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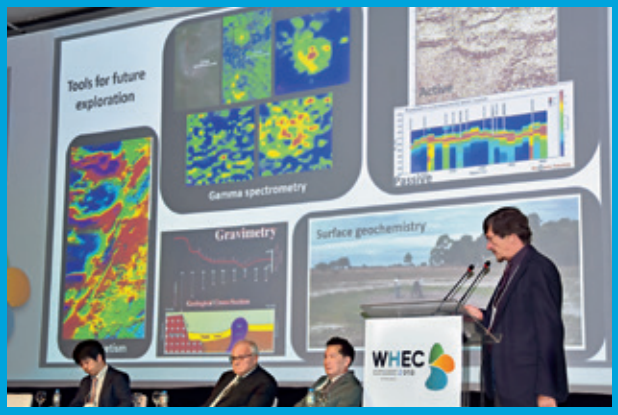

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Cover image: HY4 receives flight permit [Source: H2Fly]

FUNDAMENTAL CHANGE

Dear readers

What a year we've had. Rarely has so much, in such a short time, changed in the energy sector, particularly for the hydrogen industry. For starters, we have witnessed the arrival of a national hydrogen strategy, council and office, a European Green Deal, a European Clean Hydrogen Alliance, RED II and the IPCEI Hydrogen, as well as revisions to the German EEG.

Some of these, like the national strategy and hydrogen office, have been a long, arduous time in the making. Others, such as RED II, caused quite an uproar in some circles, with DWV boss Werner Diwald calling it an outright "slap in the face." And then there are those things which came out of the blue, such as Germany coordinating a hydrogen-focused IPCEI.

All in all, though, we can say our years of effort have paid off. Of course not on all levels, but for the most part, the statement holds true. The German government no longer caters to the auto industry's every whim. Although BMW, Daimler and VW still have a powerful influence on politicians, German and European lawmakers recently introduced emissions reduction targets that would have been unthinkable in 2019.

Renewable capacities have been increased, although projected targets are a long way from meeting the 1.5 °C global warming limit. Even the world's 2 °C goal is doubtful. Still, 2020 was the year in which hydrogen became widely recognized as the missing link in energy systems integration.

The sum of recently past events – the diesel scandal, fine dust debates, climate protests, Fridays4Future, natural disasters and the stark plunge in our insect population – has left a mark, not just on society but also on politics. The pressure to act is immense. Something even diehard reactionaries should realize by now. All things considered, 2020 was a good year for those intent on transforming our energy system.

Because: We finally have a launchpad – albeit a small one. Revamping our energy supply will take more than a few baby steps in the right direction. We need many more policies, and fast. So far, government and business leaders have paid little more than lip service to the cause. But we need to push forward, and we need to do it now.

At the same time, we need to bring those into the fold who are still hesitating for one reason or another. Many decision-makers cling stubbornly to old habits and technology. It's not enough to put a few thousand electric cars on the road and then wonder why people are bashing fossil fuel ICEs. Neither does forcing a switch from oil to gas on the heating market make much sense, considering today's gas boilers require fossil sources for another 20 years. Home fuel cells are also far from optimal, since they, too, must be fired by natural or liquified petroleum gas. What we need as soon as possible are hydrogen grids and hydrogen-powered fuel cell systems.

Looking at the big picture, we can see the European Union's democratic decision-making process and chorus of diverging opinions can nonetheless lead to a broad consensus. While arriving at a decision may not always be easy, the underlying social discourse is vital for motivating topic-related personal research to voice an informed, educated opinion. We are all obligated to participate in that exchange. There is still much to discuss. For example:

Do we really want business as usual, now that so many things are changing? Do we want to keep insisting on economic growth, although there is overwhelming evidence that this will only erase the technological progress we have achieved?

Looking back for a moment, in the past decades, we've seen great technological breakthroughs that found their way onto the market. But did they do anything to actually improve efficiency? Did they limit the ever-rising carbon dioxide emissions?

Despite clean energy sources already meeting over 40 percent of our electricity needs, average global temperatures are still rising. And even though automakers claim to focus diligently on combustion engine efficiency, VW's current Golf model burns nearly as much gas as the Golf I.

Thus far, meeting growing demand has more often than not obliterated technological advances. The more systems and gadgets, the heavier the vehicle. Ergo, the more fuel it requires. And the more people traveling in private cars, the more they render improvements in bus, train and plane efficiency meaningless. Not to mention the damage they do to an already over-burdened environment.

And yet, how else can we hold on to our current amenities and standard of living?

One idea is described in an essay on page 48 of this issue, illustrating a holistic, sustainable approach to accounting or, more specifically, financial reports. Conventional reports are limited to cash, cash equivalents and assets. They neglect other items despite their importance to business, such as innovative ideas as well as social and environmental factors.

Thinking ahead, however, it will certainly not be enough to merely improve the figures on a report. Companies should also operate sustainably; they must walk the talk.

The debate on real sustainability is still in its infancy. Nevertheless, let's use the opportunities 2020 offered and carve out a new path for a sustainable hydrogen economy this year.

Best wishes

Sven Geitmann
Editor of H2-international

ANGELIKA HEINZEL RETIRES FROM ZBT

At the end of 2020, Angelika Heinzel stepped down as chief executive of ZBT's fuel cell technology center, a research institute she led for a total of 19 years. In March, she will also leave her professorship at Duisburg-Essen University's Mechanical and Process Engineering department, and her leading scientific role at ZBT. As for her successor in the science department, the university is still in the hiring process.

Heinzel worked at Fraunhofer ISE in Freiburg before coming to Duisburg in 2001 and founding ZBT, which she has since grown into a global leader of hydrogen and fuel cell research and development services. Having matured in chemistry, her focus has always been applying scientific findings to real-world scenarios. She spent her career concentrating on process and materials development along with their manufacturing chain and business plan applications, not to mention her attention to liability and safety issues.

ZBT will now be managed by Peter Beckhaus, who said: "Throughout the last 20 years, Angelika Heinzel has developed Duisburg's research center into the reliable, expert partner it is today. We at ZBT are well-equipped to deal with the challenges awaiting us when hydrogen and fuel cell technology is brought to market." ||

DLR'S NEW LEADER

Fig. 1: Anke Kaysser-Pyzalla

One woman retires, another takes her place: On Oct. 1, 2020, Anke Kaysser-Pyzalla, was appointed chairwoman of the German Aerospace Center, DLR. A materials scientist and engineer, she took over for Pascale Ehrenfreund, who had held the position since August 2015. Kaysser-Pyzalla said she is looking forward to "leading such a multi-faceted, interdisciplinary organization." In addition to developing aviation and aerospace technology, the DLR focuses on research into energy, transportation, safety and security, and digitalization solutions. More than 9,000 people work for a total of 51 DLR institutes at 30 locations in Germany.

