his enthusiasm for the technology after visiting Knobelsdorff's Brandenburg office in August 2019 and several follow-up discussions at events in and around Berlin. When asked about Germany's hydrogen strategy, he revealed that he was hoping NOW would have a "coordinating role," considering the strategy "more or less originated" with NIP, the country's national innovation program. He added that there were no plans to reshuffle personnel or restructure the agency at this time.

Fig. 1: Kurt-Christoph von Knobelsdorff [Source: Christina Gaudlitz, IHK Cottbus]

In the meantime, however, NOW transportation and infrastructure director, Thorsten Herbert, who reportedly had his eyes on the CEO post as well, left the company of his own accord. On May 1, he then took up a job as business development manager at electrolyzer manufacturer Nel, where he will act as liaison between Norway and central Europe, primarily Germany. ||

Theme: Policy | **Author:** Sven Geitmann

GERMAN GOVERNMENT INVESTS IN GREEN HYDROGEN

"Only hydrogen from renewables is sustainable"

There it is – the national hydrogen strategy. Five federal ministries presented the cabinet-approved final concept in Berlin on June 10. Querulous months of intense cross-ministry wrangling over hydrogen colors, the targeted electrolyzer capacity and committee rosters preceded strategy publication as sector representatives prowled, yearning for news. Ultimately, the governing coalition agreed on a whopping EUR 7 billion package, plus an additional 2 billion for potential hydrogen export countries (see p. 15).

Incredibly brilliant tactics; if the delays were intentional. Dragging out the national hydrogen strategy presentation until mid-June – until Germany takes over the EU Council presidency, until the federal government launches a Covid-19 stimulus program. Bang! Establish a hydrogen economy, that's the ticket. Made in Germany but for Europe as a whole, of course. Then it's off to collective negotiations with Council President Ursula von der Leyen for a Green Deal that just might get the German and European economies – and maybe the environment, too – back on their feet. Should this put an end to the current crisis, coupled with a halfway sustainable European energy concept, the Christian Democrats can polish their campaign buttons for the national elections in 2021, aiming for a Green-Black coalition (pure speculation, that bit).

AN EXHAUSTING DISCUSSION They took their own sweet time, much too long, in fact. The German cabinet should have discussed, resolved and enacted the national hydrogen strategy before Christmas 2019. No dice. Not in early 2020 either and certainly not as the Covid-19 pandemic had us all in its grip. Yet, at the beginning of 2019, as Thomas Bareiß, of the economy ministry, met with his colleague Steffen Bilger from the ministry of transportation along with Klaus Bonhoff, NOW's former chief executive, the necessity for a national strategy was more than evident.

Fig. 1: National hydrogen strategy [Source: BMWi / Andreas Mertens]

RUSSIAN HYDROGEN GETS BAVARIA'S VOTE

In the wake of many other German states, Bavaria's economy minister Hubert Aiwanger presented a statewide hydrogen strategy in Nuremburg on May 29. At the same session, Veronika Grimm, who chairs H2.B and advises the government on economic matters, introduced the corresponding position paper. In the ensuing discussion, Aiwanger proposed Russia as a hydrogen import partner, reasoning that the Nord Stream gas pipeline could import unlimited amounts of "affordable green hydrogen" from the east. When H2-international questioned the statement's foundation, the state ministry responded: "Russia's potential for onshore wind energy expansion is enormous and quite capable of meeting Germany's hydrogen demand. The production capacity is realistically estimated at 3.5 million tons of hydrogen. That is 15 percent of the world market share."

It's the end of May and the federal ministries are still haggling. However, on June 3, the cabinet announced measures intended for the Covid-19 stimulus package. One such decision is to continue the economic incentive for electric car purchases. The German economy ministry puts forth: All vehicles that currently profit from the incentive, i.e., all-electric cars, plug-in hybrids and fuel cell vehicles, could receive an innovation bonus, independent of manufacturers' discounts. Conditions for each type of car remain as in the current system, the corresponding government incentive is then doubled. The measure will be effective until Dec. 31, 2021.

On the whole, general agreement reigned when the coalition's leaders met in Berlin. Nearly everyone wanted the stimulus package to also promote hydrogen production. To this end, German finance minister Olaf Scholz provides both generous funding and charismatic canvassing. Quote: "Ending the crisis with a bang."

COALITION COMMITTEE RESULTS ON JUNE 3

"Industrial production facilities should generate up to 5 gigawatts of total capacity by 2030, an additional 5 gigawatts by 2035, when possible."

"We strive to liberate green hydrogen production from the EEG surcharge. We will ensure this does not cause an EEG surcharge increase."

Not until the following cabinet meeting on June 10 was the national hydrogen strategy finalized at last. You must admit, though, that these endless delays led to a much more expansive, substantiated strategy than was formerly planned. What began as a six-page draft has grown to 32 pages, not only because several German states (see "Russian hydrogen gets Bavaria's vote"), but also a great variety of associations and research facilities contributed their own concepts as well as some valid criticism.

THE CHROMATICS OF HYDROGEN A core debate throughout the entire procedure surrounded the color of hydrogen and if blue H_2 should be funded in any form at all. Clean energy utility Greenpeace Energy spoke strongly against blue hydrogen when it published its position paper in January, reaping support from German hydrogen and fuel cell association DWV (see H2-international, May 2020). At April's close, German environmental action group DUH also published a position paper, asserting that climate goals can only be reached when hydrogen and other synthetic energy sources are produced "entirely from additional renewable energy capacity under strict sustainability standards." In contrast, blue hydrogen is a climate contaminant and extends the shelf life of fossil fuels, DUH said.

Sascha Müller-Kraenner, co-CEO of DUH, went further, pointing out that only green hydrogen adds value to the region. He continued: "The first step toward hydrogen technology is installing appropriate funding instruments to expand electrolyzer capacity in Germany. This, in turn, requires sufficient renewable electricity. The distance regulations for wind energy must be tabled and the PV cap must be abolished immediately." In the meantime, the coalition has revised the strategy to meet Müller-Kraenner›s last two demands: Wind turbine setbacks are now a state issue and PV capacity limits are wastepaper.

Germany's economy minister, Peter Altmaier, and the EU's executive vice president for the Green Deal, Frans Timmermans (see interview on p. 18), are joined by many industrial representatives in taking a much more open view to blue hydrogen. Bareiß noted: "I believe we need all hydrogen colors; even gray tones will do in the interim." Carbon capture's low acceptance value is no problem, so it's told, since storage facilities are far, far away in Norway.

Time is a factor in favor of blue hydrogen. A lack of electrolyzer capacity means the huge quantity of necessary hydrogen cannot be immediately produced with renewable energy sources. The downside is that enormous sums would have to be invested in fossil fuels and CCS. Money that green hydrogen as well as the solar and wind energy industries would sorely miss.

The German government translated this extensive, public discussion into national strategy goals as such: "to use green hydrogen, to expedite market growth and to establish corresponding supply chains." It states in black and white that only hydrogen produced from renewable energy sources is consistently sustainable. Yet, the ministries are not completely closed to the fossil fuel path. Consequently, the government assumes a Europe-wide and global hydrogen market will take root over the coming years, including trade with carbon-neutral hydrogen, i.e., blue and turquoise. Further: "Due to Germany's close involvement with the European energy infrastructure, carbon-neutral hydrogen will also play a role nationally and, if available, be used as an interim energy source."

5, 10 OR 20 GIGAWATTS? Impassioned debates on the electrolyzer capacity level nearly reached hydrogen color discussion proportions. One side – that would be NOW – declared 5 gigawatts "quite ambitious enough," the other – i.e., Brandenburg's economy ministry – considered it "too low." Further, the federal economy ministry said Germany doesn't have the acreage to expand electrolyzer facilities, as energate reported.

To explain: The more electrolyzers there are, the more renewable electricity is needed, which means capacity must be added if the government is to reach the agreed-upon target of 65 percent clean electricity by 2030 (currently 40 percent). The more renewable energy that flows into producing hydrogen, the harder it will be for the economy minister, who is ultimately responsible, to meet the goal. Which is why Altmaier expressly states that the government will hold fast to this target and whatever comes about with hydrogen is "icing on the cake."

German education minister Anja Karliczek, who is also a Christian Democrat, mind you, had been speaking out for 10 gigawatts of electrolyzer capacity. Nonetheless, her reaction at the national strategy presentation was conciliatory, given that an additional 5 gigawatts by 2040 was integrated into the projected targets.

"If it is a matter of technological feasibility, 5 gigawatts by 2030 and another five by 2040 should already be reality by 2030."

Gerald Linke, DVGW chairman

"The coalition's decision to invest in green hydrogen is a step in the right direction. Although a more ambitious, 10-gigawatt electrolyzer capacity would have been ideal, at least the decision puts an end to months of deadlock surrounding a direly overdue national hydrogen strategy as the core component to transform the energy market. This also gives blue hydrogen its walking papers, as it is a fossil fuel product reliant on carbon capture and storage."

Sascha Müller-Kraenner, DUH chief executive

The final crux was the composition of the national hydrogen council (see H2-international, May 2020). Which experts should sit on the panel and where to house it? Firing up another round of discussion. Karliczek clearly argued for a coordinator from her own ranks, wanting to see a "hydrogen advocate" on the committee, the FAZ reported. In the end, she was granted an innovations officer slot for "green hydrogen," a permanent guest of a ministry staff committee and the national hydrogen council, representing the German education ministry and responsible for research and development activities.

It remained to be seen just who would be on the council – presumably, leading industrial representatives, e.g., BASF, Daimler, Linde, OGE, Siemens, ThyssenKrupp, Uniper and Viessmann, but also research and environmental associations. Not all of them have to be hydrogen experts. The council should be flexible and focused on action.

Most likely, but not yet written in stone, the national council will reside with NOW.

WITH A BANG, DOUBLE-THRUST AND IGNITING SPARK In the final analysis, Altmaier terms the national hydrogen strategy a collective effort. He must be referring to the unified front and goals the five ministries eventually formed. Considering the billions Olaf Scholz granted, the collective should refer to the entire German population, since it's their tax money that will finance the EUR 130 billion stimulus program, ending the crisis "with a bang," citing Scholz. >>

German environment minister Svenja Schulze, a Social Democrat, used similar language, speaking of a "double-thrust for climate protection and sustainable economic recovery following the Covid-19 crisis." Transportation minister Andreas Scheuer, while personally missing out on the strategy presentation, previously told Funke Mediengruppe he hopes for hydrogen cars Made in Germany, with the hydrogen strategy providing the "igniting spark." He also declared: "The German government's national hydrogen strategy generates massive pressure to shape innovative transportation." He throws the ball to carmakers.

On the whole, criticism of the strategy is minimal, to say the least. The Greens' parliamentary leader, Oliver Krischer, objected: "Large production capacities are planned without a clue to whom the hydrogen will go." He demands blending quotas for aviation and the natural gas pipeline system. Sure, the national strategy mentions such quotas, but whether an "at least 2 percent quota by 2030" of renewable kerosene is possible remains to be seen.

Michael Theurer, the Free Democrats' leader in parliament, called for EEG surcharge-free electrolyzers, for a coordinated import strategy and for a hydrogen union, the last two Europe-wide – all of which is accounted for in the national hydrogen agenda.

When speaking with dpa, Kerstin Andreae, of energy and water industries association BDEW, lauded "the right impulse at the right time." The BEE alliance for clean energy applauded the coalition's focus on green hydrogen and called for an intensified expansion of renewable energy. Greenpeace Energy said: "The federal government finally recognizes that serious climate protection can only prevail with green hydrogen. […] We find it all the more disconcerting that their national strategy relies heavily on blue hydrogen, an illusory, climate-damaging solution." ||

"The German hydrogen strategy is a long-anticipated breakthrough for the industrial and technology leader after so many years at the forefront of global hydrogen energy efforts."

Kurt-Christoph von Knobelsdorff, NOW chief executive

Theme: Policy | **Author:** Sven Geitmann

TO EACH THEIR OWN HYDROGEN STRATEGY

Social and Christian Democrats are at it again

Once again, the two major German political parties lock horns over the national hydrogen strategy, increasing pressure on the governing coalition to decide before the summer recess. In early May, twelve MPs from the Christian Democrats (CDU/CSU) circulated a statement demanding a rapid escalation in renewable hydrogen facilities and calling for new partnerships with African countries. Hot on the CDU's heels, the Social Democrats (SPD) issued their version, pressing for a more ambitious hydrogen strategy and faster capacity additions.

Anja Weisgerber, CDU/CSU's special climate change envoy, also signed the position paper, urging her executive branch colleagues to act. She told dpa: "We must clearly plot out our national hydrogen strategy and we need to do it now, if we expect to build a larger number of clean hydrogen production facilities in the very near future." The proposal said: "The federal government needs to stop delays. We must broadcast a viable hydrogen strategy and lead the world in establishing a green hydrogen economy."

The Social Democrats seem to be equally impatient. Their MPs on the Business and Energy committee have drawn up their own document, listing key points and concrete plans they deem necessary to a sustainable hydrogen strategy. They reject, for example, funding systems that produce non-renewable blue or turquoise hydrogen and require a time limit on the usage of non-green variants. They also call for an increase in electrolyzer capacity that extends to at least 10,000 megawatts by 2030.

The megawatt figure triggered many heated debates. Some, such as NOW (National Organization for Hydrogen and Fuel Cell Technology), consider 5 gigawatts to "be quite ambitious enough." Others, including Brandenburg's economy ministry, believe the number to be "too low." According to energate, the federal economy ministry has long argued that limited space prohibits installing a large number of electrolyzers. Too many of them will greatly increase demand for green energy, requiring even more renewable energy capacity if Germany is to meet its goal of 65 percent green power by 2030 (currently at 40 percent). This puts the economy minister in a tight spot. In the end, he is accountable for meeting Germany's targets.

All the same, Anja Karliczek seems committed to the 10-gigawatt mark. The German science minister and CDU member strongly advocates immediate action. The economy ministry, however, insists 3 to 5 gigawatts would suffice for national supply. This despite Thomas Bareiß, a ministry employee, clearly stating that 5 gigawatts fall short of the hydrogen needed nationwide, forcing Germany to import gas from abroad.

In mid-April, Karliczek also called for "massive investments in education, research and innovative technologies," not solely as a result of the Covid-19 pandemic. What she wants to see is "a 50 percent increase between 2021 and 2023" in the federal government's EUR 40 billion annual budget for infrastructure, education and research. In addition to digitalization projects, the budget increase would support current climate action and sustainability programs, including initiatives to bolster clean hydrogen, which she sees as the energy carrier of the future.

Following up on her statements, she presented a post-Covid-19 stimulus program on May 27, demonstrating her intention to "support large offshore demonstrators for producing green hydrogen." Companies should have the opportunity to "test innovative methods outside the lab," which would "equip them with what they need in these times of growing climate concerns." This, she said, is the chance "to launch the age of green hydrogen."

> "When it comes to the environment and the climate, we must be world leaders in both technology and exportation."
>
> *German education and science minister Anja Karliczek*

Still undecided is who should sit on the national hydrogen council (see H2-international, May 2020). The agencies involved have neither appointed committee experts nor settled on a location. Karliczek is lobbying heavily for her department to fill the coordinator role, to ensure the council actively compels the government to fulfill its hydrogen agenda, the FAZ newspaper reported.

THEN THERE IS THE GREEN PARTY... The Greens leave no doubt where they stand. At their annual general meeting in Bielefeld on Nov. 16, 2019, an overwhelming majority favored supporting clean hydrogen only. They approved, almost verbatim, a document written by Ingrid Nestle, the Green Party's energy spokesperson in parliament, and five of her colleagues. The proposal, published on July 10, 2019, defines key points for a green hydrogen strategy (see H2-international, February 2020).

One aspect of the party's strategy is that hydrogen be produced in larger quantities at locations that generate an abundance of green electricity. Considering electric engines need only one-fifth or one-sixth of the energy required for power-to-x, electricity-derived fuel should only be used for transportation if there is no acceptable alternative to combustion technology. Examples include the commercial transport of goods and passengers by air, sea or over great distances, as well as of heavy cargo by road or rail.

> "Green hydrogen can help clean up energy-intensive industrial processes and eliminate the harmful emissions of heavy-duty transportation. That said, we emphatically advocate the direct use of electricity wherever possible, as it is more efficient than generating power from green hydrogen, considering the energy loss incurred by the electrolysis process."
>
> *Resolution passed at the Greens' party meeting*

Wholly dedicated to environmental issues, the Greens are adamant on one point when it comes to the hydrogen economy transition: Fossil fuel producers must not benefit from the change. The party announced it will roundly oppose suggestions funding fossil fuel infrastructure, even if that infrastructure can also deliver hydrogen.

Furthermore, the Greens demand only clean electricity be used to produce hydrogen, steering clear of a simple certification process. Rather, "there must be an additional increase in renewable facilities."

When transitioning to a green economy, the party insists clean energy prices are severely cut while fossil fuels become a high-end luxury. This will require "a more honest assessment of the carbon price we pay for fossil energy carriers." Thus far, taxpayers have borne the costs of environmental damage caused by fossil fuel consumption, giving non-renewable fuels an unfair advantage. Additionally, the Greens suggest implementing a quota for renewable kerosene usage, beginning low and increasing over time.

Those attending the meeting also spoke in favor of reforming electricity surcharges to tap local, nearly instantly available clean sources of energy to power electrolyzers. This could be achieved, for example, by reducing the surcharge set in Germany's clean energy law, EEG, whenever an excess of clean power results in such low prices on the energy exchange that operating a coal-fired power plant is no longer profitable.

Inspired by decisions taken at the meeting, Green Party MPs prepared a motion on a green hydrogen strategy in April, planning to put it to the Bundestag in the coming weeks. Signed by Ingrid Nestle, Annalena Baerbock, Katrin Göring-Eckardt and Anton Hofreiter, among others, it states >>

that "clean hydrogen and intelligent networks will have an important role to play in tomorrow's energy system."

Further, "green hydrogen has enormous potential for industries that routinely emit greenhouse gases; industries that cannot be decarbonized merely by transitioning to a clean energy network. Green hydrogen has the power to render steel industry blast furnaces climate neutral and replace petroleum or natural gas when manufacturing chemicals. […] In such scenarios, the demand for green hydrogen and clean electricity will be vast. […] A sensible short-term strategy would be to support electrolyzer capacity additions at locations that are especially suited to advancing Germany's energy market transformation."

The motion makes clear that the Greens will only back a "fixed-term electrolyzer incentive program at locations essential to the grid" in order to "use this chance to establish a verifiably clean hydrogen economy in the industrial sector." Like other political parties, it concedes the necessity to import a portion of Germany's green gas supply.

On May 27, the Greens reiterated their stance when presenting their Pact for the Future in parliament. This 47-page proposal is to be understood as a counter-suggestion to the stimulus package announced by the country's governing coalition. To support its concept, the party intends to put EUR 500 billion into a climate fund. Katrin Göring-Eckardt and Anton Hofreiter, the leaders of the Greens' parliamentary group, said that the money will go to transmission networks, a green hydrogen infrastructure, energy efficiency improvements and promoting a modal shift in transportation.

Göring-Eckardt said: "Our country does not need a stimulus program that revives the past but one that offers a courageous vision of the future." The Greens' concept suggests the government build more bike trails, expand the rail network, grow public transportation, lower the EEG surcharge and install high-speed internet cables across the country, as well as provide schools with digital equipment. Generally, support for the auto industry is not out of the question. However, funding must be tied to a pledge to change direction.

"The government's guiding principle when helping people recover from the current crisis must be a climate-neutral economy that honors the limits of our global ecosystem. It must protect both the climate and our natural environment instead of wasting precious resources. [...] In this kind of economy, all energy will be generated by renewables. This way, we will stop polluting the water we consume, the air we breathe and the ground on which we grow crops. This way, we will promote biodiversity instead of devastating more habitats. This way, we will be able to live in harmony with nature as best we can."

Green Party's Pact for the Future

... AND, OF COURSE, THE FREE DEMOCRATS (FDP) In mid-May, the Free Democrat Party then presented their own strategy paper, which they will introduce to the Bundestag. Their core argument is the same as the Greens, namely that hydrogen should be used as a storage medium in industrial settings, encompassing the potential auto market benefits. The authors write in their proposal: "Once processed into synthetic fuel, hydrogen could displace petroleum-derived diesel, gasoline and kerosene in road haulage and aviation."

The document was signed by MPs Lukas Köhler, the party's climate spokesperson in parliament, Frank Sitta and Christian Lindner, the leader of the FDP's parliamentary group. The Free Democrats promote using hydrogen of all colors, saying that a sustainable economy is the best way to ensure a climate-neutral future. As Germany's geographical and climate conditions limit domestic production, much of the demand for green hydrogen should be met by imports, especially from African regions rich in wind and solar resources. This would also offer German businesses a chance to export electrolyzers, "the latest technology supporting our fight against climate change," while keeping development and manufacturing within German borders.

However, the Free Democrats said, considering the time and money required to build facilities producing green hydrogen only, it would be irresponsible to make renewably sourced gas the be-all and end-all of a national hydrogen strategy while excluding other, equally climate-friendly options. The party has voiced strong support for blue hydrogen produced by using carbon capture and storage. The blue variant, they say, is "just as much a climate-neutral technology. So is turquoise hydrogen produced from natural gas via methane pyrolysis," adding that the turquoise version should not be denounced based solely on its fossil fuel source, natural gas.

According to the FDP, one blue hydrogen advantage is how quickly it can be available for sale. The carbon dioxide from production could be stored "safely offshore, below the North Sea." To support this argument, the proposal cites the Sleipner installation off the Norwegian coast, a project, the authors say, has "stored around one million tons of carbon dioxide under the seabed each year since its launch in 1996." With "no sign of leakage," they also claim. What they failed to mention is that at the end of 2013, scientists working for GEOMAR Helmholtz-Zentrum, an oceanographic institute based in Kiel, Germany, voiced some concerns over potentially unstable seabed spots they discovered during the ECO2 project funded by the European Commission.