Kaysser-Pyzalla started her career working for TU Berlin, a university in Germany's capital, and Hahn Meitner Institute, also in Berlin, for several years. After earning her teaching license in 2001, she held a number of jobs, including university professor at Vienna's Institute for Materials Science and Technology in Austria. Prior to becoming DLR's new leader, she was president of TU Braunschweig. ||

ADIEU, STEPHAN KOHLER

At the age of 67, Stephan Kohler's passing in late October last year came as quite a surprise. His death was reported by the German Zukunft Erdgas industry initiative, on whose supervisory board Kohler had been since 2018. Many politicians and business leaders remember Kohler as a passionate fighter for climate action. Zukunft Erdgas chairman Timm Kehler said: "Stephan Kohler was held in high esteem throughout the entire energy sector. His precise analyses and attention to detail were greatly respected and appreciated. […] We've lost a tremendous human being, a smart, passionate innovator and driving force for the energy revolution."

Kohler was a co-founder of dena, leading the agency for 15 years. In a short opening speech at the dena congress on Nov. 16, 2020, German economy minister Peter Altmaier specifically praised Kohler's dedication to his work. He also hoped dena would continue to take a "tough and assertive stance" while remaining "an important and independent partner to the government." ||

Category: News | **Author:** Sven Geitmann

KRAFTWERK IS BACK

Handheld charger still in the works

A plague of trademark disputes and court cases took eZelleron and its kraftwerk product virtually off the grid for five long years. Then, last October, kraftwerk TUBES chief executive Sascha Kühn informed H2-international that the business is coming out of "stealth mode" to demonstrate the fruits of quiet progress.

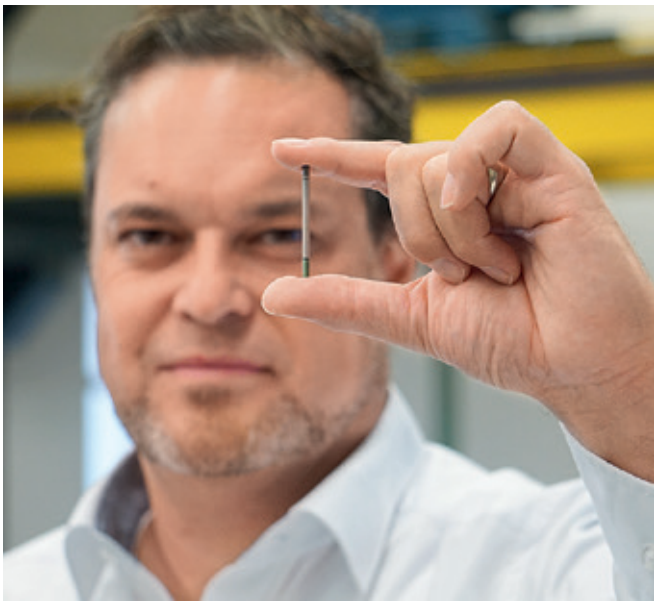


Fig. 1: Sascha Kühn showing one of the cells he is developing
Source: kraftwerk

To recap: In 2000, Kühn began researching and developing small, tubular-shaped solid oxide fuel cells made of nano-coated metal. In 2008, in Dresden, Germany, he founded eZelleron and in 2015, the company launched a crowdfunding campaign via US firm eZelleron Inc., quickly raising USD 1.5 million. Shortly thereafter, German music group Kraftwerk filed a lawsuit with Hamburg's district court, claiming the eZelleron charger's name constituted trademark infringement. Even though the case was dismissed, it caused a notable delay, threatening the company's future and prompting German eZelleron to file for bankruptcy protection a few months later (see H2-international, July 2015).

During bankruptcy proceedings, US-based kraftwerk ASSETS acquired the now-defunct company's IP, while fixed assets, materials, cells, design drafts and software went to kraftwerk TUBES in Germany. Both are wholly owned subsidiaries of kraftwerk Inc., a holding company established by Kühn and Martin Pentenrieder in Silicon Valley in 2016 as court proceedings began (see H2-international, August 2016).

The German firm's bankruptcy did not affect eZelleron Inc., which Kühn said will be "bought by an Asian-based consortium that aims to market the handheld charger over the next years." Kühn is chief executive of all four kraftwerk Group subsidiaries as well as chairman of the holding itself. He said kraftwerk Inc. employs more than 50 people in the global fuel cell industry and had "revenues over USD 3 million and more than USD 1 million in profit" in 2019. It is still unclear what happened to the money the US business transferred to the German bankruptcy administrator.

When H2-international questioned Kühn about the funds, he replied: "The crowdfunding campaign did not originate with eZelleron in Germany. The entire campaign, from start to finish, was handled by eZelleron in the United States. Our German firm didn't survive primarily due to the Kraftwerk lawsuit. Our investors got nervous and jumped ship. No one knew if we would have to pay fines in the millions." He also remarked that crowdfunding did not constitute debt but a "donation to support a cause." Then, seemingly as an act of goodwill and recompense for past disappointments, he voiced his hopes that eZelleron would soon deliver the chargers, even if the company was not legally required to do so.

As early as 2018, Kühn stated he would concentrate on developing just the cells, called tubes, aiming to deliver products to prospective partners for integration into their own devices. It is the reason, Kühn said, why he established kraftwerk TUBES as a licensing partner (see H2-international, January 2019). Otherwise, the US firm had nothing to do with the Dresden-based business. "We are merely a supplier," said Kühn.

The cells' potential application areas have not changed, namely small, portable electronic devices, such as cell phones, and automotive and aerospace equipment. In 2018, reports on the technology mentioned names such as Nissan's luxury brand Infiniti and drone manufacturer Sky-Watch. According to Kühn, his company was focused on marketing its products in China at the time.

In November 2018, kraftwerk began putting up manufacturing facilities southwest of Dresden. In the meantime, Kühn said, the factory is ready for small-volume component production. The company's first commercial product is a demonstrator for educational purposes. It has one individual cell and takes only a second to be charged using LPG.

Several different hydrocarbon gases, including methane, LPG and kerosene, can power the cell, though Kühn is also open to clean energy alternatives. Booming with confidence, he said: "We want to progress toward hydrogen." A crucial advantage of the cigarette-shaped, platinum-free and full-metal solid oxide fuel cell, Kühn said, is a thin film of substrate that allows a quick start-up and makes the device extremely robust against mechanical or thermal stress despite an operating temperature of 850 °C. When used in vehicles, there will be a two-minute window before the Fuel Cell Box becomes fully operational, which could be bridged by condensers or batteries.