All the same, the FDP expects to see hydrogen, its products and processes labeled carbon-neutral, in all three colors. ||

E3G, a climate change think tank, does not see any blue hydrogen advantages, as this pathway does nothing to eliminate all carbon dioxide emissions. Pointing to a study published by Bloomberg New Energy Finance in late March, E3G confirmed that blue hydrogen will also be more expensive than green gas in both the medium and long term.

"Because of the quantities required and their different windows for implementation, green, blue and turquoise hydrogen are not competing with each other. Blue hydrogen in particular can, and will need to, pave the way for large-scale production and consumption of green hydrogen in the future."

FDP strategy document (draft) published May 13, 2020

Theme: Policy | **Author:** Sven Geitmann

HYDROGEN-EXPORTING COUNTRIES VIE FOR TOP SPOT

Growing calls for more wind and PV power

A key objective in Germany's hydrogen strategy is to create international partnerships with green hydrogen exporters. To this end, Gerd Müller, the German minister for international development, recently signed a cooperation agreement with one of the Maghreb countries, announcing: "Together with Morocco, we are developing the first industrial system to generate green hydrogen in Africa. This creates jobs for the many young people living in that country, strengthens Germany's competitive edge in technology and helps us achieve international climate goals."

Currently, the German government's efforts concentrate on northern Africa, where there are "nearly unlimited solar resources," as Müller puts it. One unresolved issue, however, is how to transport the gas to central Europe. Options include storing hydrogen in ammonia or delivering LOHC or liquid hydrogen by tanker or via a pipeline system. Since the gas produced in Morocco should first be used to meet local needs, Müller said, there will be plenty of time to figure out how to proceed.

"The hydrogen strategy is a quantum leap in creating carbon-neutral fuels and transforming the energy market. Green hydrogen and its derivatives, such as methanol, could become tomorrow's clean source of oil."
Gerd Müller, German minister for international development

"When it comes to the environment and climate, we must be world leaders in both technology and exportation."
German science minister Anja Karliczek

Meanwhile, other countries rich in clean energy resources are preparing to set up production facilities, leaving it to the market to decide whence the least expensive green hydrogen will come. In addition to northern Africa, regions mentioned by researchers and politicians in this context include the Middle East and Australia, where an abundance of sunlight makes it easy to generate large quantities of hydrogen.

Furthermore, countries such as Argentina, Scotland and Russia are blessed with nearly inexhaustible amounts of wind energy, which enables them to produce extremely low-cost clean electricity. North Sea wind farms off the British coast would also have the advantage of being in relatively close proximity to central Europe. Likewise, off-grid energy generation zones far from any coastline offer ideal testing grounds for hydrogen production and subsequent gas exports.

Like the UK, Germany has 8 gigawatts of offshore wind power capacity installed. The British government plans to increase to 30 gigawatts by 2030, while Germany aims for "only" 20 gigawatts. As the German offshore wind farm operators association said at the parliamentary evening in Berlin in late 2019, that level of capacity will be insufficient: "We will need to produce more wind energy offshore." Andreas Feicht, who works for the German economy ministry, said: "Offshore wind energy has the potential to meet a large portion of German, British and world demand." He added: "We will need to import green hydrogen in large amounts, but expanding inland capacity is equally important."

Fig. 1: Anja Karliczek [Source: Hans-Joachim Rickel, BMBF]

Fittingly, German science minister Anja Karliczek presented a post-Covid-19 stimulus program on May 27, demonstrating her intention to "support large offshore demonstrators for producing green hydrogen." Companies should have the opportunity to "test innovative methods outside the lab," which would "equip them with what they need in these times of growing climate concerns." This, she said, is the chance "to launch the age of green hydrogen."

A month earlier, she had called for "massive investments in education, research and innovative technologies," not solely as a result of the Covid-19 pandemic. What she wants to see is "a 50 percent increase between 2021 and 2023" in the federal government's EUR 40 billion annual budget for infrastructure, education and research. In addition to digitalization projects, the budget increase would support current climate action and sustainability programs, including initiatives to bolster clean hydrogen, which she sees as the energy carrier of the future. ||

OFFSHORE WIND
In mid-May, the federal government agreed with German coastal states and grid operators on speeding up offshore capacity additions. Their new goal for connecting offshore wind farms in the North and Baltic Sea to the grid is an installed capacity of at least 20 gigawatts by 2030. This represents a 5-gigawatt increase over the government's previous target. According to the federal energy regulator, a total of 14 new interconnections will be installed between the years 2021 and 2030, one in Schleswig-Holstein, five in Mecklenburg-West Pomerania and eight in Lower Saxony. The Greens, however, want to raise that offshore wind power target to 35 gigawatts by 2035.

Theme: Policy | **Author:** Christian Schaudwet

THE FUTURE ROLE OF GRID OPERATORS AND GAS SUPPLIERS

Regulations stymy hydrogen market progress

Hybridge and Element Eins, two German flagship power-to-gas projects, have been put on hold. Managed by transmission system operators, the projects failed to secure government approval. Stakeholders now hope regulations will relax once Germany has introduced its national hydrogen strategy. Opponents warn that such a move would distort market competition.

Over a year ago, two pipeline operators, Hybridge (of Amprion and Open Grid Europe) and Element Eins (of Tennet, Thyssengas and Gasunie), submitted approval requests for their, at the time, largest German power-to-gas showcases. But the government refused to back their big plans. In the meantime, Element Eins has joined an illustrious project group, Living Labs for Climate Change. Despite the change in status, Germany's energy regulator still held fast to his red-light decision. The project must be "denied approval under current law," a spokesperson for the agency confirmed.

The newly installed BDEW energy alliance workgroup is now fervently seeking a way out of the dilemma stymying both green hydrogen projects. Considering the sharp legal strictures on electricity and gas suppliers, doubts arise as to both projects' current legality. But the biggest implementation barrier will be a new EU directive regulating the electricity market, set to be transposed into national law by Dec. 31. In Article 54(1), it states that "transmission system operators shall not own, develop, manage or operate energy storage facilities," a category under which power-to-gas systems fall.

GERMAN GOVERNMENT SEES "PROMISING APPROACHES" Nevertheless, the directive allows some exceptions. For one, operators do not have to meet "unbundling requirements" if systems are "fully integrated network components," necessary to ensure safe and reliable gas or electric grid operation. They can also advance projects when proposal requests fail to find the required electrolyzer installers and operators. However, there are companies genuinely interested in putting up the devices. Following the lead of Hybridge and Element Eins, energy supplier RWE announced plans to build a 100-megawatt storage system in the Emsland region.

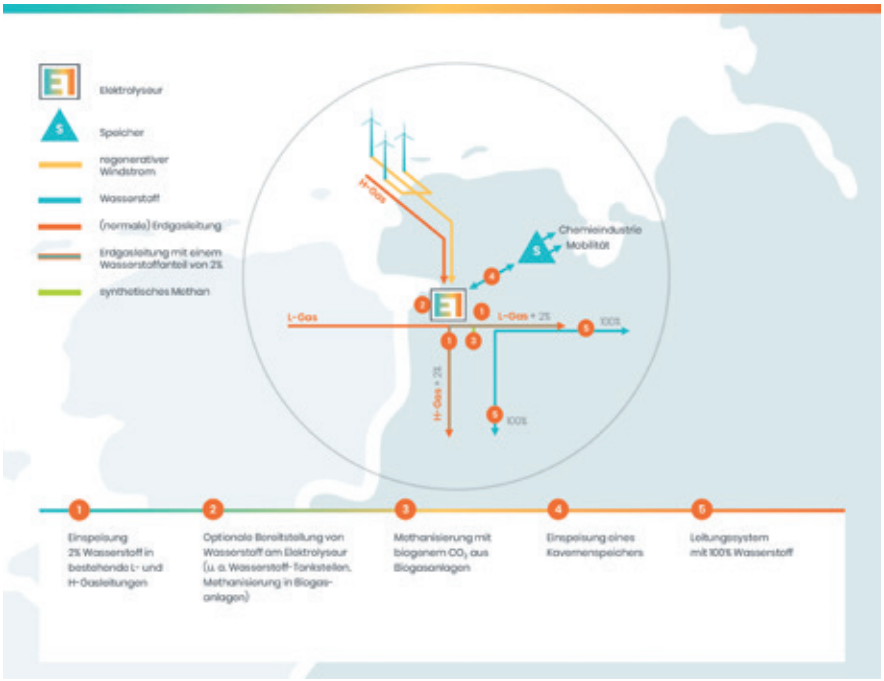

Fig. 1: Element Eins planning proposal [Source: Tennet]

The huge federal Covid-19 stimulus package offers little help to either consortium. While it contains quite a large budget for hydrogen project funding, it makes no mention of changing rules and regulations. All transmission system operators can presently do is hope for the national hydrogen strategy to come soon. Although the government has postponed strategy publication several times, the draft version includes an interesting tidbit, namely that the government intends to test "promising approaches" that relieve the national grid, produce energy at reasonable cost and ensure competitive neutrality. The document's authors speak of "one or two showcase projects," following up with a sentence the Hybridge and Element Eins consortia can pin their hopes on: "Changes to the regulatory framework to create the right environment for this type of venture are under advisement."

Will the federal government open pathways for grid operator and gas supplier projects to comply with both the national energy industry act and the European Union's electricity market directive? If so, people must be working on these plans behind the scenes. When Tagesspiegel Background asked, the economy ministry merely told them to direct their questions to Germany's energy regulator, adding it was not aware of any suggestions laying out a compromise.

DUTCH PROJECTS SHOW GREATER COMPLIANCE WITH EU RULES Despite the headwinds, grid operators have not yet given up hope. In January, Tennet completed a feasibility study on Element Eins. Additionally, the business mapped out a system design and is now waiting on the economy ministry's letter requesting a project application for the living lab. As for Hybridge, planning has progressed considerably. A spokesperson for Amprion said their project is

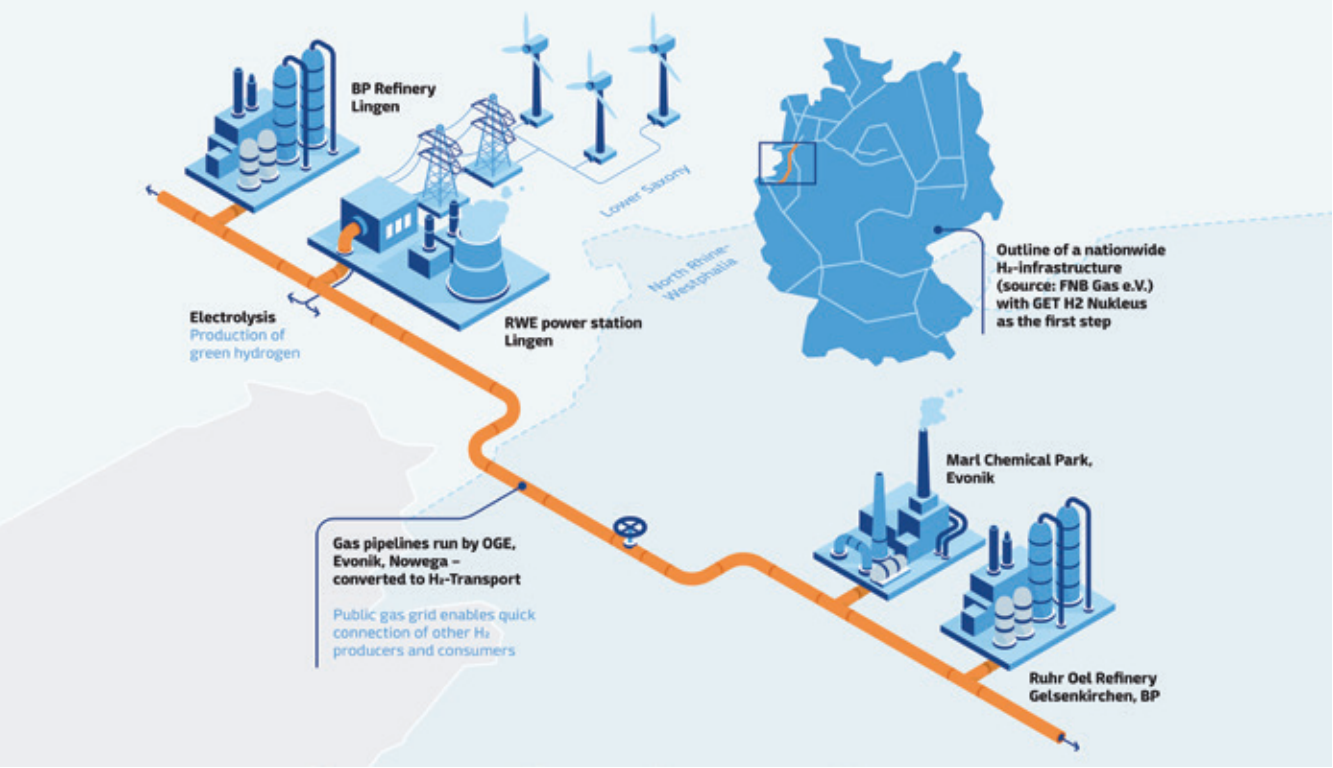

Fig. 2: GET H2 Nukleus – Germany's first public hydrogen pipeline network, will reportedly come online in late 2022 to deliver green hydrogen to industrial companies in North Rhine-Westphalia and Lower Saxony. [Source: Open Grid Europe]

ready to launch. "However, we are still waiting for the government to give us the green light." A Tennet spokesperson indicated that because of the regulatory requirements for grid operators, Tennet considers eventually transferring the project to another business entity: "In the long term, we expect companies operating in the market will run the electrolyzers." However, growing the market will require the right business, political and regulatory environment, something that has yet to materialize. Tennet hopes things will improve once the government publishes its national hydrogen strategy.

While Hybridge and Element Eins are still waiting on German politicians to act, the importance of power-to-gas is growing across the continent. In other EU countries, consortia are decidedly more directive compatible. In the Netherlands, not only pipeline operator Gasunie takes part in large projects, oil companies, port authorities and a chemical business also have their piece of the pie. Reportedly, a special company structure enables such EU compliant collectives by, for example, giving a port or an oil and gas corporation venture ownership.

OPPONENTS DEMAND ELEMENT EINS DISCLOSE PLANNING DOCUMENTS The Alliance for Fair Competition in the Hydrogen Market takes a different view of the issue. Even Germany, it says, needs business models that do not rely on transmission system operators. In a position paper published in late 2019, German clean power suppliers Enertrag, Greenpeace Energy, Naturwind and Nordgröön criticized the two projects as a waste of taxpayers' money, adding that the ventures were "detrimental to competition and innovation in the market." Enertrag and Greenpeace are already running commercial power-to-gas systems and are about to launch more related projects. As for Naturwind and Nordgröön, their power-to-gas plants are under development. In addition, Nordgröön is planning to supply electrolyzers with electricity generated by wind farms that will soon drop out of the EEG incentive program.

In September 2019, the green power alliance's legal team, Berlin-based law firm Bredow Valentin Herz, requested access to Element Eins' living lab project documents. The economy ministry refused, citing business and trade secret concerns. The firm appealed the decision in January. However, it is still waiting to hear back from the ministry, said Florian Valentin, a partner in Bredow Valentin Herz. It seems a bit conspicuous, he said, that the matter takes such a long time, as comparable cases were resolved much faster. "This raises the question: What is it that the designers do not want us to see in the project proposal?" Valentin doubts there is a reasonable argument to support the living lab venture based on the electricity market directive. He considers the whole idea behind the project to be questionable at best. "Should grid operators be allowed to burden taxpayers with grid fees as well as funding for their hydrogen generation projects?"

Opponents of Hybridge and Element Eins, however, have no issue with Germany's third 100-megawatt project, called Get H2 Nukleus, since it will be neither built nor run by transmission system operators. The electrolyzer RWE plans for the project in Lingen, Lower Saxony, will generate clean hydrogen and, starting in 2022, deliver gas through a 130-kilometer-long pipeline to industrial businesses in Lingen and farther south in Marl and Gelsenkirchen (see fig. 2). In contrast to Hybridge and Element Eins, the partners in Get H2 Nukleus come from a wide variety of industries. They include BP, Air Liquide, Evonik, Enertrag, BASF, Salzgitter and Uniper, plus some businesses that distribute electricity or gas, such as Open Grid Europe and Thyssengas. In a market as promising as this one, transmission system operators obviously do not rely on their Hybridge and Element Eins partners Amprion and Tennet alone. ||

This article was first published on April 22, 2020, in Tagesspiegel Background Energie & Klima. At that time, the national hydrogen strategy was still in the works.

Theme: Policy | **Interviewpartner:** Frans Timmermans

AN ADVOCATE OF CLEAN HYDROGEN

Interview with Frans Timmermans, European Commission

Even though the European Commission supported many hydrogen and fuel cell projects in the last several years, this industry sector was rarely mentioned in Brussels. However, all of this changed in 2019, when high-ranking German politicians started taking a second look at the technology. And soon after German economy minister Peter Altmaier said that Germany needs to become the world's leading market for hydrogen, Ursula von der Leyen, the EC's new president, unveiled the European Green Deal at the United Nations Climate Change conference in Madrid, where the plan drew considerable media attention. She also brought an advocate for a hydrogen economy on board, Frans Timmermans, who she appointed executive vice president for the Green Deal as well as commissioner for climate action. H2-international recently spoke with Timmermans about the prospects for a European hydrogen economy.


[Source: European Commission]

H2-international: What led you to become interested in the energy market and in climate action, especially in hydrogen?
My interest in the European project goes back a long way, coming from a border town in the Netherlands and having lived in different countries, I have always been fascinated about what Europe means for people. It's more than an economic market, it is also a union of values, and the embodiment of a voluntary cooperation to stand taller and stronger in the world. However, the raison d'être of the 20th century – never war again – doesn't necessarily resonate as strongly in the 21st century, even if I think that promise to ourselves remains eternally valuable.

Today, however, I am convinced that the European Union has another good reason to prove why we really need to work together to tackle one of the greatest generational challenges ever, namely the transition to a green and sustainable economy. Not just for the planet, but for ourselves and our children. The corona virus crisis has also made it clear how fragile we are, and that protecting natural ecosystems is key to boosting our resilience and preventing the emergence of future outbreaks.

Climate change if unchecked will have dire consequences for our habitat, health, and our future. Our citizens have made it clear that they want us to do something about it. We must act, as the choices we make today will define tomorrow's future. We must change our energy and transport systems, the way we build, eat, work and the way we live. We need to press fast-forward with science, innovation and clean technologies to give a cleaner planet to the next generations. And in all of this I firmly believe in hydrogen as one of the key technologies to be part of those solutions.

What do you want to accomplish with the Green Deal?
First and foremost, the Green Deal is Europe's new Growth Strategy. We want to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. It also aims to conserve and enhance the EU's natural capital and protect the health and well-being of citizens from pollution and environment-related risks. Our children and grandchildren should not have to worry about the air they breathe, the water they drink and the food they eat.

What role should hydrogen have in it?
Hydrogen is an indispensable part of our efforts to be climate neutral in 2050. As a sustainable technology, clean hydrogen can replace fossil fuels in part of the economy that are hard to decarbonize such as e.g. the chemicals and steel industry or heavy transport. As a carbon-free energy carrier, hydrogen would also allow for transport of renewable energy over long distances, for storage of large energy volumes.

When you hear the word hydrogen, do you think of it as primarily being a chemical element, a raw material for industry or a way to store energy?
The beauty is that hydrogen has multiple functions: it is a chemical element, and a raw material and a way to store energy. From the perspective of the energy transition it is first of all an energy carrier and more expensive because you need to produce it first. To build the business case for hydrogen you need to put a value on the diversity of roles that it can play, whether it is to store renewable power or to decarbonise heavy industries and transport.

How do you assess the role of hydrogen for Europe?
In my role as Executive Vice-President for the European Green Deal, it is my responsibility to put Europe on a journey to a sustainable future. This means not only defining our long-term objectives but also identifying the concrete instruments and steps to get there. We have enshrined the EU's 2050 climate-neutrality in legislation when we presented the European Climate Law in March 2020. We will present after the summer an ambitious 2030 climate target. But I also need to ensure the right investments in clean technologies that will help us to realise our ambitions. This is why I am an advocate of clean hydrogen. It is clearly one of the technological solutions to reach our goals.

Could you elaborate on what steps you intend to take to pave the way for a European hydrogen economy?
We need to start the journey now and step up the pace. The European Commission's Hydrogen Strategy and Clean Hydrogen Alliance, announced in our Industrial Strategy will

present our long-term vision for a hydrogen economy in Europe based on renewable hydrogen produced from renewable electricity, in particular solar and wind. In a transition phase, the production of low-carbon hydrogen based on natural gas, combined with carbon capture and storage (CCS) technologies, or other low-emission pathways if they are commercially available, can support the effective scale-up of renewable hydrogen by contributing to satisfy medium-term demand for hydrogen.

For kick starting an EU hydrogen economy, we need to upscale production and demand to develop a European wide market and to ensure that public acceptance and safety aspects are fully addressed. Hydrogen is today less than one percent of the energy mix. The most ambitious scenarios from the hydrogen industry point to about 24 % by 2050, illustrating that hydrogen could play a very important role in the economy. Still, large-scale deployment depends on a number of critical factors related to the regulatory framework such as certification or to financing of investments, support to technology developments, cost reduction as well as availability of infrastructure. Our Strategy addresses all these factors.

Do I understand you correctly that while you are in favour of green hydrogen, you can also live with blue hydrogen?
Renewable hydrogen emits less CO_2 than hydrogen from natural gas, combined with carbon capture and storage (CCS) technologies (so-called "blue" hydrogen). It can also help integrate renewables, provide services related to large-scale energy storage and support deep decarbonisation. However, we know that at least in a transition phase we will not have all the hydrogen needed coming from renewables, so we need also blue hydrogen, to decarbonise the existing hydrogen.

So what you said before means you do want to restructure the Union's energy market?
The energy market already took into account hydrogen as part of the energy storage provisions in the clean energy package. But yes, we will certainly analyse what needs to be done more in particular as hydrogen can represent an important part of the decarbonised gases we will have in the future energy mix.

Do you not expect strong opposition from conventional energy utilities, which fear that restructuring the market will force them to abandon their current business models?
What change did you ever see that was not challenged the status quo? And at the same time, I see a lot of interest from many stakeholders and industries. Everybody knows that we are in a fundamental era of change, and that achieving carbon neutrality means adapting to the new environment; hydrogen solutions are very promising and can facilitate this change by modernising industries and promoting new technologies in which Europe can be a leader. There are challenges ahead, but also huge opportunities for the European industry. And this is one area where we should not cede the pole position to others.

And what does Ms. von der Leyen think? Will she be supporting you in all of this?
The President and I are pulling at the same end of the rope. In her political guidelines presented last summer, Ms. von der Leyen demonstrated her strong ambition on environment, climate and energy policies, announcing that she wanted the Commission to present a Green Deal within the first 100 days of office. We delivered on that commitment in December 2019, even within two weeks in office, and increased also our climate ambition. It is clear, that hydrogen must play a critical role to achieve that ambition. President von der Leyen explicitly mentioned clean hydrogen as a key technology to invest in in her speech at the European Parliament Plenary on 13 May.

What time frame are we talking about here? How long will it take to transform the energy market?
We need to start now. This will take a few decades but the choices we make today will define tomorrow's future for the next generation. Today we have less than 1 GW of electrolyser capacity in Europe, we should support industrial endeavours to move toward 40 GW in 2030. However, depending on the scenarios, we may need up to 400 to 500 GW by 2050. The regulatory framework will need to evolve to make this transition possible. We also need to very quickly accelerate the deployment of renewable electricity that will be required to produce this hydrogen.

What do you want Germany to do when it presides over the EU Council in the next months?
It's the task of every Presidency of the EU Council to find consensus between our 27 Member States in Europe. I am convinced that Germany will do an excellent job in taking forward our Hydrogen Strategy and discussing it in the Council in the wider context of the green transition and recovery agenda. I am really looking forward to working together with them.

Would you have wished that the German government take a more proactive stance and offer broader support for the Green Deal?
The hydrogen agenda is a very wide one, requiring coordination between a variety of actors, that is true within the European Commission as well where the services responsible for energy work closely together with those responsible for the internal market, research and innovation but also with our climate experts and external relations people. While coordination takes time, it is essential to create full ownership and the comprehensive approach that is required.

How do you think European automakers should respond? Except for Renault, most of them seem to have passed up the opportunity to electrify transportation, or do you disagree?
You should also ask what consumers want. They want clean air, they want sustainable and affordable transportation. The automotive industry by and large has seen the writing on the wall. Many automotive leaders I have spoken to already have made the transition, in their mind or in their factories. And once they really move, it will go fast. Transport accounts for a quarter of the EU's greenhouse gas emissions and within transport, road emissions account for 75 % of the CO_2 emissions and those are still growing. So much more needs to be done. The Commission will propose to revise the legislation on CO_2 emission performance standards for cars and vans to ensure a clear pathway from 2025 onwards toward zero-emission mobility. By 2025, a minimum of 1 million public recharging and refueling stations will be needed for the 13 million zero- and low-emission vehicles expected on European roads. In our upcoming strategy for sustainable and smart mobility, we will tackle the challenges and tackle all emission sources.

Lastly, when will we see some concrete H_2 plans for the deal?
Immediately after the launch of the Green Deal in December 2019 and in less than six months, we already presented the first but vital parts of our efforts in delivering the Deal: the European climate law, the Green Deal Investment plan, the EU industrial strategy, the Circular economy action plan and the biodiversity and farm to fork strategies. Next up is our hydrogen strategy.

Mr. Timmermans, thank you for your time. ||

Theme: Energy storage | **Authors:** Maximilian Schleupen, Prof. Herbert Pfeifer, Dr. Joachim G. Wünning

GREEN HYDROGEN FROM BIOGAS

An opportunity for Germany?

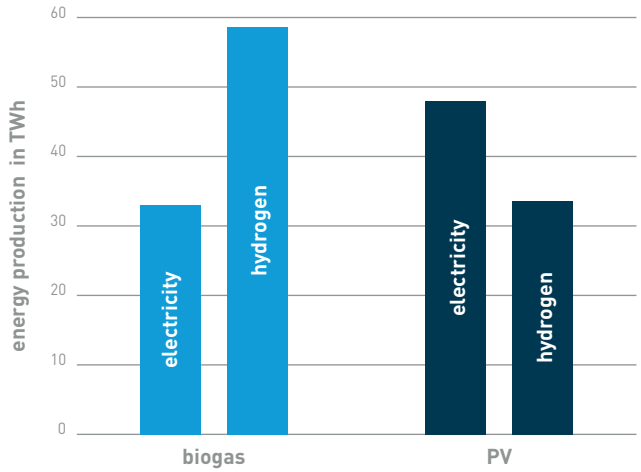

Fig. 1: Electricity generated from biogas and PV in Germany in 2019 and hydrogen production potential based on steam reforming (biogas) and PV-sourced electrolysis [2, 3]

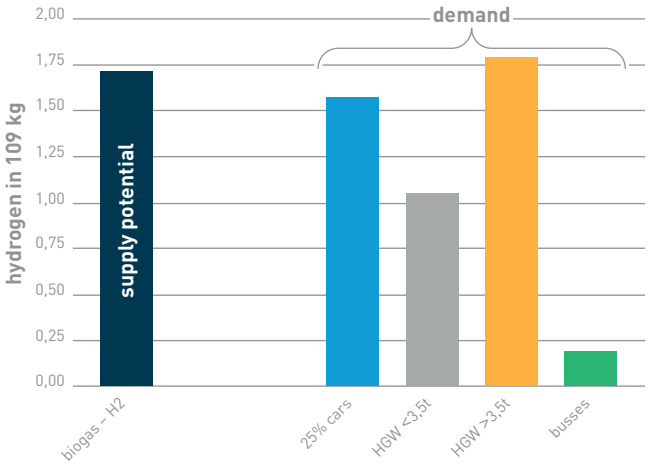

Fig. 2: Potential for producing hydrogen from biogas and demand for hydrogen from different parts of the transportation sector, calculated based on [5].

Hydrogen is considered the ideal raw material for a sustainable energy market transformation. However, some questions still await answers. Where will we get our hydrogen? Will we use the gray, blue, turquoise or green variant in the distant and not-so-distant future? Green hydrogen is produced using renewable energy sources and often generated via water electrolysis. However, one of the biggest obstacles to using the gas, most of all in transportation, is its poor conversion efficiency. From the 100 kilowatt-hours of clean power fed to an electrolyzer, only 32 will end up in the fuel tank. The remainder is lost during electrolysis, compression, delivery, and ultimately, during fuel cell conversion. By contrast, the efficiency of all-electric vehicles is around 73 percent [4]. This article will discuss the option of producing renewable hydrogen from biogas via steam reforming. A crucial advantage of this pathway is its astonishing efficiency. Compared to water electrolysis, biogas-sourced hydrogen has a cutting edge – in more ways than one.

Biogas facilities produce biogas from both biogenic waste and sustainable raw materials. Around 90 percent of the gas is fed to distributed cogeneration plants, thus producing both electricity and heat. The other 10 percent is processed into biomethane. In 2019, around 9,500 biogas systems were up and running in Germany, feeding 31.9 terawatt-hours into the national power grid [1, 3].

Yet, biogas is more than just a source of electricity and biomethane. Via steam reforming, the methane-rich gas can also be used to manufacture green hydrogen, whereby a catalyst refines and separates the hydrogen from the gas stream. Steam-reforming natural gas, with subsequent pressure-swing adsorption to remove impurities, is currently the most common hydrogen production method in all corners of the globe [8]. Small reformers, such as those required for CHP biogas plants, are already commercially available, indicating tried-and-true technology can be tapped immediately.

BRIGHT PROSPECTS FOR THE HYDROGEN INDUSTRY

Biogas-sourced hydrogen can significantly improve energy efficiency. Instead of generating 31.9 terawatt-hours of electricity a year, German biogas plants could switch to steam reforming to produce around 58 terawatt-hours, or 1.7 billion kilograms of hydrogen annually (see fig. 1). By contrast, PV systems in Germany produced 47.5 terawatt-hours in 2019, and the country's total PV generating potential would be only around 33 terawatt-hours' worth of hydrogen [2, 3].

In short, Germany has great potential for biogas-sourced green hydrogen. Even today, biogas plants could make more hydrogen with steam reforming than water electrolysis can when drawing on all the country's existing PV systems combined. The total potential for hydrogen production from biogas is around 40 percent of that for generating hydrogen from other clean sources of electricity (wind, hydropower, geothermal and biogenic waste) [2, 3]. Additionally, manufacturing hydrogen from biogas does not reduce the primary energy potential as water electrolysis does.

The current potential for green hydrogen produced from biogas is enough to meet nearly all of Germany's heavy-duty transportation demand. Alternatively, it could power a fourth of all passenger cars and the entire mass transit fleet (see fig. 2) [5].

The biogas-hydrogen pathway defies all arguments against hydrogen's energy efficiency. Compared to other hydrogen-powered solutions in transportation, it can provide fuel cell vehicles with clean fuel containing around the same amount of energy as the power fed to all-electric vehicles. It also triumphs over natural gas vehicles in a well-to-wheel analysis.

BIOGAS INCENTIVES

The number and production capacity of biogas plants in Germany far outshine those of any other country. The industry grew markedly between 2004 and 2014 [1, 2]. To support economic viability, a feed-in tariff was written into the German EEG clean energy law to cover expenses for biogas plants over the first 20 years of operation. Support

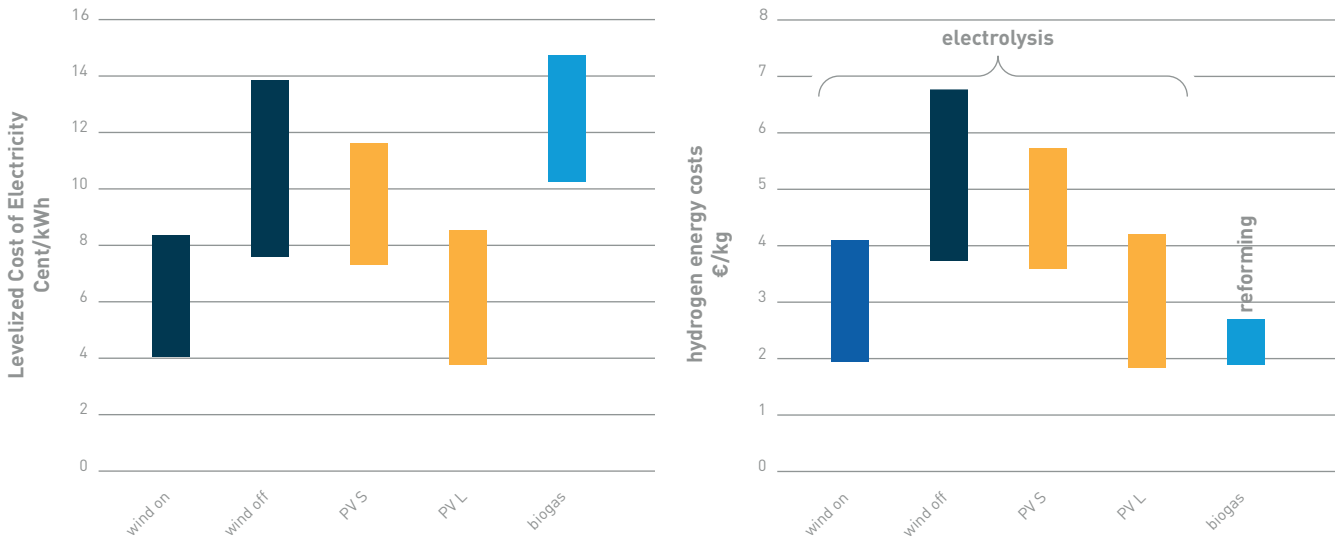

Fig. 3: (a) Levelized cost of electricity for new wind energy (WE), onshore and offshore, small and large PV systems and biogas in 2018; (b) hydrogen production costs calculated based on LCOE values [6]

for most production facilities, however, will end by 2034, and not all of them have prepared for their economic survival [7]. Thus, around 66 percent of installed capacity, i.e., 55 percent of all plants, may no longer be running by 2030. Starting in 2035, Germany will need to find other means of compensating for a loss of about 20 million tons of CO_2 equivalent, which, until then, have been diverted by energy generating organic fertilizers.

A COMPETITIVE EDGE In 2018, Fraunhofer ISE published a comparative study estimating the installation costs of various clean energy systems (see fig. 3 a) [6]. The study showed high levelized cost of electricity for biogas facilities in comparison to onshore and offshore wind energy, as well as large and small PV systems. However, producing green hydrogen with steam reforming greatly improved economic viability (see fig. 3 b), enabling biogas facilities to compete with the most profitable wind power and PV sites in Germany.

BIOGAS – A GOLDEN OPPORTUNITY TO EXPAND OUR HYDROGEN INFRASTRUCTURE? In contrast to wind turbines and PV systems, biogas facilities run in any weather. Their constant, reliable output makes supply predictable and controllable. Mass transit companies, for example, will expend a great deal more on new vehicles than they will on hydrogen supply infrastructure. Increasing fleet service hours will go far to reducing financial risks. Public buses must be available independent of weather conditions. Hence, biogas is the perfect energy source for producing hydrogen fuel.

The average biogas plant in Germany supplies around 400 kilowatts of instantly operational electric generating capacity [1]. This capacity could be used to produce around 18 kilograms of hydrogen an hour, enough to fill up about 18 fuel cell buses. Additionally, hydrogen production capacity could grow with demand since plants first produce biogas before creating hydrogen. The biogas could therefore be purified to create both hydrogen and biomethane or used to supply on-site electricity.

CONCLUSION Generating clean hydrogen from biogas is a technologically well-established production pathway. Over the next years, however, some biogas facilities risk permanent shutdown. What would give them, and all other biogas plants, a strong competitive edge in the clean energy market is their constant, economical potential for producing hydrogen. There is an abundant and readily available supply of biogas throughout Germany. Furthermore, steam-methane reforming is exceedingly efficient, a strong recommendation. Green hydrogen produced from biogas offers Germany a ready impetus for growing its hydrogen economy and infrastructure, providing a reliable, major source of hydrogen alongside electrolysis. ||

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Theme: Energy storage | **Author:** Jens Krause

THE BIRTH OF A HYDROGEN ECONOMY

The Lausitz – HyStarter region and living lab

When the Cottbus chamber of industry and commerce (IHK) and the regional economic development agency of Lausitz (WRL) announced they had submitted a bid to the German transportation ministry to be part of the HyStarter innovation cluster program, few locals believed those two had a chance to win. The field was crowded with 120 regions throughout Germany competing for one of the highly sought-after spots on the program. So, on Sept. 9, 2019, when Lausitz residents discovered their region was among the nine winners, they were more than overjoyed. The following lines are a stab at explaining how this success came about.

HYSTARTER
WASSERSTOFFREGION LAUSITZ

In the times ahead, no other region in Germany will undergo more profound economic changes than the Lausitz, whose traditional industries are dying. The government has decided that by 2038, that is, over the next 18 years, the region must shut down coal mines and power plants. A political decision with far-reaching consequences.

About every tenth kilowatt-hour of electricity used somewhere in Germany right now is produced in coal-fired power stations in the Lausitz. More than 16,000 people are currently employed at open-pit mines and energy generation facilities or as service providers and suppliers catering to the industry. In short, energy businesses have long been the backbone of the region's industrial sector.

ENERGY OF THE TIMES The regional government cherishes its decades-long ties to the energy industry. In fact, the region has all the right amenities to give power producers a home. Hydrogen could be the boost the Lausitz needs, opening up new opportunities for transporting and storing energy.

> "Hydrogen is one of the most intriguing future energy carriers."
> *Jens Krause, spokesperson for the Lausitz Hydrogen Alliance*

When transforming the region's economy, the coal industry's well-paying jobs must be replaced with other high-quality roles in industry. Local businesses also need to develop green, sustainable technology, using hydrogen instead of fossil fuels, since the gas meets all the right criteria to become a key technological showcase.

The energy carrier will play a central role in the region soon enough: The regional government plans to use wind and solar energy to produce eco-friendly hydrogen, fueling buses, cars, trucks and airplanes and blending it into the natural gas grid. There are also plans for raising factories to make fuel cell components.

The success of the program hinges on the availability of highly qualified energy specialists who have what it takes to make change happen. People who call, or want to call, the Lausitz home. People who love working there.

Lausitz science institutes have already had a foot in the hydrogen door for quite a while. Take the BTU Cottbus-Senftenberg's hydrogen center of excellence, led by Hans-Joachim Krautz, or the hydrogen-focused Combustion and Aircraft Engines chair with Heinz Peter Berg leading the way. Then there is Alexander Kratzsch at the Zittau-Görlitz University, with his similarly extensive expertise in hydrogen technology. Zittau is also home to the Fraunhofer Institute for Machine Tools and Forming, better known as IWU. In addition, Cottbus has recently founded the Center of Excellence for Climate Action in Energy-Intensive Industries.

THE PLAN By turning the Lausitz into a HyStarter innovation cluster, the German government honors local stakeholders and their hard work paving the way to a hydrogen economy. Supported by expert voices from Berlin-based Spilett New Technologies, local authorities are now preparing a well-founded, economically feasible strategy, zooming in on four types of projects:

1. Develop zero-emission fuel cell buses, trains, trucks, cars and airplanes and put up hydrogen fueling stations across the region.
2. Generate thermal hydrogen energy to heat urban apartment buildings and individual residences, with the aim of replacing all coal-fired heating systems, as power stations will be shut down by 2038 at the latest.
3. Produce hydrogen from waste in a circular economy to supplant fossil fuels by 2038 while increasing the number and range of sustainable technologies developed in the Lausitz.
4. Set up a supply chain to manufacture electrolyzers and fuel cell components in the region.

Six workshops to be held by September are part of the overall strategy. Attendees will have the opportunity to evaluate projects, to talk about where to leverage synergies and to make proposals. The subsequent phase will entail funding requests for individual projects.

DURCH H_2 ATMEN
WASSERSTOFF MODELLREGION LAUSITZ.

MAKING THINGS WORK In summer 2019, twenty business, science and government organizations came together to establish the Wasserstoffnetzwerk Lausitz durcHatmen in Cottbus. The collective's goal is to ensure the local economy benefits from hydrogen, offering hands-on solutions and keeping the industry up to date on technology advancements. IHK Cottbus and WRL are coordinating alliance activities. One item high on the agenda is exchanging information with other alliances, such as HZwo and Energy Saxony in Saxony and HYPOS in Saxony-Anhalt.

It was quickly evident to Lausitz locals that hydrogen has enormous potential, requiring the involvement of organizations throughout the region. Since then, the network has grown to nearly 100 members with supporters based in both Saxony and Brandenburg. Members and supporters include manufacturers, transportation providers, service companies, research institutes, local governments, associations and utilities. Almost every one of them has a concrete plan for a hydrogen project in the Lausitz.

"Hydrogen has the potential to become one of Lausitz's most important technological showcases. But this will require some political backing."

Jens Krause

Fortunately, the federal government has also recognized the opportunities hydrogen offers to the regional economy. As further evidence, besides the Lausitz becoming a HyStarter innovation cluster, the region recently won a nationwide idea competition, Living Labs for Climate Change. The prize is a federally funded pilot power plant using hydrogen to generate electricity at the Schwarze Pumpe industrial park.

THE DURCHATMEN CONSORTIUM AIMS TO

- Represent the interests of business, science and politics in advancing a hydrogen economy.
- Popularize hydrogen along the region's entire value chain, ranging from green hydrogen production to use of the gas in several industries.
- Identify and bring together potential producers and consumers, as well as manufacturing value chains.
- Accompany and promote flagship projects and vehicle purchases by both the public and private sector, targeting mass transit companies in particular.
- Attract investors to install hydrogen fueling stations.
- Decarbonize processes by replacing fossil fuel sources with hydrogen, starting with the transportation, heating and waste collection industries.
- Increase production capacity for fuel cell and electrolyzer parts and components.
- Map out plans for expanding the fueling infrastructure for buses, trucks and passenger cars.

SCHWARZE PUMPE SHOWCASE One of the most innovative pilots involves a power station named Schwarze Pumpe. It will be converted from a conventional coal-fired energy generation facility to a hydrogen storage plant, scheduled to go online by 2025, at the latest. The electricity required to run the plant will come from wind or solar energy facilities across the region. These, in turn, will be used to generate green hydrogen in an electrolyzer. The gas can then be temporarily stored in the natural gas grid, from where it will be retrieved to generate and feed electricity into the grid in the absence of wind or sunlight. This way, it can provide baseload capabilities to meet demand from large industrial consumers at any time. The hydrogen produced by Schwarze Pumpe will also be available to local manufacturing businesses and other consumers that need energy for transportation or heating, making the pilot a crucial part of the supply chain.

"Unless the government quickly adjusts the high tax rates and surcharges on green electricity, the national hydrogen strategy is not worth the paper it is written on."

Jens Krause

The project consortium includes several well-known German companies, all of whom intend to go down in history as technological innovators as they establish living labs in the Lausitz. To make these labs a success, the government must allow the consortium building the pilot plant to use experimental provisions, which are outside the scope of current legislation. An important milestone is expected this fall, when the European Union and the German government establish the regulatory framework for the pilot. This will be the perfect time for politicians to show that they are serious about transforming the German energy industry and that technological progress Made in Germany has a real chance.