Asked about his former company's years-long court cases, Kühn noted he prevailed in all of them. The trademark infringement was dismissed, so was a million-dollar lawsuit filed in the United States in 2018. And a lawsuit brought against him in Germany the same year, alleging he filed too late for bankruptcy protection (see H2-international, April 2018), was dropped at the end of last summer, proving he did not break any laws, he said. ||

HYDROGEN CAMPUS IN SALZGITTER

Heinz Jörg Fuhrmann

Early last September, several business, city and state representatives signed a cooperation agreement to construct a Hydrogen Campus on a Bosch-owned site in Salzgitter, Germany. The areal will be used to demonstrate industrial hydrogen applications and include research facilities for reducing a factory's carbon footprint. Lower Saxony, the German state where Salzgitter is located, will fund the initial stage with EUR 7 million taken from its economic development program.

The campus was an idea hatched by, among others, Heinz Jörg Fuhrmann, chief executive of the company bearing the city's name, and Salzgitter's mayor, Frank Klingebiel. Over the past years, Fuhrmann has been a vocal advocate of substituting hydrogen for other energy sources in steelmaking. Set to retire this summer, Fuhrmann will be succeeded by Gunnar Groebler, who currently leads Vattenfall's wind energy division. His successor on the National Hydrogen Council will be Arnd Köfler, of ThyssenKrupp (see H2-international, October 2020).

Fuhrmann said: "Green hydrogen is a central element of our decarbonization project SALCOS, also known as Salzgitter Low CO_2 Steelmaking. The new Hydrogen Campus will offer us a chance to combine expertise and inter-disciplinary work, an added value for all stakeholders and local residents (see H2-international, July 2018)." He added: "The cooperation agreement is a major step toward our hydrogen campus. It is a commitment to Salzgitter's economic promise ensuring future-proof jobs. The business transformation process is in full swing."

Other partners include Fraunhofer IST and companies such as Robert Bosch Elektronik, Alstom Transport Germany and MAN Energy Solutions. ||

GTT ACQUIRES AREVA H2GEN

In mid-October 2020, French GTT announced their acquisition of electrolyzer manufacturer Areva H2Gen. Established in 1994, GTT is the result of a Gaztransport and Technigaz merger focusing on the transport and storage of liquified natural gas. With decades of experience handling cryogenic fluids, the company offers engineering and consulting services as well as training courses.

Areva H2Gen hails from Cologne, Germany, and used to be part of Areva S.A., renamed Orano in 2017, a French government-owned nuclear energy business based in Paris. Areva H2Gen was set up in May 2014 under a partnership agreement between the then-parent company's electrolyzer division, Smart Energies subsidiary CETH2 and national agency ADEME. From the outset, Areva H2Gen has been led by Pascal Pewinski and Carsten Krause.

"Fusing our technical expertise with Areva H2Gen's wealth of knowledge will drive growth, bringing both fresh impetus to France's renewable hydrogen sector and increased value to shareholders," said GTT chief executive Philippe Berterottière. ||

CUMMINS TO START PRODUCTION IN HERTEN


Source: Cummins

In mid-November 2020, diesel and gas engine maker Cummins, which has more than 6,700 employees in Europe, announced plans to erect a production site above Germany's defunct Ewald mine in Herten. The decision was not surprising. Hydrogenics Germany lies a mere 20 kilometers west of Herten, and Cummins acquired parent company Hydrogenics Corp. in September 2019.

The new factory will reportedly have a 10-megawatt capacity per year and will focus on assembling fuel cell systems for industrial partner Alstom's hydrogen trains. Alstom, a rolling stock manufacturer, said it has received dozens of orders for its Coradia iLint railcars, each running on a total of six fuel cell modules. Besides the factory, the site in Herten will accommodate facilities for proprietary research and development. The entire complex is scheduled to come online in July 2021.

After increasing its investment in Loop Energy in March 2020, Cummins, of Columbus, Indiana, took a shift in strategy, forming a joint venture with NProxx last June. NProxx specializes in hydrogen storage systems, i.e., type IV pressure vessels, which are also needed to power fuel cell railcars. In September, Cummins then launched an additional partnership with Hyundai. ||

Category: News | **Author:** Sven Geitmann

DWV BECOMES INDUSTRY ASSOCIATION

DVGW partnership confirmed

For years now, the German Hydrogen and Fuel Cell Association, DWV, has been trying to find a new path forward. The association's annual meeting in Hamburg, Germany, last September did nothing to remedy matters as members once more put off several decisions regarding its future. Finally, a well-organized online event held on Dec. 4 greased the wheels of reform, speeding the DWV on its way to becoming a powerful industry association.

Fig. 1: Despite years of tireless efforts on behalf of the association, Eberhard Behrend ...

... and Ulrich Schmidtchen will no longer be members of the board.

The DWV meeting last fall will be remembered for its quarrels and surprisingly erratic agenda. Some members took the opportunity to air grievances about the DWV's industry lobbyist aspirations and their discontent with how the board was handling things in general. Further issues involved bylaw validity and expense billing, all of which prevented a vote on indemnifying then-board members and electing a new board. It became more than evident that some issues would need to be addressed at a later date.

When talking with H2-international after the event, Gerald Linke, chairman of the German gas and water industries association DVGW, merely stated "there was a bit of turbulence concerning DWV-internal issues. […] I am confident we will soon come to a collective agreement on our cooperation's substantive issues."

Then came the extraordinary general assembly in December, held online. A first for the organization, it clearly illustrated DWV's effort to solve the issues raised in September. Supported by a well thought-out program and perfectly prepared documents, DWV chairman Werner Diwald took charge of a meeting that was attended by nearly 100 members and lasted nearly six hours. While giving a rather absent-minded impression just a few months ago, even the (unavoidable) glitches didn't throw him in December, and he kept a steady grip on proceedings throughout the votes and debates.

Although the latest gathering did not respond to all of September's issues – simply because members failed to raise them – Diwald made sure everyone, including the executive committee candidates, could speak their minds while he himself offered as detailed an answer as possible to every question asked.

INTENSIFIED DWV-DVGW PARTNERSHIP During the December assembly, Linke broke the news that, at a meeting the day before, the DVGW's executive committee had voted unanimously to partner with the DWV. The collaboration is a financial boon to the DWV. The DVGW, on the other hand, will have access to the DWV's highly sought-after hydrogen expertise. Linke then laid out the DVGW's plan for building an outstanding hydrogen center on behalf of Germany's energy industry, adding the association is willing to invest around EUR 15 million to pursue an innovative strategy. His statements evidently appealed to many DWV members, as most attendees voiced their support for the partnership.

The overall goal, a close collaboration with the DVGW, will bring about organizational changes and a new budget, both of which were explained in great depth in December. Instead of volunteer board members, the DWV will now have two paid chairpersons and several employees working out of its own office, plus a voluntary executive committee.

Selecting board members falls to those on the newly minted executive committee, comprised of many association veterans as well as some fresh faces. Christopher Hebling, of Fraunhofer Institute for Solar Energy Systems – ISE, garnered the most votes overall this time around and Silke Frank, of Mission Hydrogen, will become the second woman to serve on the board alongside Birgit Scheppat. Stefan Garche, who represents younger DWV members, didn't make it, albeit he lost by only a few votes.

On Dec. 10, 2020, during the executive committee's first session, members then selected Oliver Weinmann, of Vattenfall Europe Innovation, to be their president. Besides Frank and Hebling, he will be supported by Uwe Ringel, who will take on a deputy role on behalf of the DVGW. While Diwald was voted in as chairman at the meeting, it will be up to the DVGW to soon suggest a second chair. ||

"Together, we have laid the foundation to establish the DWV as the primary address for all hydrogen-related energy, transportation and industrial policies, developing a non-fossil fuel economy."
Werner Diwald, DWV chair

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

DIGITAL H2 EVENTS

What's (not) hot at HOC, H2.0 and WindEnergy

How do you report on a conference you attended from your office chair or couch at home? Were you able to attend closely to each and every online presentation and workshop? I have to admit, I find webinars and online trade shows difficult to handle. I feel I have yet to develop a sense for how well (or not) attendees receive these offers, for the prevailing mood among exhibitors and speakers, and for where the real news is.

Take the Hydrogen Online Conference Oct. 8 to 9, 2020. Organized by Silke Frank and David Wenger's start-up business Mission Hydrogen, the global event drew 77 exhibitors and over 11,000 visitors. Sounds like record numbers for the hydrogen sector, at least in the digital realm.

During the 24-hour event, well-known speakers presented their companies, innovations and products. Unfortunately, some of the most intriguing presentations took place when people in central Europe were fast asleep. One such presentation was given by Sascha Kühn, announcing kraftwerk will be making a comeback (see p. 6). Since his primary target market is now Asia, he spoke at 3:30 CET, a comfortable time for potential Chinese partners.

Luckily, as a member of the press, I had free access to the HOC 2020 presentation collection. Time constraints made it impossible to watch them all. Still, I took the opportunity to look around, quickly realizing that an online event offered little more interaction than a website visit. This despite the evident pains exhibitors had taken with their virtual presentations.

I suppose only the 24-hour show's well-articulated, highly competent moderators, Frank und Wenger, could give an accurate account of the HOC's actual size. Wenger, head of Wenger Engineering, had invited his thousands of LinkedIn contacts. Frank, a highly experienced face-to-face event organizer, also mobilized her network. In the end, the global hydrogen and fuel cell market crème de la crème attended. Which did nothing to convey the industry's mood. At least not to me.

What are the hottest topics? How do stakeholders feel – emboldened or disillusioned? Which crucial questions are CEOs and engineers asking?

Not one of the online events I attended – HOC, H2.0 and WindEnergy – brought on that familiar rush of adrenaline that comes when standing in the crowd in the flesh, seeing and hearing breaking news: Look, this business acquired that one; hey, a chief executive changed jobs; wow, check out those new products. Somehow, sitting in front of my PC doesn't boot up the thrill of it all. Something is definitely missing.

That's not to say H2.0 in Husum wasn't a great conference. Event manager Mai-Inken Knackfuß had deftly arranged for key stakeholders in northern Germany to put in an appearance. Even though Covid-19 is a persistent challenge for event planning, two state ministers travelled to the "gray town by the sea," as Theodor Storm, German novelist, once said of Husum. And while Ulrich Walter moderated knowledgeably and skillfully, I still wonder whether any livestream attendees made use of the digital networking opportunity.

This is the key digital event challenge: Chance meetings and chatter are but two primary face-to-face event attractions. But how can you do that online? Who doesn't enjoy a spontaneous conversation in the lunch line during a conference break? Or bumping into an old acquaintance who tells you they've changed employers twice since the last time you met?

And let's not forget the legions of technical glitches lying in wait. One such technical snafu occurred in early December 2020. Hamburg Messe took too long installing digital presentation space for WindEnergy Hamburg's online exposition. The result? Visitors couldn't access artfully crafted exhibitor pages.

Considering all this, I say it's time to get creative, inventing new, radical communication and showcase concepts. Simply transplanting face-to-face events to the World Wide Web doesn't cut the mustard. I'm confident some start-up business somewhere will soon be breaking the ice. ||

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

HURRAY FOR HYDROGEN!

Hybrid event marks f-cell's 20th anniversary

Fig. 1: Tired but happy – 2020's 24-hour Hydrogen Rally winners

In 2001, Peter Sauber Messen und Kongresse event management kicked off the f-cell show in Stuttgart, Germany. Since that first, intimate get-together, featuring a small exposition, f-cell has become a hydrogen and fuel cell magnet. In September 2020, f-cell celebrated its 20th anniversary with a hybrid event featuring online and offline sessions. Many attendees thought the in-person meetings at Stuttgart's Haus der Wirtschaft a blessing, happy and relieved to exchange ideas and phone numbers face to face once more.

A comprehensive Covid-19 response plan allowed fuel cell industry stakeholders to meet in the flesh on Sept. 29 and 30, 2020, holding their first face-to-face conversations in months. At last, they could discuss the latest market developments in person and oh my, was there a lot to report. Never before had the industry received as much attention as it had that year.

ON-SITE AND ONLINE Split into two groups of 86 and 100, with seating in the large König-Karl-Halle and the hall below while many more participated remotely, attendees listened to primarily on-site presentations, and a smattering of digital ones. During breaks, hallways leading to the exposition bustled with activity. The event seemed practically normal if you blanked out the masks and proscribed distancing. Still, you noticed how grateful everyone was as they eagerly discussed all things hydrogen and fuel cell (in person!), knowing Sauber and his team's dedication was the event's hero.

A month earlier, Sauber's company had hosted the virtual f-cell+HFC Vancouver event from an office in Dresden. The show had already been postponed twice, from spring to summer to fall. Naturally, those months took a toll on Sauber and his team. They were overjoyed when they pulled it off in the end.

NOW CRITICIZES CLEAN ENERGY BILL AMENDMENTS Keynote speakers in Stuttgart were Kurt-Christoph von Knobelsdorff, CEO of NOW (see interview on p. 20) and Bart Biebuyck, head of the Fuel Cells and Hydrogen Joint Undertaking. The former presented Germany's current hydrogen strategy while the latter elucidated the European Union's approach. In his speech, von Knobelsdorff called German clean energy law changes (see pp. 12 and 16) "disappointing so far," describing proposed amendments as "the opposite of ambitious," and lacking "fresh impetus." Von Knobelsdorff also remarked on the generous funding, EUR 1.2 billion to be exact, adding the real challenge will be spending it wisely on transportation solutions during the program's comparatively brief run from 2020 to 2023. He then requested anyone with solid implementation ideas to immediately apply for funding.

> "We want the German market to lead the world."
>
> *Innovation Commissioner Stefan Kaufmann*

One of the 52 exhibitors was Swiss Celeroton, which proudly unveiled a fully integrated plug-and-play compressor. According to sales manager Peter Terstappen, customers need only fuel and power supplies, as the required electronic components are already incorporated. A compact design perfect for vehicle integration, for starters, he added.