THE POWERS THAT BE Right now, businesses and state governments are looking to the federal government, awaiting the national hydrogen strategy. The strategy proposal should be a kind of road map showing where the journey will go. Clearly, not only the country's renewable energy law, EEG, will need to see fundamental reforms but other provisions need to be revised as well if we want to support a hydrogen economy in the Lausitz. It is now in the hands of the German government to demonstrate that hydrogen technology truly has an economically viable future in this country. ||

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

GREEN REFINERIES

Petroleum industry wants clean hydrogen for making fuel

[Source: Neste]

Fig. 1: In Neste's biorefinery in Rotterdam, a multi-megawatt high-temperature electrolyzer will produce green hydrogen for biofuels.

In Wesseling, North Rhine-Westphalia, Germany's coal heartland, a new transportation era is dawning – at least if oil giant Shell has a say in it. "Petroleum products will continue to play an important role in the decades to come. This project will allow us to make both clean fuels and petrochemicals," Frans Dumoulin, the general manager of Rheinland Raffinerie, a Shell-owned refinery, was happy to announce in front of about 100 guests at the REFHYNE project's groundbreaking ceremony in summer 2019. "We also intend to promote hydrogen in transportation and other sectors," he promised. The refinery will soon install a 10-megawatt ITM Power PEM electrolyzer to produce 1,300 tons of green hydrogen a year.

A total of EUR 16 million will be invested in Shell's flagship project and regional showcase located between Cologne and Bonn. The aim is to show hydrogen's potential for fueling stations and thus for cars and buses. Projects such as REFHYNE enable Europe's electrolyzer manufacturers to build systems meeting even the strictest continental refinery standards, said Bart Biebuyck, the executive director of the Fuel Cells and Hydrogen Joint Undertaking, a European public-private partnership. Clean hydrogen will also help lower the carbon footprint of industrial processes, he added.

The Hydrogen Potentials Map of March 2018, an IG BCE Innovationsforum Energiewende and petroleum association MWV prognosis, estimates that clean hydrogen would immediately lower transportation-induced fuel emissions by around 104 grams of carbon dioxide per megajoule. This even exceeds regulatory carbon offsets, which credit only up to 91 grams of carbon dioxide per megajoule.

NEEDED: ONE OR TWO GIGAWATTS ELECTROLYZER CAPACITY

The savings are worth it. Refineries generate about 20 percent of all carbon dioxide emissions in Germany's industrial sector. In 2015, about 40 percent of the hydrogen produced nationwide was used to refine crude oil, according to a study published by dena, the German Energy Agency. In all, 78 percent of the hydrogen is produced at the refinery itself with 22 percent coming from external sources, i.e. natural gas reformers. According to dena, the green variant saves 9 tons of carbon dioxide emissions per ton of hydrogen, a relatively low-cost way to significantly reduce petroleum products' and fuels' carbon footprint. "Replacing all fossil fuel hydrogen in refinery processes with clean hydrogen requires an electrolyzer capacity of up to 150,000 tons a year, that is 1 to 2 gigawatts."

"The EU's recast renewable energy directive RED II, if promptly introduced, could close the economic viability gap in green hydrogen projects," said Stephan Frense, Arge Netz' chief executive. Crediting green hydrogen emission reductions is a crucial financial incentive. However, he added, the government is exceedingly sluggish to implement regulations, whereas the petroleum industry is acutely aware of the need for climate action and decarbonization. He put forth the Arge Netz power-to-heat joint venture with oil companies as a prime example of the industry's very forward-looking attitude: "Thanks to this project, homeowners in Friedrich-Wilhelm-Lübke-Koog in Schleswig-Holstein can use locally generated wind energy to supplement their oil heating system." He calls it "acceptance through participation."

Green hydrogen must be on an equal footing with fossil fuel-generated hydrogen, said Werner Diwald, the German hydrogen and fuel cell association DWV's chairman. Moreover, the required electricity must come from renewable sources only, "regardless of whether it is produced on-site or drawn from the grid," he added. To make this work, he said, we must run electrolyzers on clean power generated independent of EEG incentives, i.e., electricity from direct sales or energy contracts, as that would increase neither EEG surcharges nor consumer bills.

DWV CALLS FOR IMPLEMENTING RED II

Green hydrogen is crucial to meeting Germany's climate targets. To expedite market availability, DWV suggests the

government lower taxes on green hydrogen or derivative products for making transportation fuels. "What we really need is for the German environment ministry to get moving and transpose the European Union's RED II into national law by the end of this year," Diwald said. Green hydrogen suppliers that make fuels, add hydrogen derivatives or use the gas directly in transportation, he added, must be allowed to credit emission reductions against climate targets. During its EU presidency, Germany must come up with a detailed suggestion on how to accomplish this, as refineries are a cost-effective option for integrating clean hydrogen into the economy.

Fig. 2: This compact power-to-liquid pilot plant put up at Karlsruher Institut für Technologie – KIT synthesizes fuel from carbon dioxide in the air. [Source: Sunfire]

The petroleum industry supports green hydrogen production at refineries, since the gas can be almost immediately incorporated into their processes, Diwald said. When eco-power or clean hydrogen fuels are used to refine oil, it instantly lowers emissions in the transportation sector, too. The association's Performing Energy expert committee, whose members include oil corporations such as Total and BP, has been analyzing the European and German regulatory landscape for years. They aim to create a legal framework for crediting green hydrogen production against GHG reduction targets, offering an economically viable path for the refinery market. So far, fuel quality standards have made that impossible.

Demonstration projects such as Shell Rheinland's REFHYNE in Wesseling illustrate the petroleum industry's vested interest in clean hydrogen production, Diwald said. To meet legal obligations, oil corporations are also pouring large sums of money into fueling infrastructure projects for hydrogen-powered vehicles. In short, the industry can and wants to reduce emissions by 1.7 million tons of carbon dioxide a year.

OIL COMPANIES WANT MORE GREEN HYDROGEN Oil corporations, Diwald said, are not to blame for the current lack of results, as the German environment ministry has yet to turn RED II into law. "The petroleum industry is willing to increase green hydrogen use and lower emissions, but the German government must provide the regulatory framework to make it financially worthwhile," he added.

The government estimates that nationwide demand for hydrogen will increase to 55 terawatt-hours a year by 2030. Considering current climate targets, the increase must be clean energy-sourced, which requires adding a minimum of 20 gigawatts by 2030. "However, we must talk about whether this electrolyzer capacity has to be installed entirely in Germany," Diwald said. Refineries alone require 2 gigawatts to substitute the hydrogen currently produced by reforming natural gas. The DWV is calling for a national onshore and offshore wind market of 5 gigawatts each and imports of 10 gigawatts.

Diwald reiterated that achieving Germany's climate targets requires sizable clean energy imports to both Germany and Europe. Most industry experts expect imported eco-power to exceed 1,000 terawatt-hours per year. Hydrogen and its derivatives could help meet this demand. Resistance, Diwald said, is rather coming from those who refuse to accept hard facts.

AN OPPORTUNITY TO CREATE JOBS DWV sees the refinery market as a golden opportunity to meet the huge hydrogen demand while providing enormous economic benefits. The association's market outlook study states that at least 35,000 people could be working in electrolytic hydrogen production in Germany by 2030. In Europe, the medium-term potential is 5.4 million jobs across the continent at annual revenues of EUR 800 billion, according to estimates by Hydrogen Europe and the European Commission.

However, the Cologne venture is not the only project planning to use clean hydrogen to make biofuel. In March, biofuel producer Neste launched MULTIPLHY, intending to manufacture hydrogen at its Rotterdam refinery. The project's 2.6-megawatt electrolyzer will come from Sunfire based in Dresden, Germany. The consortium that will install, integrate and operate the device also includes industrial equipment manufacturer and Sunfire investor Paul Wurth. The electrolyzer will reportedly generate 60 kilograms of hydrogen an hour, or 525.6 tons a year. Sunfire's chief executive, Nils Aldag, said the consortium partners hope to eventually upscale the project to 100 megawatts. That would be the next important milestone for transforming the transportation sector in Germany and Europe. ||

UP TO 85 PERCENT LESS CARBON DIOXIDE

In early 2016, the German University of Stuttgart's Lifecycle Engineering Department published an environmental status report announcing synthetic diesel can make internal combustion engine vehicles much more eco-friendly. The study, commissioned by the German education ministry, compares synthetic fuel, known as blue crude, with biogenic and fossil energy carriers.

"Initial results indicate that 'blue crude' can reduce fossil fuel-induced carbon dioxide emissions from 35 to over 85 percent, offering significant environmental benefits under certain conditions," Aleksandar Lozanovski, the project's manager, noted. The synthetic diesel fuel was produced by startup company Sunfire from carbon dioxide and water for the first time in March 2015 (see HZwei, January 2015).

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

THE ONE-STOP H_2 CONTRACTOR

Apex Energy provides hydrogen supply chain

Apex Energy Teterow CEO Mathias Hehmann has one vision: to turn his Rostock-based business into a one-stop hydrogen contractor. He intends Apex Energy to design, plan and install devices producing and storing hydrogen as well as run and maintain them over their lifetime. He will also do away with complex, time-consuming contract negotiations and pre-project work. Instead, his company will offer custom-tailored system packages covering everything from energy generation, electrolysis and storage to fuel cell or CHP installation. Since May, Apex Energy, an Apex Group subsidiary, has been giving visitors to its offices in Laage, Germany, a first glimpse of what to expect from the company's product portfolio.

Hehmann, 47, has bought a large piece of land right next to Rostock-Laage Airport. There, he will build a pilot system to publicly demonstrate his idea of a distributed energy grid. Currently, all required components are being delivered to Apex Energy's premises, where it will link them up one by one.

On May 8, Proton Motor's fuel cell arrived in a small, blue container (see fig. 1). Hard by is a green one holding a 2G CHP plant. More containers are scattered about the yard, all painted white. Inside of each of them is a hydrogen tank that came straight from manufacturer emano. Toward the back of the site, a hydrogen fueling station is being built in collaboration with McPhy and Resato. But first things first.

A COMPLETE SUPPLY CHAIN SOLUTION

The spacious halls Hehmann and his team moved into 18 months ago used to house a printing company. At present, they are pretty much one big empty space. Only a dozen containers have been put up, spread out over a wide, gray field of concrete, as if someone forgot to take them away. This is where the company is planning to install a variety of several partners' production lines.

> "As a full-service provider, we deliver custom-tailored system solutions to generate the energy of tomorrow."
> *Mathias Hehmann, chief executive, Apex Energy Teterow*

Hehmann, who sees his company as a connecting element along the value chain, is planning to offer customers one-stop solutions for their energy needs, with components ranging from PV systems to hydrogen storage tanks. As a longtime professional in the PV industry, he is elated about the growth of the hydrogen market. According to him, the energy carrier offers the "missing piece of the puzzle," that is, how to get solar electricity onto the heating and transportation markets.

He laid the foundation for his venture on April 1, when Heek-based 2G started up its agenitor 404c H2 CHP unit. The device runs on pure hydrogen and offers 115 kilowatts of electric and 129 kilowatts of thermal capacity. Its fuel is to be supplied by a 2-megawatt McPhy alkaline electrolyzer, which will be integrated with Apex Energy's hydrogen storage. In addition to the CHP unit, the company owns a fuel cell system made up of five 150-kilowatt Proton Motor PM400 modules and a stationary 1-megawatt-hour battery by Wemag, used as buffer storage to provide operational flexibility.

The entire system came online on June 12 (after the editorial deadline), following a short address by Mecklenburg-West Pomerania's governor, Manuela Schwesig, to commemorate the occasion. Christian Pegel, her executive branch colleague and state energy minister, had already visited the site and is supporting the company's objectives.

Fig. 1: On the premises, Apex Energy is putting up Germany's biggest sustainable, distributed energy resource to date.

Fig. 2: Mathias Hehmann (l.) and Mischa Paterna stand next to the containers on Apex Energy's premises.

Hehmann, who lives in a nearby village, started working in the solar industry when he was 26. In this "first life," he managed up to 150 staff. During the 2011 crisis in the PV industry, however, his company lost all of its revenue. He then had to tell each one of his employees that he could no longer keep the business afloat. In the end, only he and his secretary were left.

In 2012, he and Hubert Börger, emano Kunststofftechnik's chief executive, began working on the idea of storing solar electricity in hydrogen. Börger's business emano specializes in plastic fabrication. It not only manufactures Porta-Potties but also casings for Kärcher cleaning equipment. Together, Börger and Hehmann were searching for a polymer to keep hydrogen fully contained inside a storage system. Upon discovering a granule that could do the job, they had it tested at Fraunhofer IGP in Rostock from 2013 to 2015. Drawing on the research institute's findings, they then built their own tank model. Today, the business in Teterow has over 200 employees and manufactures 1,000-liter tanks that can store 150 kilowatt-hours of hydrogen at 60 bars (see photo on p. 3).

A PROJECT TO REPLICATE Apex Energy said its grid-connected network can produce up to 16 gigawatt-hours a year and is the only installation of its kind in Germany and the biggest hydrogen grid in Europe. Through a ring-shaped pipe and cable system, the company intends to supply carbon-neutral gas from its site not only to two hotels that are to be built in the immediate vicinity, but also to the neighboring industrial park and to the town's civilian airport, as well as their critical infrastructure.

According to the company, the public hydrogen fueling station that is being installed on the premises will be able to fill up 200 cars and 40 buses a day. The station will form part of an east-west route that could help revive the BlueLine, launched collectively by Schwerin's utility provider, the local chamber of industry and commerce, Wemag and Volker Rumstich transportation services in May 2019. During this project, Mecklenburg-West Pomerania's energy ministry, under the leadership of Christian Pegel, helped fund a pre-feasibility study to pave the way for a fueling station network in the western part of the state, along its main traffic route, the A24. The network could run from Schwerin via Laage and may, at a later time, also include the Karls Erdbeerhof theme park.

The similarities between the Apex Energy initiative and Schleswig-Holstein's eFarm project (see H2-international, January 2019) are anything but accidental. One could say Apex Energy intends to follow in GP Joule's footsteps. The venture that GP Joule launched in Germany's northwest has been termed the country's "largest green hydrogen transportation project" to date. The business aims to establish an entire hydrogen supply chain, from production to electricity and fuel for vehicle fleets.

NEW HYDROGEN PIPELINES IN MECKLENBURG-WEST POMERANIA

Mischa Paterna, Apex Energy's sales director, is one of the founding members of Wasserstoffenergiecluster Mecklenburg-Vorpommern, which plans to coordinate hydrogen and fuel cell activities in Mecklenburg-West Pomerania. The association articles have already been drawn up, Paterna said. But the Covid-19 pandemic has forced the organization to hold its first meeting online. Its members include Stralsund's university of applied sciences and the Leibniz Institute for Catalysis, also known as LIKAT Rostock.

The go-to contact for hydrogen and fuel cells in Germany's northeast used to be WTI Wasserstofftechnologie-Initiative Mecklenburg-Vorpommern, supported by ATI Küste. But in the past several years, the initiative has gone very quiet. Nevertheless, Paterna said his newly founded alliance plans to set up a partnership with WTI, the "association that kicked off the hydrogen industry in Mecklenburg-West Pomerania," while also expanding into other German states.

GREEN HYDROGEN INFRASTRUCTURE Apex Energy is a privately funded business and has 35 staff members. The next milestone is 200 employees, who will manage component deliveries from and to the company. With their help, Hehmann will shorten the time it takes Apex Energy to ship electrolyzers, fuel cells, fueling stations and turnkey systems. Thus far, customers have had to wait 10 months or more before orders were filled. Similarly, the company spent two years on the design of its own fueling station and has been waiting for fuel cell buses 18 months already (see p. 34).

Hehmann, whose demeanor is vaguely reminiscent of Tesla CEO Elon Musk's, is already describing the site as "northern Germany's hydrogen center of excellence." How much truth there is to his claim will entirely depend on whether Apex Energy is able to deliver. There is no lack of determination.

For example, the company wants to set up central offices in Rostock. This will expedite orders more efficiently than when all stakeholders are working out of their respective headquarters. To this end, Apex Energy offers partner businesses and inspection agency TÜV both office and factory space, ensuring short routes and fast decision-making. This way, Apex (Latin for 'peak') wants to help "create a path to a green hydrogen infrastructure."

He was indeed a bit disappointed, Hehmann said, that Rostock did not become a HyLand hydrogen cluster. But at least Rügen-Stralsund was chosen for the HyStarter program. And maybe he really will succeed in setting up a northeast German hydrogen center near the A24 south of Rostock. ||

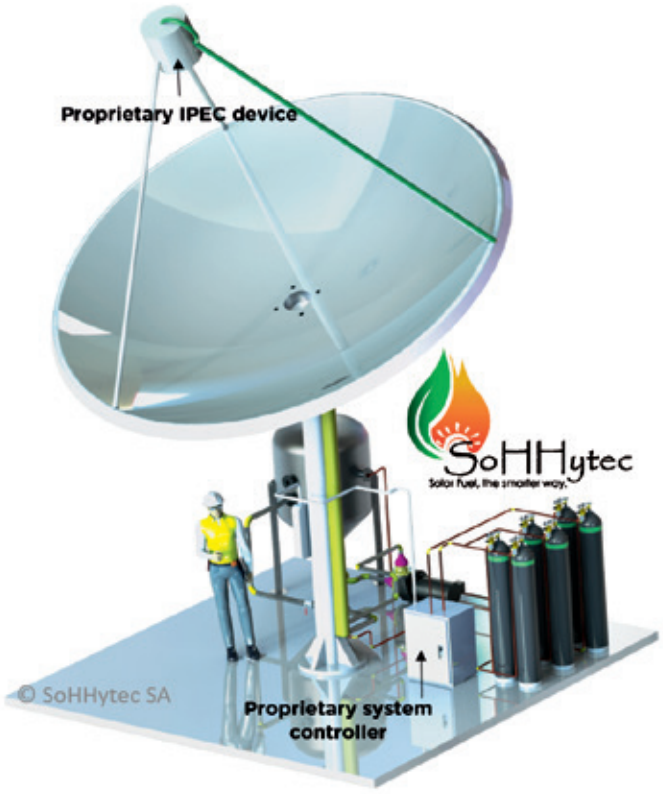
"We want to be the first to install this technology in northeast Germany."

Peter Sponholz, chief technology officer, Apex Energy Teterow

Theme: Energy storage | **Authors:** Dr. Saurabh Tembhurne, Prof. Sophia Haussener

USING CONCENTRATED SOLAR POWER TO PRODUCE HYDROGEN

SoHHytec, the direct way to solar fuel



Reducing environmental pollution is becoming ever more important. This is especially true now, seeing how pollution has worsened the impact of the recent Covid-19 virus outbreak. As a result, the search for alternative fuels is no longer just a building block for long-term climate action but vital to public health today. Although solar energy is intermittent by nature, converting it into chemical energy via photoelectrochemical (PEC) processes is a viable path to producing and storing renewable fuel. To be successful, however, any such approach needs to be efficient, robust, cost competitive and sustainable.

Studies show that photoelectrochemical devices running at great optical concentration and current density can meet all the requirements for producing solar fuel at the point of use [1]. They do so despite including expensive but high-performance photoabsorbing materials and catalysts. The photoactive and electrochemical component that is part of these systems allows for not only greater current densities but highly efficient equipment [2, 3]. SoHHytec, a spin-off from Swiss-based EPFL's Laboratory of Renewable Engineering Science and Engineering, has been developing a cogeneration system to produce cost-effective renewable hydrogen, electricity and heat on-site. It uses innovative, patented technology to concentrate solar energy onto a thermally and electrically integrated photoelectrochemical device (IPEC).

Called Arb, SoHHytec's product runs on sunlight and water alone. It turns (concentrated) solar energy into fuel through PEC water splitting and produces electricity and heat at the same time. It shows both high solar-to-fuel and solar-to-electric efficiencies, works at unprecedented power and current densities and offers cost-effective fuel and power. Moreover, it has potential to remain in operation for a long time to come.

The most common methods for producing solar hydrogen employ either PECs or PV systems plus electrolyzers (EC). Conventional photoelectrochemical pathways have severe limitations, a result of their semiconductor-electrolyte interfaces. However, approaches based on the PV plus EC method (which omits the semiconductor-electrolyte interface) incur significant losses stemming from their electrical connections and heat production. Additionally, all photoabsorbers capture only specific wavelengths, i.e., convert merely a part of the incoming sunlight into usable energy, while the rest is usually wasted as heat. Current-generation solar panels do not use this waste heat because of an implied increase in system complexity. This means that PV plus EC pathways cannot benefit from it either.

SoHHytec has designed an IPEC system that aims to combine the best of both worlds. It employs concentrated sunlight and high-performance materials and has thermally and electrically integrated PV and EC components but no semiconductor-electrolyte interfaces. Furthermore, smart thermal management improves its solar-to-hydrogen efficiency while maintaining high current density.

Solar hydrogen production was recently demonstrated using a lab-scale IPEC prototype that runs at irradiation levels

474 times the typical solar radiation (that is, at 474 kW/m^2 of incident flux) [3]. The solar-to-hydrogen efficiency during these tests was 17.12 percent, while current density was around 1 A/cm^2 (0.88 A/cm^2 in the EC component and 6 A/cm^2 in the PV component) and output power around 30 W. The prototype was a step forward in creating a competitive product and we are now running a first commercial-scale pilot on the EPFL campus.

This pilot comprises a commercially available parabolic solar concentrator that has a collection area of 38.5 m^2 (corresponding to a diameter of 7 meters). Sunlight is redirected by the parabolic reflector onto the focus, where it goes through an integrated flux homogenizer before reaching the PV unit of the IPEC device. The PV unit uses the concentrated energy to produce both fuel (hydrogen and oxygen) and power (electricity and heat). Water consumption is around 13 liters at an estimated daily production rate of 1.5 kg of hydrogen and 12 kg of oxygen, plus 126 kWh of thermal energy, when operated in fuel production mode and run on sunlight alone.