GERMAN 24-HOUR HYDROGEN RALLY In conjunction with f-cell's conference, 17 teams lined up on Sept. 28 in Constance to compete in the rally conceived to demonstrate hydrogen's eco-friendly technology. The racing route traversed three countries and drivers' scores tallied not only the number of climate-neutral kilometers driven, but also the creativity exhibited in photos taken and videos made along the way – which they then shared publicly on social media. When Peter Sauber heard Covid-19 restrictions prohibited a Swagelok team from crossing the Austrian border, he quickly devised an alternative route that enabled them to participate.

Most teams drove the entire 24 hours, taking only nominal breaks for food or fuel. The winners, four-member Dedicated Fuel Cell Drivers, visited Berlin's legendary Curry 36 diner at four in the morning (see fig. 1) before finishing the race with a total of 1,894 kilometers (1,177 miles) driven. The team stopped at 20 hydrogen fueling stations, their tanks always filled within three to four minutes.

An intriguing fun fact: Despite Covid-19, the f-cell conference attracted peak numbers compared to previous years. Especially the rally, combined with a comparatively large number of exhibitors drew approximately 650 visitors.

AWARD FOR FRAUNHOFER ISE For the first time in 20 years, Fraunhofer ISE received one of f-cell's annual awards, a conference tradition since f-cell's inception in 2001. The Research & Development prize honored the Fraunhofer research group led by Matthias Klingele for improving a scalable industrial manufacturing technique – flatbed silkscreen printing – to make fuel cell electrodes.

The Best Product or Market award went to Ionomr. CSO Benjamin Britton joined f-cell via livestream from Canada, accepting the award virtually.

Endowed with EUR 10,000 prize money provided by Baden-Württemberg's state energy ministry and Stuttgart's Economic Development Agency the prize has been awarded by the state's environment minister, Franz Untersteller for the past 20 years. A touch of melancholy colored this year's ceremony, since Untersteller will not run for re-election next term (see fig. 2).

Fig. 2: Attending his last f-cell award ceremony as state environment minister, Franz Untersteller said: "Everyone wants a piece of the hydrogen pie."

WHTC 2021 IN MONTREAL Meanwhile, Sauber is already planning the World Hydrogen Technologies Convention and f-cell+HFC in Montreal, Canada, from June 20 to 24, 2021. Although event management companies are currently in crisis mode, he said it was too early to throw in the towel. He did announce he would no longer organize homebuilding shows, but despite his nearly 70 years, Sauber has no intention of leaving the fuel cell community anytime soon. ||

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

POLITICAL LEADERS JUST LOVE HYDROGEN

On AFID, EEG, IPCEI, RED II and the Green Deal

Leaders are in the hot seat. The German government is expected to fix it all – the Covid-19 crisis, the climate crisis, the energy crisis, and the auto industry crisis. Summit after summit after summit. We're hearing an awful lot from the chancellor, ministers, business leaders and lobbyists these days. And comparably little from parliament, where the laws are actually passed. But which political topics or summits are truly relevant to hydrogen and fuel cell technology?

Fig. 1: German economy minister Peter Altmaier defines the launch of IPCEI Hydrogen as a "huge success."

It's still not clear just where the auto industry is heading. Obviously, for most politicians and industry representatives, batteries take a front seat since small all-electric cars could be the solution to clean, urban transportation. As yet undecided is who will be responsible for expanding EV station availability to avoid long lines at the charging columns.

Early last December, the Charging Column Summit decided matters as German transportation minister Andreas Scheuer announced: "In the coming years, the German transportation ministry will invest over EUR 4 billion in charging infrastructure – along the highways, at work, while shopping and in private garages. In short, charging options for everyone, everywhere, at all times."

And what about hydrogen-powered cars? The latest update tells us primarily Japanese and South Korean FCEVs will be fueling up at local hydrogen stations in the coming years. European carmakers have hung their hats on batteries, at least for passenger cars. But when it comes to commercial vehicles, various European manufacturers are by no means going to surrender the sector to Hyundai without a fight. By the end of the decade, new and converted diesel trucks will be fueling up at stations H2 Mobility will erect in the coming months and years.

CARS, TRUCKS, BUSES, VANS AND CHARGERS So what happens to vehicles already on the road? The German government announced a scrappage bonus for commercial vehicles to finally eradicate old polluters, replacing them with new, low-emission models. In mid-November, the economy, environment, labor and finance ministries collectively agreed on a EUR 3 billion stimulus package for the auto industry in addition to Covid-19 support.

At the summit press conference, economy minister Peter Altmaier said a mouthful when he announced: "We grant the auto industry more than EUR 5 billion to surmount the economic crisis." Only when questioned more closely did he concede that EUR 2 billion of the Covid-19 stimulus package had already been distributed. That leaves us with EUR 3 billion in funding to play with:

- EUR 1 billion will extend the economic incentive for electric car purchases until 2025 – due to expire in 2021. Gradually reducing the bonus as of 2022 is not scheduled.
- EUR 1.16 billion funding until 2023 for commercial vehicles running on alternative fuels (50 percent in scrappage bonuses, 50 percent for publicly owned trucks).
- EUR 1 billion in endowments for advanced learning and retraining programs.

Not enough, according to automakers and lobbyists. During the commercial vehicle summit a week earlier, Markus Olligschläger, German Association of Trade, Transportation and Logistics – BWVL chief executive, had already explained to EuroTransport that "without a clear destination, money alone will not convince the masses to buy into alternative drivetrain technology." Marten Bosselmann, Package and Express Logistics Association – BIEK chairman, demanded planning security: "In order to invest, businesses need flesh-and-blood prospects. […] Then we can be sure the appropriate vehicles will also be available." For the record, Dirk Engelhardt, spokesperson for German Road Haulage, Logistics and Waste Disposal Association – BGL, was relieved, telling the Verkehrsrundschau trade magazine: "Thank God we now have a clearly defined strategy – regional and local all-electric transportation, hydrogen for the long haul."

Transportation minister Andreas Scheuer's words, talking about open innovations in the commercial vehicle market, sound pretty much the same as those spoken for years about the passenger car sector, obviously now committed to batteries. Nevertheless, official transportation ministry decisions on which technology to fund for which application will only be made somewhere between 2023 and 2026. Scheuer's declared goal is "to take old Euro III, IV and V vehicles off the market." Since very few hydrogen-powered trucks will hit the roads in the coming years, the entire funding will most likely go to modern internal combustion engines meeting emission standard VI.