Depending on a user's needs, the system can produce not only fuel but also electricity and heat at fully adjustable output ratios. This degree of flexibility makes it an ideal choice for those who intend to use green hydrogen as feedstock or raw material or even those who need a long-term storage solution. In short, SoHHytec can meet the fueling, electricity and heating needs of many industries, e.g., businesses that produce fertilizers and chemicals, provide transportation services, process metals or make food, plus the residential sector. It can likewise produce hydrogen 24/7, as it can be run at night in power-to-fuel mode by using external energy sources, such as grid electricity.

SoHHytec is helping to reduce the world's dependency on fossil fuel by offering a cleaner, more sustainable and cost-effective system for producing electricity and fuel. The system prevents losses from transporting hydrogen and transmitting electric power by generating both on-site. It allows distributed as well as centralized production and improves grid stability by storing intermittent renewables, such as solar energy, in an energy-dense fuel. Our aim is to help create a sustainable hydrogen economy and we are working to make the fuel of the future, that is, hydrogen, a reality of today. ||

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Theme: Energy storage | **Author:** Michael Nallinger

GREEN GAS: A BUSINESS MODEL

Biological methanation is ready for the market

Viessmann is restructuring both its fuel cell and biomethane divisions. Its newly founded holding company, Schmack BioEnergie, specializes in biogas with an increasing focus on biological methanation. As early as this year, Viessmann will start construction on the first commercial methanation unit in Switzerland. The biological method offers multiple benefits, including outstanding efficiency, low susceptibility to contaminants and a highly responsive on-off mode.

When it comes to hydrogen, biomethane and fuel cells, Viessmann is standing strong. Alexander Dauensteiner, Viessmann's fuel cell division director, said that "all three areas interact perfectly in the energy scenario." That is an interesting market approach. Then, this globally operating concern is certain that green gases such as hydrogen and biomethane are going to play a dominant role throughout all industries.

For one, long-term seasonal storage is the only way the German government will meet climate targets of a 60 to 95 percent carbon dioxide reduction. For another, taken together, the electrolysis method and power reconversion via fuel cells cover all bases. If renewable electricity needs to be stored, the electrolyzer turns it into clean gas. When applications need electricity, a fuel cell extracts energy, as well as heat, from the stored gas.

With an eye on existing infrastructure, Viessmann sees biological methanation as a vital building block to erecting a carbon-neutral society. "Germany's pipeline system and underground caverns offer several months' worth of storage capacity. Therefore, our most climate-friendly energy source, produced via biological methanation, can be stored for a long time, generating power, heat, or fuel for natural gas vehicles, independent of production sites," said Dauensteiner.

NEW SWISS FACTORY As early as 2011, Viessmann's subsidiary microbEnergy began initial biological methanation tests, which relatively quickly magnified into prototype reactors. In 2015, the company's first pilot system came online at headquarters in Allendorf. "Drawing on what we learned from analyzing these systems, we have begun engineering other pilot plants to compile reliable data for upcoming field tests," said Manuel Götz, microbEnergy's new chief executive since February.

Fig. 1: In 2015, Viessmann brought online its first biological methanation pilot plant at headquarters in Allendorf, Germany. [Source: Viessmann]

In 2019, microbEnergy began drawing up detailed specifications for an industrial-scale system. It will be installed in Switzerland, where energy supplier Limeco is constructing the world's largest power-to-gas plant thus far. Among other things, the plant will use microorganisms to generate hydrogen from methane. Construction is scheduled to begin later this year.

In the course of the project, Viessmann redistributed responsibilities among Schmack Biogas and microbEnergy. Schwandorf-based Schmack is now in charge of putting up the power-to-gas plant in Switzerland, having both constructed the pilot in Allendorf and more than 20 years' experience in multi-megawatt biogas projects. This will bond the two companies, which have been sharing the Schmack BioEnergie umbrella since October 2019. Emerging from Schmack's former research division, microbEnergy will continue to advance bio-methanation and be "the go-to provider for power-to-gas project ideas," said Götz.

The intention is to propagate the advantages of biological methanation, particularly when compared to the catalytic reforming techniques currently dominating the market. A cutting edge factor is efficiency. Catalysts produce methane by adding carbon dioxide at a temperature of 300 °C and a pressure of 60 bars when processing hydrogen. Biological methods require only 60 °C and 6 bars, allowing the Archaea microorganisms inside the BiON reactor to work most efficiently.

And that is but one biological methanation advantage. Götz considers the microbes' resilience to contaminants almost more important than their conversion performance. He noted that "besides pure gases, we can feed the tank with gas from sewage treatment plants, biogas facilities or even pyrolysis systems," adding that catalytic systems are sometimes highly susceptible to raw gas impurities, such as sulfur compounds, which can damage many types of catalysts.

METHOD OF CHOICE Another advantage, Götz said, was that the BiON process is devoid of unwanted byproducts, which can cause problems when postprocessing the gas. He said that "here, too, catalyst systems are more difficult to manage. Especially when operating conditions or input qualities change, they deliver undesirable byproducts."

A result, according to Götz, that has an impact on the on-off cycles: "We can simply turn off our system. Closing the valve will prevent gas from flowing in and methane production immediately comes to a halt." The system only generates methane – almost instantly and at over 97 percent purity – when fed gases. Catalytic processes are more sluggish, continuing to make gas as long as the temperature is right and input material is available.

This is where Götz hits upon another catalysis weakness. A system abruptly stopped will create long-chain hydrocarbons, which need to be flushed out from the device before it can operate again. "These systems are unsuitable for on-off cycles. They cannot be started up quickly, as operating temperature and pressure must be increased gradually," he said. Given the various benefits of biological methanation, he concludes: "If you need faster response times and a standby mode until regular use, BiON is your method of choice." The bio-system, he added, can be run dynamically and provides enough flexibility for switching between standby mode, minimum load and regular load.

With years of intensive research, BiON has matured remarkably, becoming quite the marketable product. And yet, microbEnergy continues to optimize the equipment, especially its operating costs and process efficiency. More specifically, it aims to further increase hydrogen and methane throughput and improve purity.


Source: Viessmann

Fig. 2: Manuel Götz is the new chief executive of Schmack BioEnergie, with microbEnergy operating under the company's umbrella.

In addition, Schmack wants to expand the biogas product portfolio to include additional carbon dioxide-rich gases, such as those produced via pyrolysis. Its cost-cutting agenda includes reducing additives, such as the nutrients required for microorganism growth, downsizing reactors, and designing modular systems for different plant sizes.

And the company has already taken an important step further. One of the biggest challenges was how to transfer the hydrogen mass from the gas phase to the liquid phase and, ultimately, to the microbes. "Getting a grip on this important process was a big leap forward in developing our production technique," noted Götz. The company gradually improved the process to the point that stable, automated control systems consistently ensure "very high purity with large space-time yields."

VIESSMANN KEEPS FUEL CELL BUSINESS ALIVE The promising prospects of biomethane and hydrogen production are intertwined with equally encouraging fuel cell developments. Viessmann is now concentrating on system integration of both relevant technologies, PEMs and SOFCs. "Collaborating effectively with Panasonic confirms that necessary PEM scaling can be successfully applied," said Dauensteiner. Over 330,000 Panasonic fuel cell systems were sold on the Japanese market by September 2019. In Germany, Viessmann reached the 10,000 mark. "We lead the market by a large margin," he added.

SOFCs are equally important to Viessmann, since they can easily meet the requirements of existing building stock and offer large capacities. In mid-March, Viessmann announced its intention to shut down Swiss subsidiary Hexis (see H2-international, May 2020), soon finding an industrial partner willing to buy the company. On June 1, Hexis became part of mPower (see p. 8). The acquisition documents spell out a future collaboration agreement, in which Hexis will deliver SOFC fuel cell modules to its former owner. As Viessmann announced, the family business is banking on integrating fuel cell modules into its own energy generation devices. Neither company disclosed sale figures. Dauensteiner expressly made known that "Viessmann remains an important supplier of residential fuel cells." ||

Theme: Energy storage | **Author:** Stefan Bergander

FUTURE ENERGY STORAGE

HYPOS projects investigate potential of underground caverns

Fig. 1: Gas pressure and control line in Bad Lauchstädt [Source: VNG Gasspeicher]

The energy source of the future is hydrogen. It can be produced from renewables and used as a raw material or an energy source in multiple industries. The biggest challenge industrial companies face with hydrogen is also key to implementing energy systems integration in general. The challenge is: How to store the gas? Since clean electricity is not available 24/7, green hydrogen output will fluctuate. However, large hydrogen consumers in industry and transportation cannot rely on volatile renewable sources for their energy needs. A solution could be to store green hydrogen in salt caverns, as they can provide reliable, long-term and centralized gas supply. As part of HYPOS, two project teams are now working on implementing this idea.

Typically, underground rock formations provide a suitable environment with a sufficiently large capacity to store and retrieve fluids. HYPOS' H2-Forschungskaverne project is investigating a salt cavern in Bad Lauchstädt in Saxony-Anhalt, Germany. Salt caverns are created artificially by pumping water into salt deposits several thousand feet below ground. The salt dissolves, leaving behind cavities that can hold gases long term.

Since the 1970s, the oil and gas industry has set up well over 200 of these caverns, a testament to its decades-long experience in building and operating underground storage facilities. In Bad Lauchstädt, VNG Gasspeicher operates multiple natural gas storage sites, including salt caverns. The goal of HYPOS' H2-Forschungskaverne is to develop and design a safe, efficient and large-capacity green hydrogen storage system inside one of these caverns. The system envisioned for the project will have a working gas capacity of around 50 million normal cubic meters, the energy content equivalent of around 150 gigawatt-hours, making it the largest of its kind to date.

Plans for the following years include preparing a large-capacity cavern for hydrogen storage. Storing hydrogen in caverns is a strategy that has not yet been pursued in Germany. Still, this storage technique is not completely unknown. There are underground caverns storing gray hydrogen, such as Moss Bluff, Spindletop and Clemens Dome in the United States and Teesside in the UK. These supply local industry. However, it will be very difficult to adapt their cavern design or geological specifications to meet green hydrogen storage requirements.

Pairing green hydrogen produced from renewables via water splitting with underground storage poses special challenges for cavern operators. For example, equipment needs to be faster and more responsive when storing and retrieving gas to closely match the load profiles of solar and wind energy systems, as well as electrolyzers.

INITIAL FILLING IN 2024 Aside from the above, most of what is installed in and around a hydrogen cavern is also found at a conventional natural gas storage facility. Above ground, this includes measuring and control equipment, a compressor station, filters and purifiers, as well as piping. Underground, cavern design needs to take into account borehole casing locations and cementing, as gas leaks must be avoided at all costs. However, in the case of hydrogen, there are unique chemical and physical properties to consider as well. Finding answers to these and other questions is the objective of HYPOS project H2-UGS (see below).

H2-FORSCHUNGSKAVERNE
Project partners are VNG Gasspeicher, ONTRAS Gastransport, Fraunhofer IMWS, DBI – Gastechnologisches Institut Freiberg, and IfG – Institut für Gebirgsmechanik. Associated partners are Terrawatt Planungsgesellschaft, Linde, Dow and Uniper. The project has a total budget of EUR 1.3 million and will present an operating concept, a for-profit business model and a legal permit for building the storage systems, all by mid-2021.

The H2-Forschungskaverne project partners have scheduled the initial cavern fill for 2024. But first, the research project will need to make extensive preparations. These include creating in-depth plant design draft and operating concept documents. The concept is necessary should the operating plan find approval according to German mining regulations and the BImSchG rules on pollution levels. Because the hydrogen cavern in Bad Lauchstädt is the first of its kind, its designers have sought a close working relationship with the relevant authorities and institutions from the very beginning.

Another project objective is to investigate a variety of strategies for operating underground storage facilities. This includes compiling and comparing diverse cavern storage technologies and equipment, analyzing their strengths and weaknesses and estimating the capital and operating costs of each option. The cavern storage system will be operated in conjunction with an appropriately sized electrolyzer. The current target capacity is around 30 megawatts. A nearby wind farm will provide the clean electricity needed to run the device.

In addition, the first project stage includes detailed technical descriptions of how to connect the cavern to a hydrogen pipeline running across the region. This critical infrastructure component connects the centralized steam reforming plant that Linde runs in Leuna to many large hydrogen consumers in the chemical and petrochemical industries in what is known as the Middle German Chemical Triangle. The cavern could be linked to the grid via ONTRAS' nearby, currently defunct 20-kilometer-long natural gas pipeline. This would greatly benefit Bad Lauchstädt, considering the cavern would not be located in the middle of nowhere. It would also make it possible to set up a direct link to consumers with the help of existing infrastructure and thus provide a complete supply chain from green hydrogen production to (seasonal) storage and use.

H2-UGS
Project partners are DBI Gas- und Umwelttechnik, ESK, IfG – Institut für Gebirgsmechanik, Isodetect, MicroPro, Technische Universität Bergakademie Freiberg, Helmholtz-Zentrum für Umweltforschung, Untergrundspeicher- und Geotechnologie-Systeme and Fraunhofer IWM. Associated partners are VNG Gasspeicher, Salzgitter Mannesmann Line Pipe and PSE Engineering. The project has a total budget of around EUR 4.5 million. Its aim is to present, by the end of 2021, guidelines for setting up and managing hydrogen caverns.

While H2-Forschungskaverne concentrates on building a plant in Bad Lauchstädt, HYPOS' H2-UGS project looks at hydrogen caverns in general. Since September 2018, the project partners have been conducting the necessary basic research for operating such novel storage plants safely. Work

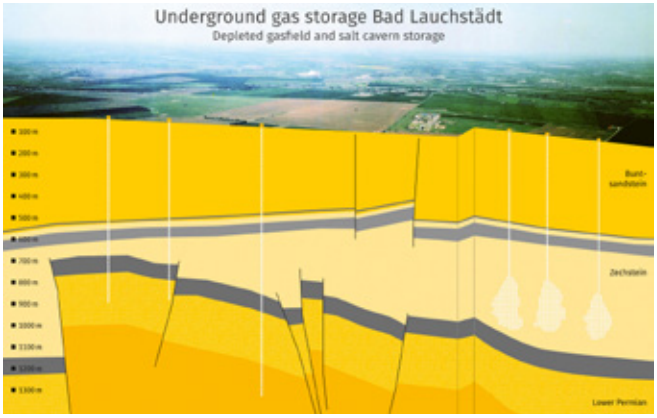

Fig. 2: The Bad Lauchstädt storage caverns, carved out of a 500-meter-thick layer of salt (1640 feet), are between 765 and 925 meters (2510 and 3035 feet) below the ground. [Source: VNG Gasspeicher]

packages cover a wide variety of topics, ranging from degradation resistance, geo-mechanical properties and microbiology to gas blends, thermodynamic issues, and storage and plant design.

Regarding degradation resistance, investigations examine the interactions between different storage materials and hydrogen. When it comes to geo-mechanical properties, the project partners will analyze infiltration thresholds and hydrogen permeation. They also took samples on site to research microbiological populations and the reciprocal impact of higher hydrogen concentrations on microorganisms. As for gas blends and thermodynamic issues, the partners are studying the impact of fluctuating temperatures on the storage gas and the resulting geochemical reactions. The work on storage and plant design is to deliver insights on technical equipment and borehole specifications and especially operating procedures and storage integrity.

All findings will be compiled in a guide on hydrogen cavern evaluation and approval. The guide will encompass a comprehensive list of measures needed to set up and operate hydrogen caverns. It is the first rule book on hydrogen caverns and therefore targets investors and approval authorities alike. The standardized findings will allow interested partied to analyze the technical and business aspects of hydrogen caverns, will reduce uncertainty and increase the overall efficiency of processes, saving all stakeholders valuable time. ||

HYPOS
HYPOS is an alliance of hydrogen economy advocates with over 100 members unifying their strengths – small business innovation, industrial know-how, university and research expertise. HYPOS members' shared goal is to set up a green hydrogen supply chain across multiple industries. Currently, 32 project consortia investigate the innovation potential for green hydrogen production, storage, distribution, and consumption in the chemical, refinery, transportation and energy markets. German education ministry BMBF is supporting the project as part of Zwanzig20 – Partnerschaft für Innovation with EUR 45 million.

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

WANTED: FUEL CELL BUSES

Market grinds to a halt as bus makers fail to deliver

Lately, potential customers from all over the world are complaining about the severe shortage of fuel cell buses. However, automakers have only themselves to blame. The few clean buses that have made it onto the market are either hybrid or all-electric. It is a rare specimen that runs on fuel cells. And if a customer gets lucky, the delivery time is extensive. With each passing day, the bus industry's years-long failure to rise to demand is becoming increasingly evident, missing opportunity after opportunity to get on track. Apparently, though, bus makers now seem to have their engines running.

Most manufacturers do not even have a fuel cell model concept yet. And those finally taking a closer look at hydrogen and fuel cell technology have little to no manufacturing capacity to produce vehicles. This deficit stands in stark contrast to the huge demand for fuel cell buses, which could not only help big cities meet environmental targets but also have few range limitations.

Rome is a prime example. In February, mass transit company ATAC invited bids for five fuel cell buses as part of the European 3Emotion project. Not one bus manufacturer showed an interest in the project. The official city gazette said there were "no bids and no applications to participate." This was the second time Italy's capital failed to attract proposals for fuel cell buses. The first was in January 2019, when it requested vehicles and a fueling station. Despite the budget expanding to EUR 4 million, a fifty-fifty split between the European Union and the regional government, Rome's efforts failed utterly.

Fig. 1: Electric MetroDecker by Optare [Source: Optare]

DAIMLER'S MANUFACTURING CAPACITY DROPS TO 50 PERCENT Many consider Mercedes-Benz the go-to manufacturer for fuel cell buses in Germany, since the company started designing a fuel cell bus called NeBus (new electric bus) two decades ago. Since then, it has participated in many publicly funded showcase projects. However, not a single vehicle was marketed.

The automaker is currently relying on batteries to power its cars, trucks and buses. At the 2018 IAA Commercial Vehicles show, Mercedes-Benz unveiled its all-electric eCitaro bus. In November of the same year, the first batch was delivered to mass transit company Hamburger Hochbahn. Hochbahn had put several types of engine designs to the test prior to buying the vehicles, since, effective January 2020, new regulations ban the purchase of anything other than zero-emission buses. Hochbahn stated it had originally planned to deploy fuel cell vehicles but aborted the operation following negative results during the test trial. There were few issues with the technology, but the manufacturer's low-quality maintenance was more than discouraging.

In response to a state lawmaker's inquiry, Hamburg's government said the prototype fuel cell hybrid buses made by Mercedes-Benz' subsidiary Evobus were fraught with defects. Initially, Hochbahn spent between EUR 230,000 and EUR 300,000 a year on maintenance and upkeep. Further into the trial, running costs were EUR 400,000 or even EUR 550,000 annually. Ultimately, the company paid over EUR 2.5 million over seven years of testing. Excessive downtime, the state government said, was the result of "work on innovative components, which often required the help of experts working for the bus maker or special-purpose and diagnostics tools that were not immediately available." Each vehicle came with a price tag of EUR 1.8 million in 2012, with the federal government footing 50 percent of the bill.

DC chargers especially caused the bus operator big headaches, as one charger after another "went up in a cloud of smoke." But they were not the only parts responsible for downtime. For example, doors and brakes included rare, exclusive components not easily replaced. Despite these issues, the bus maker refused to acknowledge constructive feedback and suggestions.

> "The four hybrid fuel cell buses worked smoothly only around 50 percent, or even less than 50 percent, of the time throughout the project, far below that of vehicles sold on the market today. Downtime was primarily due to extensive vehicle repairs.
> In contrast, Solaris buses, currently undergoing testing, already show a greater level of reliability than the four hybrid vehicles withdrawn in 2018. The Solaris models run on electric motors with fuel cells to extend their range."
> *Government Publication 21/16431*

After 15 years of testing fuel cell technology, Hochbahn decided to focus on all-electric vehicles. Besides inviting Europe-wide bids for up to 530 battery-electric buses by 2025, the company installed charging equipment throughout its new

45,000 m² bus depot in Hamburg's City Nord district. Opened in April 2019, the depot has space for 240 zero-emission buses, charged overnight with green electricity. The transit operator also built an on-site substation to reduce voltage from 110 kilovolts to the required 20 kilovolts. Hochbahn plans to grow its all-electric fleet in Alsterdorf to 120 buses by 2023 and to 1,000 by 2030, the deadline for withdrawing the last fossil fuel bus.

However, all-electric vehicles alone are not what state economy minister Michael Westhagemann or hySolutions' former chief executive Heinrich Klingenberg (see p. 5) had in mind. Fortunately, Hochbahn has reverted back to a more inclusive approach, as Peter Lindlahr, hySolutions' current chief executive, confirmed to H2-international. Now, the new depot houses hydrogen equipment as well. There are also plans to deploy a larger number of fuel cell buses in northern Germany within the living lab context, Lindlahr said, because there is "no viable alternative" to fuel cells. A corresponding request for proposals is in the works, he added. The project could additionally lead to fuel cell shuttles at Hamburg Airport.

Hamburger Hochbahn said: "We will use fuel cells to extend the range of our battery-electric buses, which already reach 150 kilometers (93 miles) on a single charge. However, we have no plans at this time to deploy hydrogen-only buses. We feel the technology has not yet advanced enough, is not reliable enough, for public transportation schedules. The results of our multi-year trial with hydrogen buses revealed their susceptibility to downtime, requiring frequent repairs."

"Hydrogen and fuel cells will be key technologies for Hamburg and Germany's future."
Henrik Falk, chief executive of Hamburger Hochbahn

The vehicles decommissioned in Hamburg went to bus operator Winzenhöler. Three of them now run as part of the regular service throughout the Rhein-Main area. The fourth provides spare parts, Christian Winzenhöler, the company's chief executive, told H2-international. His fleet of fuel cell buses, including some made in Switzerland, runs reliably more than 93 percent of the time (see H2-international, April 2019).

DAIMLER TO BECOME CARBON NEUTRAL BY 2039

Meanwhile, Mercedes-Benz' customers will need to wait until 2022 before they can get new eCitaro buses equipped with fuel cell range extenders. One of them is transportation company SWEG, which aims to have 10 of the vehicles drive daily routes during the H2W project. The fuel cell extends the range of the battery-electric buses from 150 kilometers (93 miles) to over 300 kilometers (186 miles). Stephan Wisser, head of SWEG's bus technology and maintenance division, said this would allow "the eCitaro REX to drive regular routes throughout the day with no recharge."

Each bus will have only one fuel cell system. The prior version had two systems, which were originally designed for passenger cars. An unnecessary layout for these buses, as the vehicle's main storage device is the battery, not the hydrogen tank. The German transportation ministry has allocated EUR 3.3 million to advance the model's hybrid development.

"Only batteries or hydrogen can ensure carbon-neutral local transportation services."
Martin Daum, Daimler's vice president for trucks and buses

Furthermore, Daimler Trucks & Buses said it will cease European, Japanese and NAFTA distribution of vehicles that are not tank-to-wheel carbon neutral. Of course, this means it may very well keep offering them elsewhere.

JAPANESE AND PORTUGUESE COMPANIES JOIN FORCES

In short, fuel cell buses are simply not available. One only needs to hear what André Steinau, of Reußenköge-based GP Joule, has to say about the current situation in Schleswig-Holstein, where he heads the green hydrogen project eFarm. He sent many inquiries but received only one quote from a Polish manufacturer. In the end, however, he decided on a CaetanoBus, a newcomer to the market. In mid-May, GP Joule ordered two buses from the startup company, intended for regular service between Niebüll and Husum as part of eFarm. Although planned for July, delivery was put off until fall.

CaetanoBus unveiled its H2.City Gold at the Brussels-based Busworld show in October 2019. The vehicle, built by a Toyota factory in Portugal, is 12 meters (39 feet) long, >>

EXAMPLE: GELDERLAND

"The vehicles meet our expectations and we see bright prospects ahead for fuel cell buses in general, especially for long-distance vehicles," said René von Nekkers, of Keolis. A Dutch public transportation provider, Keolis owns two fuel cell buses, powered by HyMove fuel cell systems, that carry passengers around Apeldoorn and on longer trips throughout the Gelderland region. They run regular routes, travelling 270 to 440 kilometers (167 to 273 miles) each day. Both need 6.1 kilograms of hydrogen per 100 kilometers (62 miles), considerably less than comparable models require. According to their operator, they are in service 96 percent of the time, with average costs per mile similar to those of diesel and natural gas vehicles.

HyMove told H2-international that "the fuel cell buses in Gelderland came from two different manufacturers, Solbus and Ursus Bus (see H2-international, August 2017)." Meanwhile, however, the Polish bus makers have turned their attention to other markets and dropped most of their fuel cell bus models. Frank Ex, the founder and chief executive of Zett, an Arnhem leasing company, told H2-international that his startup will bring to market fuel cell buses, "based on the Solbus design," adding that "the body is constructed in Poland, while the powertrain is installed in the Netherlands."

carrying the same fuel cell system used in the Japanese automaker's Mirai model, giving the bus a range of 400 kilometers (249 miles). The range in particular made Steinau happy: "An impressive 400 kilometers on a single tank – made possible by Toyota's highly advanced fuel cell technology."

In France, the main fuel cell bus maker is Safra, whose Businova model comes with a 30-kilowatt fuel cell made by Symbio, a Michelin-Faurecia joint venture. The bus is also equipped with a 30-kilogram hydrogen tank and a 132-kilowatt-hour battery. Safra's first customer is the city of Auxerre, which ordered five Businovas. More will be shipped later to Lens-based transportation services provider Artois-Gohelle, to Toulouse-Blagnac Airport, to Versailles and to Le Mans. The Businova H2 range is approximately 350 kilometers (217 miles).

SOLARIS DELIVERS Without a doubt, the Rhein-Ruhr megalopolis is Germany's pioneering fuel cell hotspot, running as many as 37 fuel cell buses, 35 Van Hools and two Phileases. With JIVE 2, a new EU funding opportunity, Cologne's regional transit company RVK and Wuppertal's WSW Mobil have, again, placed orders for hydrogen-powered buses. In March, they requested 25 vehicles, 15 for RVK and 10 for WSW, from Polish bus maker Solaris Bus & Coach. Delivery of the Urbino 12 hydrogen will start in 2021. Purchase support comes from the Fuel Cells and Hydrogen Joint Undertaking, the National Innovation Program (NIP 2) and state funds.

RVK said three manufacturers responded to a standard request for proposals. Solaris submitted the cheapest offer and remained below the funding organization's maximum price target, EUR 625,000 per bus. The hydrogen buses will also serve two new fueling stations in Meckenheim and Wermelskirchen, which are planned to come online soon (see H2-international, April 2019).

Fig. 3: Solaris Urbino 12 hydrogen [Source: Solaris]

Another sizeable order for Solaris vehicles came from the Netherlands, or, more specifically, from Connexxion, a Transdev Netherlands Group enterprise catering to the populous Zuid-Holland province. There is a fueling station near its bus depot in Heinenoord. By 2021, the company plans to have 20 Solaris Urbino 12 hydrogen in service. The province's transportation minister, Floor Vermeulen, explained: "The well-being of our bus passengers and our residents is of vital importance to us. Installing buses that ensure clean air marks a big step in the right direction."

Twelve more buses were ordered by Italy's SASA Bolzano last year. All these Solaris vehicles run off 70-kilowatt Ballard fuel cell systems called FCmove-HD. The fuel is stored on the roof in five 1,560-liter Type IV tanks made by Agility Fuel Solutions, a Hexagon Composites subsidiary.

Ballard also supplies fuel cell stacks to Solaris' competitor Van Hool. In December 2019, the Belgian bus maker ordered twenty 85-kilowatt FCveloCity®-HD systems for its A330 fuel cell buses, which are planned to serve Dutch transportation company Qbuzz in Groningen as part of JIVE 2. Groningen already has two fuel cell buses in operation. Fleur Gräper-van Koolwijk, the Dutch minister of Groningen province, said "hydrogen is no longer an experimental fuel but has become a viable zero-emission drivetrain used in everyday public transportation."

Things are progressing in Switzerland, too, albeit rather conceptually. The recently founded initiative H2 Mobilität Schweiz wants to promote fuel cell buses to keep the air in the Swiss Alps pollution-free. Led by Mario Schädler, the alliance aims for a low-emission, regular bus service over the country's serpentine roads. H2 Mobilität transfers the efforts of H2 Energy, a fuel cell truck maker, onto the bus market. To this end, Schädler went so far as to found a company, Cityebus Schädler H2. The original business prototype, a mail truck, was to be converted by September. However, when H2-international asked, Schädler said there is a dire lack of manufacturers able to deliver the right kind of fuel cell buses.

STACKS MADE IN GERMANY Of note is also a German and Czech partnership, set up in early 2019 as Puchheim-based Proton Motor Fuel Cell announced a collaboration with Škoda Electric. The two companies signed a memorandum of understanding regarding the development, sale and maintenance of fuel cell electric buses. These buses will be equipped with HyRange® systems, Proton Motor's range extenders designed specifically for battery-electric buses, as well as commercial and community vehicles.

Faiz Nahab, chief executive of Proton Motor Power Systems, formerly Proton Power Systems, noted: "It is with great pleasure that we announce our collaboration with Škoda Electric. This partnership provides further proof that our HyRange products are both necessary and in demand." Reportedly, the initial goal is to construct 10 prototype vehicles for European bus operators. However, when H2-international asked, Proton Motor's sales manager, Manfred Limbrunner, could not confirm the number, since the company was "still in negotiations" with Škoda.

Furthermore, in April 2019, Proton Motor announced it closed a EUR 4 million deal with ebe Europa, a firm in Memmingen, Germany. The aim of the agreement is to equip 15 electric buses with 60-kilowatt fuel cells and deliver the

vehicles to four cities, Frankfurt a. M., Mainz, Münster and Wiesbaden, where they will run as part of JIVE 2. Altogether, the project wants to put a total of 290 fuel cell buses onto European roads.

WRIGHTBUS IS BACK Bus maker Wrightbus, which Bamford Bus Company saved from bankruptcy in late 2019 (see H2-international, February 2020), is still working on hydrogen-powered double-decker buses. Jo Bamford, who leads both Bamford Bus Company and British agricultural equipment manufacturer J.C. Bamford Excavators, is also CEO of Ryse Hydrogen, which works out of Oxford. Ryse is planning to offer fleet operators one-stop service, that is, green hydrogen and inexpensive fueling stations from a single source.

Early this year, Bamford said in Belfast: "We have got a half-full order book for the year and some wonderfully loyal customers, who have been fantastic for us." He also announced Wrightbus will deliver 20 hydrogen-powered buses to Transport for London in the UK's capital and another 15 to Aberdeen, where 10 have already been running since 2015.

In addition to Wrightbus in Northern Ireland, the British Isles are now also home to bus designer Optare, a UK subsidiary of Ashok Leyland, a commercial vehicle manufacturer in India. In partnership with auto supplier Arcola Energy, Optare intends to bring its own fuel cell double-decker bus to market. The MetroDecker FCEV is based on the company's battery-electric variant, exchanging part of the battery for an Arcola fuel cell (see fig. 1), which gives the bus a range of up to 400 kilometers (249 miles). Sales should begin in 2021.

In Canada, Vancouver's Loop Energy is the main fuel cell bus maker of note. With fewer than 40 staff members, it is planning to deliver 3,000 eFlows® to China, where Nanjing will outfit battery-electric buses with these 50-kilowatt range extenders. Ben Nyland, Loop Energy's president, said: "This agreement marks an important milestone for Loop, as it signifies a ramp-up of commercial activity. But it is also a testament to the growing market recognition of Loop product's performance and cost advantages." He chose not to reveal his Chinese partner company, but let on that US-based Cummins, Hydrogenics' parent company, has invested further in Loop.

HORIZON AND HYZON Hyzon Motors, a market entrant in North America, is making headlines with its ambitious plans. The company signed a memorandum of understanding to build 1,000 fuel cell buses. Yet, details about the agreement are few and far between. Hyzon is a brand-new US venture intent on powering buses and trucks with Horizon fuel cell stacks.

Horizon, a fuel cell manufacturer in Singapore, is also partner to GOLDI Mobility and Hy-Hybrid Energy on a Hungarian project aiming to develop 18-meter-long (59 feet) fuel cell buses powered by 100-kilowatt Horizon Group PEM fuel cells. These fuel cell systems will later be available for 12-meter-long, i.e., 39-feet-long, buses as well.

Naveed Akhtar, Hy-Hybrid Energy's chief executive, noted: "We chose Horizon as our fuel cell partner, since their business strategy jibes with Goldi Mobility's clean transportation ambitions. We also thought it important to leverage Horizon engineers' valuable experience on the Chinese market, where hundreds of commercial vehicles are already powered by Horizon systems and many more systems are being deployed as we go to market."

George Gu, Horizon Group chairman, said: "Horizon is pleased to confirm our first European customer for the new Horizon 100-kilowatt fuel cell system, which we believe has the potential to become the benchmark for high-power fuel cell modules. Working with partners in Europe and other markets, we aim to establish sufficient demand to justify local manufacture of fuel cells, as we essentially replicate many times over our new facility designed to produce 10,000 vehicle stacks per year."

Fig. 4: Faiz Francois Nahab [Source: Proton Motor]

Horizon's chief executive, Craig Knight, added in February: "We have been extremely impressed with the very business-like approach of the Hungarian government in seeking to attract forward-looking, vehicle-related capabilities to Hungary. The country is already very well known as a high-quality manufacturing base for Tier 1 automotive OEMs, and Horizon believes it is a very suitable location for fuel cell system production and vehicle integration."

Gu founded Horizon Fuel Cell Technologies in 2003 and was its chief executive until Craig Knight took over in September 2019. In August 2019, he was appointed chairman of both Horizon Fuel Cell Technologies and the Horizon Education Group. In January, he also became the chief executive of Hyzon Motors. Craig Knight previously served as Horizon Fuel Cell Technologies' commercial director from 2006 to 2019.

The Australian market is warming up as well. In May, a consortium consisting primarily of Ballard Power Systems, BOC Limited, Palisade Investment Partners, ITM Power and Transit Systems signed a memorandum of understanding to put 100 fuel cell buses on the streets of 10 Australian cities. During the first stage of what is known as H2OzBus, the project partners will develop a fitting design concept. Charles Purkess, of ITM Power, provided H2-international with a few details: "We estimate our buses will go into action sometime in 2022, depending on individual participants' schedules. In phase two, we hope to increase the number of buses throughout Australia to 1,000 or more." ||

ZEB 2020
Because of the global Covid-19 virus outbreak, the European Zero Emission Bus Conference (ZEB) in Paris has been postponed and will take place in fall 2020.

Theme: Electric transportation | **Author:** Alexandra Huss

TIME TO TAKE A DIFFERENT ROUTE

NPM designs future-proof transportation system

Fig. 1: In this Dec. 11, 2019, photo, Henning Kagermann, NPM's steering committee chairman, hands NPM's research report to Germany's transportation minister, Andreas Scheuer. [Source: BMVI, Ralf Brandt]

Hardly anything is as important to people around the world as getting from one place to another. Nearly everyone on Earth uses some mode of transportation. Thus, it should come as no surprise that, in September 2018, the German government set up an expert panel to devise new methods for staying on the move and to provide recommendations for redesigning the national transportation network. The NPM initiative is scheduled to run until the end of 2021, merging around 250 influential voices from the worlds of politics, business and civil society. Six workgroups discuss, free from technological bias, what policies would most likely create an environmentally, economically and socially sustainable path to a future-proof transportation system.

Led by Henning Kagermann, NPM picks up where NPE, a national electric transportation program that ran from 2010 to 2018, left off. In contrast to NPE, NPM pursues an integrated approach that considers not only the technological prerequisites but also the economic and social consequences of a changing transportation environment. Besides traffic routing and climate action initiatives, smart vehicle systems, novel engine designs and alternative fuels, the project focuses on helping Germany retain its status as Europe's most important vehicle market, secure jobs in the industry, bring the energy and transportation markets closer together and standardize electric components.

NPM's vision is to establish a predominantly carbon-neutral and environmentally friendly transportation network, a safe and efficient, affordable and high-quality system that moves people and goods by air, land and sea. Still, the country also needs to stay competitive if its auto industry is to keep its cutting edge and continue to provide work for millions of people. The question, then, is not simply what mode of transportation people will choose.

In short, NPM focuses on more than just how to get from point A to point B. The project takes a broader view of the transportation sector, analyzing what consequences the smart systems trend has for vehicle design, for one. Digitalization in particular has had a profound impact on how we work and live, turning transportation into a closely intertwined, shared experience in an increasingly automated world. We are also seeing breakthroughs in engine layout, energy systems integration and value chain management, and climate and environmental action debates are likewise influencing people's attitudes.

These factors have sparked a transformative process that

we must prepare ourselves to meet. Clearly, transportation is an essential service, and this service must remain accessible to everyone, regardless of social standing. The success of an environmentally, economically and socially balanced network will, most of all, depend on how quickly new transportation modes and solutions gain traction and how well they align with people's needs and schedules.

AN INFLUENTIAL COMMITTEE NPM members do not merely draw up and collectively approve recommendations before passing them on to the general public. Their work also serves as a blueprint for government policy. As early as March 2019, the organization published its first report, "How to meet Germany's 2030 climate targets in transportation," created by Workgroup 1. The recommendations in the document include calls for a carbon pricing program and seven to 10.5 million electric vehicles by 2030. The government's special committee on the climate crisis picked up on both of these proposals, as well as other NPM recommendations, and made them part of the 2030 climate action program and the government's new climate rules at the federal level.

In the meantime, the other five NPM workgroups have created their own expert documents, 16 to be exact, covering a wide range of transportation issues. NPM also published its first progress report in late 2019 and presented it to Andreas Scheuer, Germany's transportation minister (see fig. 1).

REGULAR UPDATES Hydrogen is central to NPM's work. Not only is hydrogen the basis for alternative engine and fuel development, but, more importantly, it also unites energy systems across multiple pathways and scales, integrating them within the transportation sector. NPM considers fuel cell engines the third pillar of any future transportation system, alongside all-electric vehicles as well as biomass and electricity-derived fuels.

To connect the energy market to the vehicle sector, NPM is calling for facilities that generate green hydrogen or use power-to-x production techniques. Once the government passes its national hydrogen strategy, the NPM workgroups will revisit their hydrogen targets for transportation, adjusting their trajectories where needed.

Similarly, NPM brings the Covid-19 pandemic to the conference table. While lockdown measures have done damage to the economy and job numbers, the rules preventing large gatherings and travel have likewise prompted a renewed trend to go digital. Consequently, social distancing regulations and stricter hygiene measures are gradually changing the way people go from place to place. In the medium and long term, all of the above will affect people's behavior and choices.

And although the NPM workgroups have been focused on designing a future-proof transportation grid for 2030 and beyond, the pandemic is already causing economic and social repercussions that will eventually also have an impact on NPM's continued work. The members of NPM are not resistant to change. On the contrary, they are keeping two eyes on the challenges triggered by the current crisis. They will continue to watch them closely and adjust their own assumptions and suggestions if necessary. ||

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

DAIMLER'S FUEL CELL CLUSTER

German automaker partners with Volvo and Rolls-Royce

In April, Daimler announced plans to enter a joint venture with Volvo to develop fuel cell trucks. In mid-June, preliminary agreements solidified as Daimler Truck set up a new subsidiary, Daimler Truck Fuel Cell, to pool fuel cell expertise. Christian Mohrdieck, the new company's chief executive, is well known throughout the industry. He began working on fuel cells at Daimler in 1999 and was put in charge of fuel cell activities in 2003. Mohrdieck will now be leading the subsidiary together with Andreas Gorbach.

Fig. 1: Andreas Gorbach (left) and Christian Mohrdieck [Source: Daimler]

Mohrdieck also heads the fuel cell business unit formerly known as NuCellSys. Renamed Mercedes-Benz Fuel Cell in January 2019, it will be incorporated into the subsidiary. The Volvo Group's 50 percent stake in the planned joint venture is valued at EUR 600 million. The partnership will focus on designing, manufacturing and marketing fuel cell systems for heavy-duty trucking and other applications, such as stationary power plants. However, Daimler's heavy-duty fuel cell vehicles will not enter the market before the second half of this year.

Together with Rolls-Royce Power Systems, Mercedes-Benz has also begun designing emergency power supplies (see H2-international, May 2020). Under its MTU brand, the British partner intends to market the Mercedes-Benz and Volvo joint venture's fuel cell systems to server room operators using conventional diesel engines to meet electricity needs. Mercedes-Benz plans to install the same fuel cell systems in both its heavy-duty trucks and stationary power plants.

> "Our new subsidiary will be the direct launching pad for our joint venture. There, we will pool the wealth of fuel cell development expertise and experience we have garnered over several decades – and merge it with proven trucking proficiency."
>
> *Martin Daum, Daimler Truck chairman*

Daimler Truck Fuel Cell will initially be in Nabern, a spokesperson told H2-international. Whether the new venture will also settle at Daimler's fuel cell cluster, as Mercedes-Benz Fuel Cell has thus far, remains to be seen. All the same, Baden-Württemberg state's economy minister, Nicole Hoffmeister-Kraut, said: "I see this project as a great chance for Germany, creating both added value and jobs in one of the automobile technologies of the future." She then promoted the idea of setting up a special European Union fund for hydrogen technology.

THE MEDIA'S ROLE Several recent news reports alleged Daimler was turning away from the fuel cell industry. These reports originate with the automaker's announcement that it is cancelling plans to mass-produce the GLC F-Cell model. Nothing new there. But some journalists interpreted this to mean that Daimler was about to leave the market altogether. And yet, when NuCellSys got a new name, Mohrdieck had already made clear that "fuel cells are an integral part of engine development at Mercedes-Benz Fuel Cell. […] The new name sends a clear message about our focus and underlines how important fuel cell technology will be in the years to come."

The collaborations with Volvo and Rolls-Royce show no automaker can afford to ignore the fuel cell market. What auto companies are still searching for, however, is how to get production volume up and costs down. ||

Theme: Stocks | **Author:** Sven Jösting

CHINA CHARGES AHEAD

Sven Jösting's stock market analysis

You can feel it – the wave of optimism sweeping through the hydrogen and fuel cell industry. All the more disappointing that the German government is taking its own sweet time setting up market regulations. It is a murky green light. Sure, there have been plenty of speeches. Yet, there is a decided lack of enthusiastic momentum. Even then, as the national hydrogen strategy was announced in early June. At least there is a ray of hope for hydrogen research funding in the Covid-19 stimulus package. But truly clearing the way for the technology, it is not. The path remains the destination.

The same can be said for revisions to Germany's renewable energy law EEG. Many professionals, industry agents and association representatives agree it should be scrapped, suggesting we use something else to generate revenue. Like a cap-and-trade program instead of yet another consumer surcharge. It seems China will beat us to the punch, again. It is allegedly investing in hydrogen and fuel cells, intent on cornering the market. A battery déjà vu. Lowering the EEG surcharge in Germany may sound good when you hear it for the first time.

Fig. 1: Historical prices of the five stocks discussed in this issue. Retrieved June 13, 2020 [Source: wallstreet-online.de]

The Chinese, however, are much more pragmatic. Their plans encompass power-to-X.