FUEL CELL OR BATTERY? The VW Group is a prime example of the laborious decision-making process regarding

the future's best engine technology. While VW boss Herbert Diess is a confirmed advocate of all-electric cars, in November Porsche argued they should not take hydrogen out of the game (see e-fuels, below). Porsche chief executive Oliver Blume said in the German auto motor and sport magazine: "Synfuels are not all-electric vehicle competitors; they are a sensible supplement." His company, he added, is considering the prospect of synthetic fuels in motor sports, but also, later on, in mass production. He projects that "in a bit over 10 years," there will be one hundred percent sustainably designed fuels. VW still insists pairing up clean hydrogen and passenger cars is "nonsense."

> "Considering there are already billions of cars on the roads, we need to come at it from both sides, moving forward with all-electric transportation and using synfuels for existing vehicle stock."
>
> *Oliver Blume, Porsche*

The German Automotive Industry Association, VDA, takes a different view and is now advocating "climate-neutral mobility by 2050 at the latest, in compliance with the Paris Agreement." Practically speaking at the end of October 2020: "Our top priority is rapid electric vehicle growth until 2030, with an emphasis on passenger cars and light commercial vehicles. […] Alternative drivetrains and fuels such as hydrogen and e-fuels will also participate in attaining climate-neutral transportation by 2050." The VDA intends to ride on multiple tracks: "Modern electric vehicles running on green electricity power and climate-friendly, economical ICEs using synfuels and hydrogen produced from renewables."

E-FUELS OR DIRECT CLEAN ELECTRICITY? As the discussion on hydrogen versus batteries in passenger cars continues, two embittered factions vehemently argue the sense or senselessness of e-fuels. One major bloc contends the path from clean electricity to hydrogen production to synfuels is utterly inefficient and only delays the urgent need for blanket electric transportation. The other rivaling, no less populous faction is determined to take precisely this – admittedly loss-incurring – transformative path to clean up endless numbers of internal combustion engines roaming the streets for years to come.

While VW adamantly maintains e-fuels are a waste of time and money, the German Hydrogen and Fuel Cell Association, DWV, joined forces with auto and petroleum industries. In a joint press release at the end of October, the DWV, German Engineering Association VDMA, the VDA and German Petroleum Industry Association MWV expressed flat out their apprehension that e-fuels were being outmaneuvered; that the German environment ministry is clearly endangering hydrogen market growth with its unambitious national implementation of the Renewable Energy Directive, RED II.

According to the German environment ministry, the 14 percent share of transportation sector renewables, the minimum proscribed by the European Union, will mostly go to all-electric vehicles. The associations protest that concentrating on batteries not only ignores the national hydrogen strategy but also fails to reduce additional transportation-induced carbon emissions. Citing the frontier study, "only synfuel applications will truly transform transportation and reach the EU climate targets by 2030. And only so-called e-fuels can achieve a rapid, effective carbon dioxide reduction in the current ICE fleet."

> "The environment ministry's proposal left us flabbergasted. It is utterly inacceptable, utterly lethargic. It is even less than what the German government allowed for in the national hydrogen strategy. […] I can now say the issue is on the table."
>
> *Steffen Bilger, German transportation ministry*

> "E-fuels make progress toward climate-neutral mobility possible."
>
> *Hans-Ulrich Rülke, FDP chairman, Baden-Württemberg*

> "E-fuel is the right way to go. […] It's not about keeping outdated technology alive."
>
> *Werner Diwald, DWV chairman*

> "We need more hydrogen applications and less ICE bashing."
>
> *Hubert Aiwanger, economy minister, Bavaria*

In response to H2-international's question whether synthetic fuels have factual climate policy advantages or only serve to extend ICE lifespan, NOW chief executive Kurt-Christoph von Knobelsdorff (interview on p. 20) firmly stated at the Hydrogen Dialogue event: "E-fuels are indispensable. We need the current fleet's contribution to carbon reduction." Innovation commissioner Kaufmann made it more than clear: "Even if we stopped producing combustion engines today, there would still be 40 million on German roads." Synfuels, he stressed, "contribute to decarbonization."

Holger Lösch, BDI deputy CEO, said: "Combustion engines aren't the climate problem; it's the fuel that drives them." The national hydrogen council also promotes e-fuel production, aiming for a steadily growing demand for hydrogen, which would affect lower prices. And Porsche CEO Blume, who on Dec. 2, 2020, together with Siemens received a funding go-ahead to build power-to-X facilities in Chile, declared: "With e-fuels, combustion technology will become part of the interim solution."

In the meantime, the environment ministry's recurring idea to bring super credits into play triggers further discussions. Hence, after calculating the actual emissions factor of electric vehicles drawing on a German energy mix, the ensuing carbon reduction contribution will count fourfold toward the GHG quota. Speaking to climate reporters, Elmar Baumann, German Biofuels Association chief executive, criticizes the approach as "seriously problematic." Although the calculated reduction does not reflect reality, the environment ministry books its "balancing act as factual reduction," he added.

BLUE HYDROGEN INTERIM? Similarly controversial are the unresolved blue hydrogen debates. Would introducing and funding new technology serve as an interim solution to attain long-term goals? The ultimate transportation sector goal may be blanket electricity, but the manufacturing, chemical and heat sectors essentially want a full departure from fossil fuels. So, how much funding should temporarily go into blue or turquoise hydrogen? And how temporary is temporary?

During a Bundestag economic committee hearing regarding the national hydrogen strategy at the end of last year, several experts advocated temporary blue hydrogen use. Among them was Felix Matthes, Öko-Institut's energy and climate policy research coordinator. "We must increase fossil fuel prices," he explained, viewing realistic carbon prices >>

at over EUR 100 per ton to generate the appropriate impact. Fraunhofer IEG's Mario Ragwitz also asserted that "carbon prices are not where they should be, namely at EUR 100 to 150 per ton."

"The federal and state negotiations committee agreed on a carbon price of EUR 25 per ton as of January 2021, gradually increasing to EUR 55 by 2025. The price corridor in 2026 should be at least EUR 55 at a EUR 65 maximum. The government passed the correlating changes to the Fuel Emissions Trading Act – BEHG on May 20, 2020, which were confirmed by the Bundesrat on Oct. 8, 2020."
German federal government, Nov. 10, 2020

"The transformation process must be limited in both time and quantity."
Werner Diwald, DWV chairman

Experts do not reckon with large turquoise hydrogen quantities until after 2030, which is why Marcel Keiffenheim, of Greenpeace Energy, describes the current discussion as "tactical in nature" to ensure the fossil fuel basis "isn't taken out of the talk." He speaks against the option: "It only serves to keep fossil fuels in the game." And he warned: "We cannot afford to prolong the fossil fuel economy's lifespan. Of course, the companies have an enormous interest in continuing their practices beneath the hydrogen flag, but we shouldn't support them. Transitioning to renewables is economically the wiser option."