The same with solar and wind energy. Here, too, the People's Republic is uncontested leader of the pack. Tooling down the highway to hydrogen, China is at the wheel. Remember the fuel cell joint venture between Daimler Truck and the Volvo Group? That only happened because Chinese automaker and major shareholder Geely made it so. The worldwide market for trucks, buses and other heavy-duty vehicles is vast. Yet, these are the most emission-profuse vehicles and they primarily travel long distance, as Geely well knows. Geely also knows fuel cells can drive fossil fuel engines to extinction.

Batteries can only support, not replace fuel cells. Their weight and recharging time make them much less suitable for the task, despite Tesla's Elon Musk claims to the contrary. Just recently, he announced the Semi, Tesla's electric 18-wheeler, is postponing its debut until 2021 (see p. 45).

Of the five businesses discussed in this issue, global market leader Ballard Power was quick to respond to new developments, getting business partners on board. As you read these lines, China's new incentive program is probably already in place. Planned to arrive in early 2020, the Chinese government postponed publication until the third quarter. Politicking takes time. And yet, in matters of policy too, China will soon overtake us. If we Europeans want to avert another debacle, think Transrapid, we need to get in gear now. Our politicians cannot afford to hesitate. Opportunity only knocks so often. We have just entered the hydrogen decade, on the stock market as well.

BALLARD POWER AND LCS IN CHINA – THE EARLY BIRD CATCHES THE WORM

Ballard [Nasdaq: BLDP] and Weichai, Ballard partner and major shareholder, announced they are building an LCS factory in China. Past tense, it has probably already been built. Production should begin this year. The pre-launch event has been celebrated, so expect project completion on schedule. An opportune venture for Weichai, as it supplies the Chinese market with fuel cell stacks for trucks and buses. Ballard can cater to the rest of the world. In any event, only good news arrives from Ballard's China operations. For example, the company's stacks in commercial vehicles have already travelled 23 million cross-country kilometers (14 million miles) on >>

"We have, I believe, the strongest possible platform in the China market and a huge competitive advantage because of our relationship with Weichai."

Ballard CEO Randy MacEwen

Fig. 2: Weichai and Ballard's envisioned factory layout [Source: Ballard]

hydrogen alone. What other fuel cell business can boast such powerful market endorsement?

Word has it Ballard has teamed up with four OEMs, Yutong, Asiastar, Zhongtong and Sinotruck, to manufacture a range of fuel cell buses, with 55 models available so far. Joining another three partner companies, Ballard also intends to bring fuel cell forklift trucks to market. If you ask me, the partner to watch here is not US-based Plug Power, which uses Ballard's stacks in addition to its own, but rather Kion or Linde. The former owns forklift truck manufacturer Still. The latter has announced it will use fuel cells to power its latest equipment. Weichai, by the way, is Linde's major shareholder.

Apparently, Kion has also founded a subsidiary to promote hydrogen. Called Kion Hydrogen or something like it, I am not sure. In any case, forklift trucks are another Ballard target market. As for railroad vehicles, the world's first hydrogen streetcar started up earlier this year. Designed by Ballard partner company CRRC and equipped with Ballard fuel cell stacks, it runs in Gaoming, Foshan, in Guangdong province. This is surely not the last we will hear about hydrogen-powered rail vehicles. Many of them will probably have Ballard stacks on board.

A PROMISING VIEW Results for 2020's first quarter were all right but nothing to write home about. Ballard's chief executive, Randy MacEwen, announced earlier that the company intends massive investment in R&D. So, it might be a while before Ballard begins reaping rewards. Still, business should pick up steam in the second half of 2020, according to Ballard's first-quarter conference call. I quote: "Fairly strong second half – a very strong 2021 with the joint venture." The call transcript is available online if you want to take a look at it. It is a good source of information. Only a Covid-19 setback, with a second wave of infections, can put a damper on Ballard's plans. First-quarter revenue was USD 24 million, the gross margin 22 percent. Net loss per share was USD 0.06. However, more important are the company's prospects. The Daimler Truck and Volvo Group joint venture in particular shows which market will benefit from a fuel cell upgrade first.

> "I do not believe batteries are going to be able to satisfy the use cases for a number of these class heavy-duty trucks."
>
> *Ballard CEO Randy MacEwen*

Actually, it sounds like Ballard is most eager to supply stacks to the above-mentioned companies and Nikola Motors, too, keeping them busy making trucks, not fuel cell systems.

Nikola Motors has hitched up with electronics giant Bosch, while Bosch owns part of Swedish PowerCell, granting Bosch a fuel cell production license. PowerCell once belonged to the Volvo Group but is not doing any work for Nikola these days, says the grapevine. On a side note, early 2020, Bosch purchased an 18-percent stake in UK-based Ceres Power for EUR 90 million. One step ahead, Weichai had already bought into the stationary SOFC systems company, taking 19.7 percent for approximately GBP 40 million.

Incentive programs, industry initiatives: 15 Chinese provinces are already pumping up the hydrogen and fuel cell market all over the country. The upcoming national support program will take things even further, as it concentrates on commercial vehicles and infrastructure incentives, or, more, specifically hydrogen fueling stations. It is a good thing, too, for VW's chairman Herbert Diess, giving him time to get over his infatuation with all-electric vehicles and get hydrogen-powered cars out there instead. The VW truck-making subsidiary Traton, via Scania, is already on it. Fortunately, the German automaker has 39 factories in China.

Fig. 3: In this May 26, 2020, photo, Ballard celebrates 25 years of being listed on Nasdaq. [Source: Nasdaq]

ATM PROGRAM NEARLY COMPLETE Of the USD 75 million Ballard planned to raise with an at-the-market program, USD 52.6 million was already on the company's account by March 31. An additional USD 12.3 million was deposited in April, so I expect the USD 10.1 million difference will be raised and spent by the time you read this. Ballard's major shareholder, Weichai, clearly signaled the intention to hold onto its 19.9 percent share (anti-dilution rights) and will most likely purchase underwritten shares when the ATM program closes,

bringing Ballad an extra USD 15 million to USD 17 million. That is a nest egg of more than USD 210 million. Is there an acquisition on the horizon? A new joint venture? Why does the Canadian business need so much money?

APPROVED: UP TO USD 750 MILLIONS OF FRESH CAPITAL Early June saw Ballard's general meeting of shareholders approve a USD 750 million mixed shelf. A program on its way out is now revived and the cash total raised. This means Ballard can issue, for example, new shares or convertible bonds up to that amount. That would be around 65 million new shares. I applaud the move as it finally creates a doorway should large corporate strategic partners want a piece of the pie.

GLOBAL DEVELOPMENTS Besides China and Japan, many regions are planning large-scale programs similar to the European Union's Green Deal, focusing on green or blue hydrogen. In the United States, California was and is the avant-garde. Ballard chief MacEwen expects other US states to eventually copy the Golden State's blueprints for their own programs. I expect even bigger initiatives should the Democrats win back the White House. Then, the huge economic aid congress has approved in the wake of the Covid-19 virus pandemic should be invested in sustainable issues, building on environmentally sound and climate-friendly solutions.

Interesting to note is that more and more oil companies are starting to zero in on hydrogen. The dramatic drop in oil prices has generated massive pressure on the industry to finally rethink their strategies.

The new price target for Ballard is USD 16, according to H.C. Wainwright & Co. Just a milestone on the way up, in my opinion. Look at Nikola Motors, whose initial offering of USD 10 literally exploded to over USD 90.

BLOOM ENERGY'S FIRST QUARTER EXCEEDS EXPECTATIONS

Projected first-quarter returns were between USD 140 million and USD 160 million. In the end, Bloom Energy took in USD 156.7 million. However, if I interpret the numbers right, another USD 40 million was shifted to the second quarter. From projects that have not been billed yet, I do believe. The company's bottom line posts a USD 9.8 million loss, according to GAAP, far less than the predicted USD 15 million to USD 25 million. Cash on hand remained more or less steady at USD 354 million, although this includes restricted cash and power purchase agreements.

One intriguing management statement tells us Bloom Energy [NYSE: BE] is currently prefabricating to reliably deliver an expected peak demand in the second half of 2020. Not one project was cancelled because of Covid-19; not one customer lost. I am looking forward to this quarter's results – breakeven? – and especially to the second half year, which should ultimately be a good year for the company. The number of shorts went down from over 22 million to 19.3 million, implying short sellers also expect the price to go up and are closing out their positions.

Meanwhile, the Pacific Gas and Electric restructuring plan awaits approval. The utility provider was elbowed into creditor protection after a high number of damage claims due to Californian wildfires and power outages brought it to the brink of bankruptcy. The plan is to start afresh, purportedly including microgrid construction. Rumors have it that Bloom Energy might just be a candidate for PG&E contracts. While pure speculation at this point, it is worth keeping in mind.

BZVISION SAMPLE PORTFOLIO SHOWS STABLE, HIGH PRICES

The fuel cell stocks in the BZVision sample portfolio have done well. I also expect prices to jump noticeably over the year if the numbers, i.e. revenue, increase in bookings, etc., develop as projected. Compared to buying other fuel cell companies' shares, such as those of ITM Power and Nel Asa, purchasing Ballard, Bloom or FuelCell Energy stock seems quite the bargain right now.

Despite the sharp rise in Tesla stock to over USD 950 and the simultaneous fall of my put options (which I use to profit from falling prices) my portfolio barely took a hit. I could even accept a 10 to 15 percent total loss if stocks such as Bloom's and Ballard's went up by just USD 1 a share. Actually, I expect that fuel cell prices will easily cross that mark, while I think Tesla stock is in for a rough ride. If that happens, my put options could be worth a lot more. The hype around Tesla's sister company SpaceX can die down quickly. Morgan Stanley analyst Adam Jonas sees Tesla dropping to USD 650 soon, as he recently predicted in a research note.

The carmaker's decision to cut Model X and Model S prices by USD 5,000 each and the price for Model 3 by USD 2,000 will lower its profit margin even if those discounts draw in more customers. Second-quarter results will tell the tale. And should prices keep dropping overall, I still have my put options to cushion the fall and secure my portfolio.

PLUG POWER TO PRODUCE ELECTROLYZERS AND HYDROGEN

In my view, Plug Power [Nasdaq: PLUG] is definitely on the right track: Building and expanding liquid hydrogen production facilities while planning to acquire United Hydrogen. The latter's 6.5-ton annual capacity should be raised to 10 tons, thus meeting 25 percent of Plug's in-house demand, meaning eventually the profit margin can come from consumables. Plug is also negotiating with an electrolyzer manufacturer that could or should be absorbed. That all looks very good to me. In a few years' time, Plug intends to cover more than 50 percent of its own production with green hydrogen.

Now, gross billings should add up to USD 300 million this year and the goal is nearly met. Plug also intends to branch out into the backup power market, having already developed a new 125-kilowatt stack. In the most recent funding round, USD 200 million were raised via convertible senior notes with 3.75 percent interest and a 2025 maturity date. Called green bonds, they can be repaid in cash, in shares or through a combination of both. Plug decides how to pay back the money, while bondholders choose the date. Proceeds should be used to settle prior debt obligations and to provide funds for general business activities. However, I am somewhat leery of an investment brochure paragraph stating the notes can be terminated if certain requirements are not met. And Generate Capital's debt facility of USD 100 million at 9.5 percent >>

interest could turn out be some complex construct, i.e., be tied to certain conditions stockholders need to be wary of, like in FuelCell Energy's case. My personal opinion.

Plug's ability to wave through capital raises is certainly not a bad thing. But at the end of the day, what counts is the terms and dilution effect (increase in free float). Amazon and Walmart own over 50 million option rights to buy Plug stock at around USD 1.19 per share. Converting them, that is, purchasing shares by exercising those rights would make sense, as I expect they will. That may give Plug a quickly rising number of shares, but also a solid USD 100 million, without having to worry about accounting issues. Amazon and Walmart would earn a good deal of money and essentially fund their own bookings. Can things get any better than that?

What I am asking myself is: Could the above be related to the more than 70 million shares that are being sold short? Is it some kind of safety net? Since early June, Plug's stock has known only one way: up. The Barclays bank analyst covering the market has set a price target of USD 7. I would close the position at USD 6.

FUELCELL ENERGY – NEW PROJECTS AHEAD

FuelCell Energy recently announced that, since launching business, it had produced over 10 million megawatts of clean electricity, saving over 1.5 million tons of carbon dioxide. Its basis for success is the SureSource platform. The company is now gradually fulfilling orders worth more than USD 1.3 billion. New bookings season the pot, as they are expected to lead to high margins. With the coming Green Deal, orders from across Europe will soon supplement the company's success in Korea, where absolute reliability earned FuelCell top grades. By the way, E.ON Business Solutions is one of FuelCell's partners now. An approved capital raise via an at-the-market program, like in the case of Ballard Power, will also bring in fresh capital. Money I assume will be reinvested only when the stock rises, thus dampening dilution. Based on the decision made at the annual general meeting, the company can now increase the number of outstanding stock to 337.5 million shares.

HIGHER SECOND-QUARTER RESULTS FuelCell Energy [Nasdaq: FCEL] managed to complete the quarter ended April 30 at a revenue of USD 18.9 million, a remarkable 105-percent year-on-year increase. Net loss per share was USD 0.07, and USD 0.02 of that amount was the result of including in the balance sheet option rights granted to Orion Energy Partners, FuelCell's biggest individual stockholder. Orion has provided FuelCell with more than USD 200 million.

New contracts to build fuel cell power plants, portfolio expansion – currently encompassing eight projects with 37.4 megawatts -- and improving the profit margin let fantasies fly when it comes to FuelCell stock. I am banking on additional CCS technology bookings, as the company is currently carrying out a USD 60 million contract for ExxonMobil.

5-PERCENT CONVERTIBLE PREFERRED STOCK CLASS B WITH HIGH DIVIDENDS An alternative to investing in common stock could be to buy 5-percent Class B preferred shares (FCELB). Their face value is USD 1,000 and the market value at the time of this writing was about USD 380. Now, 5 percent equals USD 50, and putting this in relation to the current price gives you a dividend of more than 13 percent. The better FuelCell Energy is doing, the lower dividends will get as prices rise. The company can pay stockholders in cash or shares, the exact amount determined by the average price over the last five trading days before payment date. If another business wanted to acquire FuelCell Energy, it would have to pay face value. Preferred stock could be a good addition or an alternative to a current investment portfolio. However, as a low-volume market, investors should have a personal interest in the product.

NIKOLA GOES PUBLIC – AND BRINGS ON THE FIREWORKS

Long anticipated, Nikola Motors [Nasdaq: NKLA] finally goes public. In order to get a foot in the door early, the truck maker used a reverse merger. Investors acquired a public shell company, a special type of investment vehicle. By issuing new shares, Nikola raised USD 700 million. The stock shot up from around USD 33 (original issue price: around USD 10) to over USD 90. Nikola's market cap, an impressive USD 25 billion, is the result of high expectations. And yet, it seems a bit over the top to me. By that logic, Ballard, which is already producing commercially available stacks for buses and trucks in China, would have to be worth USD 10 billion or more by now. My theory.

A positive turn is that Nikola already has 14,000 trucks on preorder, worth well over USD 10 billion. A fuel cell system and a small battery will provide them with a range of around 1,100 kilometers (684 miles). The hydrogen tank, which holds 100 kilograms, will be used on long-distance trips, while the battery will meet short-term needs. Other vehicles, including an SUV and a pickup truck named Badger (equipped with either a battery, a fuel cell and a battery, or a fuel cell retrofit kit), are to be introduced at a later date.

In partnership with Nel Asa, Nikola intends to install its own hydrogen infrastructure. Over the next eight to 10 years, the company will build 700 fueling stations in the United States and 70 in Europe. The factory in Ulm, Germany, will begin truck production towards the end of 2021. In 2022, in the United States. To reach its goals, the business is partnering up with Iveco, Bosch and Mahle, to name a few.

As a side note, Nikola is suing Tesla. Nikola alleges the Semi design is a clear copy of the Tre model. Tesla will bring the Semi on the market in 2021.

My conclusion is that Nikola is an intriguing newcomer to the world of stock-listed fuel cell manufacturers. And yet, I do not believe there is much to gain from investing in the

Fig. 4: The Badger pickup truck envisioned by Nikola will reportedly put out 666 kW and 1,328 Nm. [Source: Nikola]

truck maker at this time. If you want, buy a few shares now and purchase more stock after the price has fallen. Clearly, the commercial vehicle market offers one of the best opportunities for fuel cell companies. Just recently, Toyota announced it founded a joint venture in China with five of the country's biggest auto companies. The aim is to make fuel cell stacks for trucks. Nikola is focusing on the submarket that offers fuel cell businesses the largest potential for growth. And if Tesla intends to bring all-electric trucks to market, it might find itself out in the cold.

TESLA – UP, UP AND AWAY BUT FOR HOW LONG?

An unexpectedly profitable three months propelled Tesla's stock to over USD 850 before it plunged to USD 670 when the electric carmaker's chief executive, Elon Musk, sent out a tweet complaining about the high price. Not much later, though, the stock rallied again, racing toward USD 1,000 after sister company SpaceX, which is also headed by Musk, announced it successfully sent one of its rockets into orbit. The announcement prompted not only SpaceX' but also Tesla's stock to go through the roof. Seen that way, the rally was more likely the result of enthusiasm gone overboard than a genuine assessment of the carmaker's strengths and weaknesses. But let us start at the beginning:

Based on GAAP accounting rules, the first quarter of this year netted investors only a tiny profit, USD 0.09 per share. Using non-GAAP standards, which had been expected to lead to a loss of around USD 0.36 a share, earnings increased to USD 1.24 and sparked a wave of euphoria among Tesla aficionados. Since then, however, people in several online auto forums have raised questions about the veracity of the numbers, the reason being that most of the company's profits for the first three months of 2020 seem to stem from the sale of regulatory credits, also known as ZEVs in California, to FiatChrysler. Selling them brought in as much as USD 354 million, far more than expected, but not still revenue generated from marketing vehicles. Recently, more news reports were driving up Tesla's price. For example, one outlet said Tesla [Nasdaq: TSLA] could soon join the S&P 500. A stock split could also boost its price, even if such a move is purely cosmetic.

The bright prospects on the stock market stand in stark contrast to the dreary facts on the ground. Tesla's main factory in Fremont shut down because of Covid-19. For a while, the same was true for Shanghai, even if the factory in China has since resumed operations. As is typical of Musk, he could not resist leveling criticism at government officials. Promising revenge, he threatened to transfer Tesla's headquarters from California to another state – Texas seemed favored, Austin specifically – failing to see why health regulations kept him from starting up production.

Whether Musk has spoken with Tesla's board members about his plans is another question altogether. If he did not, his tweet could cause him his job as the company's chief executive. SEC rules dictate such statements be approved by both Tesla's executive and supervisory boards. Rules Musk has broken, costing him and Tesla USD 20 million each. Will the SEC drop the hammer on him? If so, many Tesla fans will lose their guru. Elon Musk a common shareholder or board member? Unthinkable.

Musk's bonus plan is based on performance and milestones. One of them was to see Tesla's market cap exceed USD 100.1 billion for about six months. Now that this milestone has been reached, he can purchase 1.7 million shares for USD 350 each, netting him more than USD 800 million at current prices. However, it is said he needs to keep the stock for at least five years. Well done!

CHINA AS TESLA'S PLAYGROUND? Manufacturing cars in China does make a lot of sense. The question is, though, under what contractual terms? Chinese banks lent Tesla more than USD 2 billion to build its factory, recently followed by another USD 565 million in new credit. From what I have read, all of the funds can only be used for projects in China so Tesla will have to figure out whether it can sell enough cars in the People's Republic to make the loans worthwhile.

This also means that as long as the loans are running in China, Tesla may not be allowed to distribute profits to the United States. And in a few years, the company will have to pay minimum taxes in China as well, independent of sales, or, more specifically, of revenues, losses and profits. Not that long ago, Tesla reduced the prices for all cars manufactured and sold in the country by 10 percent, within the acceptable price level for federal clean technology incentives. Tesla has justified the price reduction by saying it would generate more sales and via the production scale balance out the profit margin.

One analyst remarked that if Model 3 and Model Y are later exported from China to Japan, Australia, etc., it could trigger an in-house competition between the Chinese site and its production facilities in Fremont. Another question is whether Tesla's total liquidity of over USD 8.3 billion includes the credit facilities in China. One commenter said that Tesla would need to maintain a USD 2 billion reserve and that factory closures due to Covid-19 could have cost the electric carmaker between USD 700 million and USD 1 billion a quarter. Meaning, even a USD 8.3 billion financial cushion is not much to work with.

Do not get me wrong, I think Tesla cars are classy and sleek. I know plenty of Tesla owners. There is even a Tesla parked in the garage beneath the apartment complex where I live. Still, the stock market values seem absurdly high and artificially generated. The prospects of acceptance into the S&P 500 Index (unsubstantiated) or a stock split for cosmetic improvement may certainly have short-term benefits, but it is Tesla's numbers that count and those require a foundation of steadily rising profits. In addition, relying solely on batteries is extremely risky business if fuel cells and hydrogen continue to flourish, as I expect they will. Then, Tesla may well find itself at the end of the road while the stock market merrily reroutes. But that may take a while yet – longer than I think. ||

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.

Theme: Research and development | **Authors:** Dr. Holger Brauer, Marco Henel, Albert Großmann

IN WITH THE NEW, REPURPOSING THE USED

H2-PIMS or how to safely transport hydrogen blends

Renewably sourced hydrogen is an essential energy carrier for achieving COP21 climate targets. The gas can store and deliver energy anywhere, anytime, meeting demand regardless of generation facilities and end users. However, a reliable and safe infrastructure, including pipelines and control systems, is needed to ensure that a storage medium such as hydrogen can really play to its strengths and guarantee supply. This spawned the idea of using the national pipeline system, as well as its underground storage facilities, to transport, distribute and store hydrogen blends and use, or, more specifically, convert sections of the network to deliver pure hydrogen. The challenging part is how to safely handle a gas that has very special physical properties. H2-PIMS, a project supported by the HYPOS initiative, is currently tackling this issue. It has created a rating system, PIMS, for pipelines transporting hydrogen blends. PIMS stands for Pipeline Integrity Management System, and is used to investigate, on behalf of the pipeline operator, whether the current gas infrastructure meets the safety and material standards required to deliver blends. The PIMS safety and suitability assessment will form the basis for suggestions on how to run an economically and technically viable system, what needs refurbishing and where to build new pipelines.