EXPANDING RENEWABLES One fact goes undisputed – expanding renewable energy sources is essential to launching a hydrogen economy. Even though Altmaier conceded just a few weeks ago that too little has been done for the renewable market ("We have constantly allowed seemingly more important issues to distract us from the climate crisis. That has now changed."), energy policy course corrections have been few and far between. Altmaier's supporters may consider his approach prudent, but, after he ensured the German solar industry's demise, the greater part of the renewable energy sector hold him also accountable for snuffing out wind energy businesses.

On Dec. 17, 2020, the Bundestag debated EEG amendments, arriving at an "ambitious goal," said Altmaier – 65 percent clean electricity by 2030, currently at 46 percent (details on p. 16), and climate neutrality by 2050, at the latest.

EEG SURCHARGE EXEMPTION
Initially, the governing coalition agreed on a total EEG surcharge exemption for green hydrogen (see p. 16) last November. While DWV chairman Werner Diwald welcomed the suggestion as "more than constructive," the opposition claimed general exemption could trigger higher carbon emissions. Green party's Ingrid Nestle and Julia Verlinden then proposed: "It would be sensible to boot up hydrogen production when the energy mix is particularly low-carbon. EEG surcharges should be lowered as soon as abundant renewables are available and power exchange prices are so low that coal power stations are no longer viable."

As to expanding renewable energies, there is plenty of wrangling over whether future solar and wind facilities will benefit hydrogen production or if the gas will be imported – and if yes, how much? German Renewable Energy Federation – BEE president Simone Peter commented: "True, a portion of the German hydrogen demand will be met via imports, but we must first exploit all potential."

EU REDUCES CARBON EMISSIONS BY 55 PERCENT The European Union is also redirecting energies toward a hydrogen economy. European Commission president Ursula von der Leyen's demand to further tighten carbon reduction goals caused a ruckus last September. Compared to 1990, a 40 percent reduction by 2030, she said, is not enough. She suggested a goal of minus 55 percent. After long, hard negotiating on Dec. 11, 2020, the European Council agreed. Von der Leyen praised the agreement, saying: "The way is now clear for climate neutrality by 2050."

The European Parliament environmental committee (minus 60 percent) and environmental associations (65 percent) voiced more drastic reduction goals. The auto lobby vehemently protested the hike. Yet, Center for Automotive Research director Ferdinand Dudenhöffer claimed the 55 percent is feasible, calmly calculating it only means 64 percent of new vehicles must be fully electric, not 54 percent as previously assumed. In other words, the new target corresponds to 47.5 grams of carbon dioxide per kilometer instead of 59 grams. Now, compared to 2021, passenger cars must achieve a 50 percent reduction, not a 37.5 percent reduction, by 2030.

Most interesting is just who will contribute how much to the collective goal. The 55 percent reflects a Europe-wide average. Individual countries could therefore emit far more. Poland, heavily reliant on coal-fired energy, could be particularly impacted, which may be why the eastern European country hesitated to accept the agreement.

"A 55 percent reduction by 2030 is just not enough to keep us below the 1.5-degree margin."
Özden Terli, ZDF meteorologist

"It is truly baffling how little credence we give to scientific findings regarding the climate crisis."
Michael Bloss, Greens/EFA, European Parliament

EUROPEAN GREEN DEAL All this time, numerous countries are intensifying their efforts to make Europe the hydrogen economy avant-garde. Leading nations could be Germany

and France, both having produced multi-billion-euro hydrogen strategies. In a dialogue with von der Leyen, German chancellor Angela Merkel and French president Emmanuel Macron proposed close cooperation and the construction of an electrolysis giga-factory in a consensus of non-competitive, mutual progress toward a shared destination. The giga-factory prospects echo Germany and France's joint involvement with Airbus aviation and their plans for joint European battery cell manufacture.

In this context, Jorgo Chatzimarkakis, Hydrogen Europe general secretary, spoke of a "replace strategy," with hydrogen replacing coal, oil or natural gas. Even gray hydrogen should be displaced with green. His coinage "hydrogenewable" defines a green hydrogen economy. At HOC (see p. 9), Chatzimarkakis said he was pleased 600 CEOs had signed onto the new European Clean Hydrogen Alliance, ECH2A, by September 2020. Membership had risen to 800 when Germany joined on Nov. 25.

> "Hydrogen Europe is committed to working hand in hand with the renewables sector to pave the way, together, toward a climate-neutral economy based on 'HydroGenewables'!"
>
> *Hydrogen Europe*

Supporting the alliance, the national hydrogen council published a position paper last fall with concrete activity recommendations, one such being a European commitment to hydrogen's "essential role" in global climate action. The paper demanded uniform rules and standards as well as further expanding a transborder hydrogen infrastructure.

In addition, the EU is currently revising the alternative fuels infrastructure directive, AFID. New content was negotiated at the end of 2020, while Germany held the European Council presidency. According to the German transportation ministry, the new draft should appear in 2021's second quarter. Presumably, the new AFID will obligate all EU countries – not only the current 14 – to establish a hydrogen infrastructure.

In mid-December 2020, the European Commission brought forth an interesting proposal: to cut future Union funding to transnational oil and gas infrastructures, striking gas and oil pipelines from the list of common interest projects. Instead, Brussels intends to support smart grids and renewable, low-carbon gases, including hydrogen.

EUROPEAN COUNCIL PRESIDENCY The Covid-19 pandemic did much to foil the German government and its European Council presidency's ambitions, including those to powerfully promote a Europe-wide hydrogen economy. All the same, during a video conference among the Union's energy ministers on Dec. 14, 2020, Altmaier was satisfied: "We're preparing to enter a global hydrogen economy. Just as we had global fossil fuel networks, we will have global green hydrogen and green energy grids." EU commissioner Kadri Simson was also happy with the results and confident things would develop well, saying: "China, South Korea, Japan and other countries have recently announced climate neutrality objectives. If the US makes a similar commitment, about two-thirds of the global economy, more than half of the world's emissions would be covered."

IPCEI – EUROPE, NUMBER ONE WORLDWIDE Shortly before its European Council presidency ended, Germany landed a coup, launching an Important Project of Common European Interest – IPCEI specifically for hydrogen. On Dec. 17, 2020, Altmaier announced 22 member countries plus Norway had signed the IPCEI Hydrogen, ensuring support toward a European value chain to produce predominantly green hydrogen as well as toward multi-billions in investments. IPCEIs carry a much higher funding rate than usual, up to 100 percent. Altmaier explained: "With mutual European hydrogen projects and joint investments in hydrogen technology, we want to become number one worldwide." German government-coordinated, initial IPCEI projects can begin in 2022. Suggestions can be submitted immediately.

AND THEN THERE'S NUCLEAR POWER As if there isn't already enough to discuss, new debates on the role of nuclear energy have been ignited. Particularly environmental organizations are expressing serious concern that exploiting the current boom in hydrogen interest could open the back door for nuclear energy's comeback. Especially the burgeoning hydrogen activities in eastern Europe feed these suspicions. During the mid-December EU summit, several countries demanded more technological transparence to pave the way for nuclear energy.