PIMS is based on pipeline specifications, some of which fluctuate while the network is in operation. The reasons for this are manifold, ranging from erosion and insulation issues to outside intervention, previously unknown material defects (e.g., in the weld seam) and transient process parameters.

THE BASICS Current discussions center around how to use network specifications, process parameters and pipe measurements (e.g., diameter and wall thickness, material and grade, surface quality, test results, and time in operation) to reveal the layout needed to convert pipelines. There are strong arguments for taking a staunchly conservative approach to first assessments of network stability to reduce stresses on pipe walls and provide a rough estimate of hydrogen-induced damage under steady-state operating conditions. To this end, one could use the tensile strengths mentioned in EIGA's IGC DOC 121/14 guidelines. Other quality and design issues for constructing or converting pipelines that deliver hydrogen can be found in ASME standard B31.12-2019.

Pipeline operators could also lower pipe pressure until the required threshold values are met. If that does not help either, they can turn to PIMS, supported by the German education and science ministry. This will expand the list of methods at their disposal by including tools designed for analyzing hydrogen blends. PIMS offers suitable, descriptive models and verified analytical and predictive algorithms that provide operators with highly granular analyses of network conditions and illustrate quality changes over time.

Findings can later be used to determine what pipeline sections to refurbish and which strategies to follow, for example, when expanding the network.

CHARACTERIZING MATERIALS Initially, project members focused on characterizing pipeline materials to identify both their suitability for delivering hydrogen [1] and what type of damage the gas can cause to networks. In addition to analyzing material behavior, they determined fracture toughness, i.e., fracture growth, in the presence of pressurized hydrogen, since delivering hydrogen through the pipeline system creates highly fluctuating internal pressures. A variety of studies have

shown that even a small increase in pressure, combined with low-level hydrogen blends, can accelerate fracture growth by about a factor of 10 [2,3].

This means that those designing pipelines for hydrogen delivery must take material toughness into account, as well as possible discontinuities or fractures in existing pipes. The required layout is defined in British standard BS 7910 and American standard ASME B31.12-2019. Both include models of incipient and growing pipe or weld seam fractures. These can be used to calculate fracture growth at each pressure change and the related strain when pressure on a line starts to increase.

The above-described material factors, e.g., incipient fractures and fracture growth, as well as fracture toughness, may be key to determining grid resilience but are often not available for analysis. For this reason, H2-PIMS conducted a ground-breaking investigation into existing pipe materials, the results of which are expected at the end of this year. The findings will make it possible to perform a preliminary characterization of materials and decide how broad and thorough subsequent investigations into the impact of hydrogen on material properties must be.

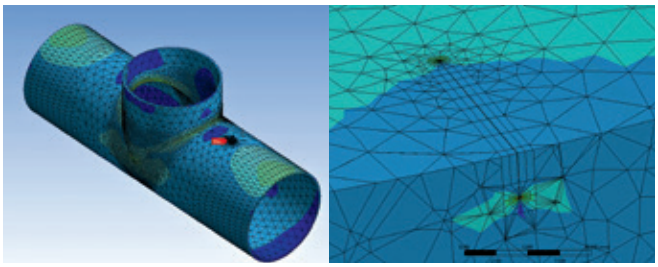

Fig. 1: Finite element model of a tee piece with a surface fracture

CREATING A MODEL H2-PIMS currently addresses creating computer models that illustrate the impact hydrogen has on the integrity and safety of pipeline components. Static and cycle tests of material properties and process parameters assess the network's condition once subjected to hydrogen-induced damage. These models also consider component-specific attributes.

More specifically, the PIMS rating system includes individual assessments for straight pipes, tees (see fig. 1), pipes with stubs, elbows and reducers. It uses not only conventional deterministic but also statistical models to render statements on network quality, allowing both a quantitative risk assessment (QRA) and a structural reliability analysis (SRA).

The advantage of statistical methods is that they consider very unlikely events, such as imprecise measurements of fracture depths or fluctuations in energy amounts absorbed by the fractures. These insights can be combined and findings included in H2-PIMS to ultimately calculate the likelihood of seeing fractures turn up in certain pipeline sections.

The likelihood of failure changes at the border of each section. Sections can be very short (e.g., covering only corroding areas that may have formed fractures or areas around the weld seams) or span great distances as long as the average pipe diameter remains the same and there are no documented issues for that section. As the basic modelling data has a profound impact on analytical results, pipeline operators need to consistently monitor network quality and track changes.

SRA results are useful whenever planning and approval procedures require thorough safety assessments (for example, when creating QRAs). When planning, surveying, constructing or operating gas pipelines that deliver hydrogen blends, the results offer proof that the network continues to meet high regulatory standards.

DEVELOPING A ROAD MAP TO CERTIFY AND REPURPOSE PIPELINES Efforts to certify or repurpose natural gas pipelines concentrate on how to blend hydrogen with natural gas within the confines of DVGW regulations and how to convert some pipelines to deliver hydrogen only. The road map for this project concentrates on making required adjustments a reality. Adjustments are grouped into the following categories: operational strategies and capacity planning, measurement techniques, client networks' hydrogen tolerances, safety concepts, maintenance schedules, marketing, legal matters and pipeline materials.

The road map targets pipeline operators and, in the course of time, distributors. It can guide them toward implementing the necessary changes. The main incentive for operators is their growing determination to provide customers with a greener gas supply, which means they have a sincere interest in making the existing infrastructure fit for the future. The road map can be a starting point for specifying, from a technical and a regulatory perspective, the measures needed to repurpose pipelines. It does not offer cost estimation models, as these depend on a wide variety of factors. Additionally, pipeline sections may differ markedly from each other, making it impossible to provide even a rough estimate. ||

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HOW FUEL CELL MEMBRANES DEGRADE

Ex-situ analysis using Fenton's test

Understanding how the presence of cations causes polymer electrolyte membranes to degrade is important to advancing PEM research. Fraunhofer ISE has been focused on analyzing various types of cations for their impact on perfluorosulfonic acid (PFSA) membranes. This analysis is significant in understanding the catalytic effect individual cations have on forming radicals that attack PFSA polymers. How chemical stable these polymers are was investigated using Fenton's reaction. This ex-situ method for accelerated chemical degradation employs an ion-selective electrode (ISE) to measure fluoride ion (F^-) release and determine the fluoride emission ratio (FER). It can be used together with other methods such as NMR, ATR-IR and Raman spectroscopy to analyze PFSA polymer degradation.

One of the main challenges to ensuring that PEM fuel cells remain stable is how to retain membrane durability. Due to their excellent stability, perfluorosulfonic acid (PFSA) membranes are now widely used in PEMFCs [1]. And yet, some conditions may cause membranes to become thinner or pinholes to form [1, 2], which increases gas crossover and can lead to lower performance or create safety issues [3].

A membrane can degrade chemically when hydroxyl (·OH) or hydroperoxyl (·OOH) radical species attack its polymer material [2]. These radicals form during oxygen reduction reactions or the decomposition of hydrogen peroxide (H_2O_2), which is created under certain conditions and in secondary reactions inside a PEMFC [2, 3]. For example, in open circuit (where electrodes are supplied with reactant gases but no current is drawn) and dry conditions, H_2O_2 forms from gases crossing the membrane, especially at the anode, because of existing potential [3, 4]. The process by which oxygen or hydrogen permeates the very thin membrane is called gas crossover. Although it is undesirable, it is an inevitable part of operating PEMFCs [3]. Since it creates H_2O_2 and, ultimately, radicals that attack the membrane and increase the crossover of gases, the negative effects become more pronounced over time.

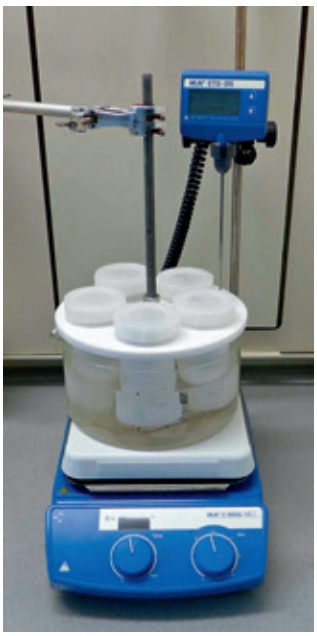

Fig. 1: Test setup, including 5 sample containers, to initiate an ex-situ Fenton's reaction. [Source: Fraunhofer ISE]

When catalysts are absent, the rate of H_2O_2 decomposition is comparatively low. By contrast, transition metal ions can accelerate decomposition and create ·OH and ·OOH radicals that will degrade membranes relatively quickly. Iron cations (Fe^{2+}) are known to be a particularly effective catalyst when breaking down H_2O_2 [5, 6]. The catalytic effect of any cation other than iron is rarely discussed in the literature, despite the fact that the water in PEMFC stacks contains various kinds of cations. They originate from, for example, assembly materials or salts contained in air humidifiers and enter the system during operation [7, 8]. Although most of them are present in low concentrations, they can still accelerate polymer degradation within the membrane.

Thus, one of Fraunhofer ISE's aims has been to analyze what catalytic effect a wide variety of cations have on chemically decomposing PFSA membranes. Fenton's reaction is an ideal testing method to achieve this, since it allows for a relatively easy insertion and controlled contact between cations and membrane samples.

TEST SETUP AND MATERIALS The experiment described in this article was conducted using the Nafion® XL (Chemours) PFSA membrane. Each membrane sample was dipped into 75 mL of Fenton's reagent, which contained 30 percent hydrogen peroxide (H_2O_2) and 20 mg/L of a metal salt (originating from a standard solution) and was stored in high-density polyethylene (HDPE) containers. To ensure a safe testing environment and prevent the solution from being contaminated by metals and other compounds, the test bench was made of HDPE components and the test equipment of HDPE or ceramic materials. Circle-shaped HDPE membrane holders guaranteed that samples remained flat and fully submerged in the solution. This was important because folded or rolled-up membranes could affect the reaction and, consequently, degradation. The test setup included 5 sample containers, as shown in figure 1. They were partially submerged in an oil bath to control their temperature.

The samples were gradually heated to 80 °C, a typical PEMFC operating temperature, to initiate and accelerate decomposition and degradation. Fenton's reagent that evaporated condensed in the upper part of the halfway-filled HDPE containers, eliminating the need for reflux coolers. Small openings in the container lids ensured pressure equalization.

Collecting and analyzing liquid samples in specific intervals over the 72-hour testing period for each membrane later allowed a quantitative comparison of FERs.

FINDINGS The effect of using Fenton's reagent for different cations is shown in figure 2. Whereas copper and iron cations resulted in high fluoride ion concentrations within the solution, i.e., affected catalytic H_2O_2 decomposition and thus the PFSA polymers, manganese and zinc showed relatively modest concentrations. Flattening curves in the case of iron and copper also indicate a greater rate of reaction. This is because one of the reactants (H_2O_2) was consumed in a comparatively short amount of time and fewer radicals were available for breaking down PFSA polymers. Decomposition in the absence of metal ions was analyzed using blank samples. These consisted of membrane pieces submerged in hydrogen peroxide without metal cations added, and they were tested at the same time as the other samples.

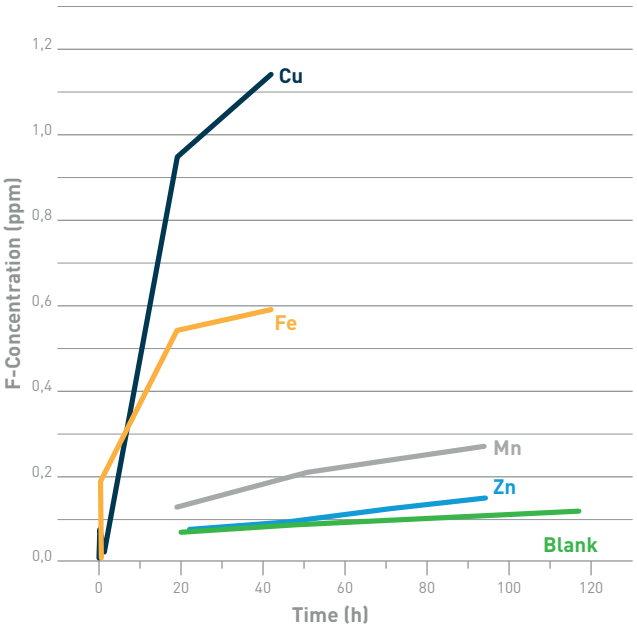

Fig. 2: Measured fluoride ion concentration after metal ions were added to Fenton's reagent as compared to blank samples containing none of these ions. [Source: Fraunhofer ISE]

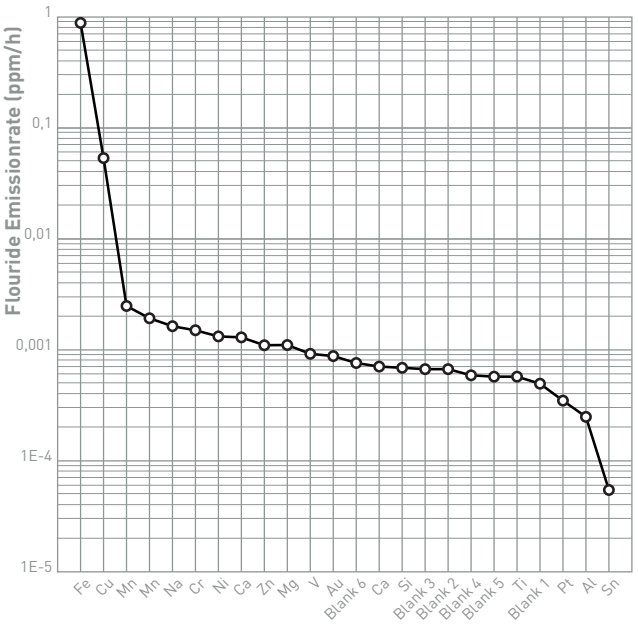

Fig. 3: Fluoride emission rates of metal ions and blank samples (membranes submerged in H_2O_2 without metal ions added) tested by Fraunhofer ISE, plotted on a logarithmic scale. [Source: Fraunhofer ISE]

The decrease in fluoride ion concentrations over time made it possible to determine FERs, as shown in figure 3. Regarding iron and copper, the FERs had to be estimated based on fluoride concentrations in the early stages of testing, since those two cause strongly exothermic reactions and H_2O_2 concentrations decline comparatively fast. Thus, their actual FERs are likely greater than estimated. Figure 3 shows that iron and copper resulted in high FERs (0.89 and 0.05 ppm/h, respectively), with a strong catalytic effect on membrane decomposition, whereas a large portion of the other elements analyzed led to FERs two magnitudes lower (between 10^4 and 10^3 ppm × h^{-1}). For example, copper and iron turned out to be respectively 100 times and 1500 times more harmful to membranes than the heat-induced effect in the absence of metal ions. Nickel and manganese, and possibly Na, Cr, Mg and Zn, showed slightly increased FERs, whereas Ca, V, Pt, Au, Sn, Si, Ti and Al had no discernible effect on degradation.

CONCLUSION Fenton's tests are well-suited to investigating the effect several kinds of cations have when hydrogen peroxide decomposes into radicals and subsequently causes PFSA membranes to degrade. The fluoride emission rates measured during the experiments made it possible to compare how severely cations affected membranes and how stable different types of PFSA membranes actually were. The analysis described in this article showed that iron and copper are the most intrusive of the cations tested, while aluminum and titanium are the least intrusive. This method can be easily adapted to analyze several types of membranes in order to determine how well they are able to withstand intrusion. It can also be employed together with other methods to advance knowledge of membrane degradation. ||

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Theme: World | **Author:** Ken Silverstein

IT IS 'ABSOLUTELY FEASIBLE'

A hydrogen plant to fuel Los Angeles

When it comes to electricity generated from pure hydrogen, there's good news: The Los Angeles Department of Water and Power has reached an agreement with authorities in Utah to buy much of the output from the Intermountain Power Project, which will produce green hydrogen from wind and solar.

All the signs point in the right direction for this to work: For starters, Los Angeles is going all-green by 2045 and it is already getting some of its electricity from this Utah-based 1,800-megawatt coal power plant. Together, the partners agreed that the plant will be converted to a combined-cycle facility that can burn not only natural gas but also hydrogen. By 2025, 30 percent of its fuel will come from green hydrogen and by 2045, all of the electricity will.

"It is absolutely feasible," Janice Lin, founder of the Green Hydrogen Coalition, which is spearheading the effort, said in a talk with this writer. "This is not just an idea. This project is going to happen."

Why the positive outlook? Obviously, the cost of wind and solar power has dropped dramatically, making the associated technologies and fuels cost-effective. Plus, the western United States is rich with such resources. And when coupled with the fact that the IPP sits atop a salt dome and that the transmission wires are in place, the odds of success go up.

Already, green hydrogen can be blended with natural gas at a rate of 15 percent. Getting to 30 percent by 2035 is reasonable. Secondly, hydrogen is often criticized for having smaller molecules that can easily escape from storage. But a salt dome is the best of all possible storage sites, said Lin, noting the dome can hold the equivalent of 100,000 MW. An abundance of wind and solar can thus be used to generate clean hydrogen and store it in the dome. And when this hydrogen is needed, it can be called up as a fuel, while the power produced from it can be transported to Los Angeles via existing transmission infrastructure.

To be clear, more than 99 percent of the world's hydrogen production to date has been from fossil fuels: natural gas, oil and coal. That is called grey hydrogen. The objective is to get to green hydrogen, whereby technologies such as solar panels and wind turbines produce electricity that is put through an electrolyzer to create pure hydrogen gas.

Fig. 1: Intermountain Power Project Site – Solar and ... [Source: LADWP]

"Right now, I can see no way of getting to 100 percent renewable energy without hydrogen in the mix," said Martin L. Adams, the L.A. utility's general manager and chief engineer. "The ability to use green hydrogen as an alternative to fossil fuels in existing infrastructure not only ensures reliability but will also make our clean energy future much more affordable."

SOME BIG TESTS AHEAD The Los Angeles Department of Water and Power is on record saying that it expects significant reductions in CO_2 based on the switch from coal to natural gas. It also noted that when hydrogen is blended in, such emissions will fall further.

Bloomberg NEF agrees with that thinking. In its Hydrogen Economy Outlook, it wrote that green hydrogen could cut global greenhouse gases by 34 percent by 2050. To achieve this, however, it underscores that major policy revisions are needed. Hydrogen could be produced from wind and solar for between USD 0.8 and USD 1.6 a kilogram. That is roughly the cost of natural gas.

Making the switch will require USD 150 billion in subsidies over the next decade, although that is less than what fossil fuels now receive. The money would go toward creating a supply chain and adding infrastructure. Without such progressive policies, it noted, reaching a favorable pricing point will remain elusive.

"Hydrogen has potential to become the fuel that powers a clean economy," wrote Kobad Bhavnagri, lead author of the report and head of its industrial decarbonization effort. "In the years ahead, it will be possible to produce it at low cost using wind and solar power, to store it underground for months, and then to pipe it on-demand to power everything from ships to steel mills." He added: "If the clean hydrogen industry can scale up, many of the hard-to-abate sectors could be decarbonized using hydrogen, at surprisingly low costs."

The good news is that prices for electrolyzers are falling. These devices split water into hydrogen and oxygen. The hydrogen gas can then be stored before it is piped into a fuel cell to create clean electricity with no emissions.

The challenges? Since hydrogen has around a third of the Btu of natural gas, it will be hard to just discontinue using the fossil fuel. That means more emissions. Critics, in fact, say the process of using solar power to separate hydrogen from water before taking the gas to produce electricity results in 70 percent energy losses.

As for California, it wants to have a carbon-neutral economy by 2045, said Wade Shafer, a director of IHS Markit's North American Power Analytics Team. He added: "This could mean net-zero goals and that an offset is required. In that case, the Intermountain Power Plant would continue to use natural gas."

No doubt, there will be engineering, technological and political tests ahead. But Los Angeles has the muscle to get this massive hydrogen project off the ground, a goal endorsed by leaders at every level in California and Utah. Given the renewable energy mandate, the existing transmission system and the salt dome that lies beneath the power plant, the project could be a winner and have far-reaching implications as a result. ||

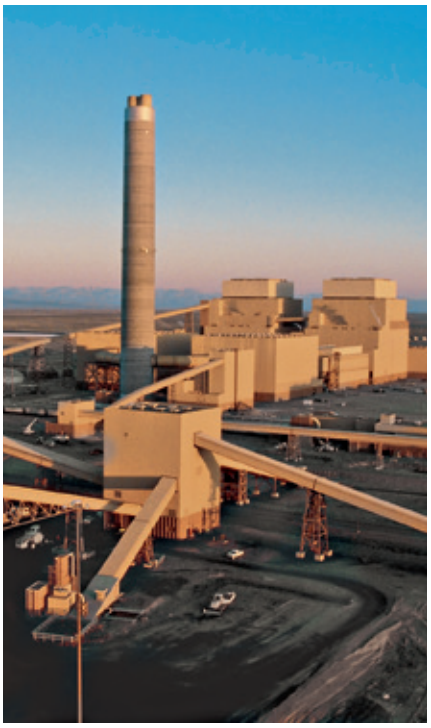

Fig. 2: ... coal plant in Utah [Source: LADWP]

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EVENTS

Due to the current situation, we will refrain from announcing events this time, as most of them will not take place in the near future anyway.

Please have a look at the following web page where you can find some upcoming online and face-to-face events:
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