According to the German Spiegel magazine, with the departure from national coal-fired power, the Visegrád Four – Poland, the Czech Republic, Slovakia and Hungary – are setting their sights on a nuclear revival. Apparently, Russia and the new US president Joe Biden are also not reluctant to use nuclear power. Talking with H2-international, BUND speaker Oliver Powalla interpreted the catchword "safe and sustainable low-carbon hydrogen" as an "expression gratifying the US FCHEA's ambition to certify nuclear hydrogen as green."

Steffen Bukold of Energy Comment, however, gave the all-clear. "Practically speaking, nothing is happening and nothing will happen over the coming years." According to his findings, large nuclear projects in the United States are collapsing one by one. ||

AND THE CONSUMER?
H2-international asked both economy minister Peter Altmaier as well as the ministry's spokesperson which measures or percentage of the EUR 9 billion hydrogen economy funding would ultimately benefit consumers. We have yet to receive a clear answer.

Category: Policy | **Author:** Michael Nallinger

EEG TO 'JUMP-START A GREEN HYDROGEN ECONOMY'

Amendments cut clean energy surcharges on hydrogen

Experts agree, German parliament has scored an important hydrogen economy victory. EEG amendments exempt hydrogen from a good portion of clean energy surcharges. What we need now is a renewable capacity to match.

The Bundesrat, Germany's version of the Senate, passed an amended EEG at its last 2020 session shortly before the Christmas holidays. Most importantly, the EEG now holds a 2050 GHG-neutrality goal throughout powerhouse Germany. The Bundestag had already approved the bill the day before with 357 votes in favor of the amendments and 260 against them. Unfortunately, politicians have still not agreed on the volume of renewable capacity additions by 2030, albeit crucial to hydrogen economy's success. Nonetheless, the governing coalition postponed pertinent debates until 2021.

The new Special Compensation Rules, known as BesAR, will exempt clean electricity electrolyzers from the EEG surcharge, an important milestone for the industry. Regulations offer both partial and full exemption. Partial exemption allows businesses with large electricity needs to apply for BesAR funding, possibly reducing their surcharge payments by 85 percent, the overall minimum being 0.1 Euro cents per kilowatt-hour. Initially, electricity sources will not be relevant, although the government could later insist on clean hydrogen. While there is no minimum electricity consumption threshold, most of a company's added value must come from hydrogen production. Eventually, the law could even allow full exemption for green hydrogen producers contingent on an administrative order spelling out specific green hydrogen requirements. In light of the EU's Renewable Energy Directive – RED II and at the time of this writing, the government was still waiting to kick off national and European debates and implementation measures. Expectations are that the market will be able to go it alone by 2030, so exemptions will be granted only to systems coming online by then.

"A GOOD STEP FORWARD" Lobby organization Zukunft Erdgas claimed the "government has taken a good step forward," not only demonstrating the administration's belief in hydrogen's significance, but also highlighting the gas grid's role as a giant battery to power Germany's energy market transformation. Not to mention the grid option of storing renewables for future energy systems integration. Zukunft Erdgas now hopes the coalition will take "further decisive action to bring hydrogen to the fore," i.e., when transposing RED II into national law.

Power-to-X, a multi-industry alliance of associations and businesses, also welcomes the amendments, calling on the EEG's role as an essential tool for growing renewable capacity. Having already changed the face of the electricity market, the EEG could now "jump-start a green hydrogen economy." Alliance spokesmen – Christian Küchen, head of the German petroleum association, and Gerald Linke, chairman of gas and water industries association DVGW – are calling for additional measures to roll out power-to-X's full potential for supporting climate action, growth and jobs.

Energy and water industries association BDEW said the envisaged green hydrogen exemption constitutes "real progress." Removing electricity surcharges would give the country a much-needed boost, laying fast tracks to a hydrogen economy. BDEW also made clear that this is "only a starting point" for a successful transformation, that the German energy industry needs profound change, a "radical restructuring of all fees and charges." Going further, the association recommended, clean energy incentives should be free of technological bias – a criterion particularly important for climate-neutral gases such as biomethane or hydrogen produced from decarbonized natural gas. Both could also greatly reduce carbon dioxide emissions from energy production and support power-to-heat.

MARKET INCENTIVES FOR SMART CHOICES Equally important to the BDEW are climate-neutral hydrogen incentives for industries. A central association demand, however, is equal opportunities for all network operators, sectors and sizes, regardless of whether they benefit from BesAR funds or not. As Germany's largest energy industry association, the BDEW substantially supports two options for cutting electricity costs, BesAR and a full exemption.

Source: BDEW/Horn

Fig. 1: Kerstin Andreae, who has been calling for new ideas and realistic targets.

The BDEW sees EEG section 69b as suitable for exempting renewable hydrogen production from all statutory surcharges, as announced in Germany's 2030 climate action program and envisaged by the federal cabinet's national hydrogen strategy of June 2020. The association also believes reducing CHP surcharges, pursuant to section 27d of the German CHP Act, as well as offshore grid fees, section 17f, paragraph 5 of the German Energy Industry Act – EnWG, will help bring hydrogen technology to market.

Despite an optimistic outlook, the BDEW noted there's still room for improvement, namely introducing a ret-

Fig. 2: Andreas Feicht, German economy ministry [Source: BMWi]

Fig. 3: Andreas Kuhlmann, dena [Source: dena]

roactive exemption effective Jan. 1, 2021, to support projects that are already underway. "Beyond that, we urgently need to give the owners of countless renewable energy generation systems in Germany more opportunities to increase their hydrogen production capacity," the association urged. Since, according to EEG section 93, section 69b can only become law once an administrative order specifying green hydrogen production rules and requirements is established, the BDEW is calling for the order's prompt implementation.

The EEG aside, there are also issues elsewhere, the association said, especially when it comes to gas supply. According to the BDEW, putting the debate about the federal electricity infrastructure bill to good use via targeted adjustments to the EnWG and to GasNZV gas network regulations could make the regulatory framework "fit for hydrogen."

PUSHING FOR MORE AMBITIOUS EXPANSION TARGETS While these are important topics, one eclipses all other green hydrogen prerequisites: additional renewable capacity for the necessary energy. Since the government has postponed capacity increase discussions based on its climate action goals, the Power-to-X alliance is using the interim to promote new, more ambitious targets for 2030 and beyond. The growing gap between expectations and reality is easily calculated: Experts estimate that increasing Germany's share of European Union 2030 climate targets to 55 percent would increase clean electricity energy sources from 65 percent to at least 70 percent by 2030.

The government's low electricity consumption reckoning could prove devastating. Current energy policy assumes that 2030 power demand will peak at 580 terawatt-hours, roughly the same amount consumed today. Experts, however, calculate at least a 10 percent increase by that time due to a growing number of electric vehicles, heat pumps, hydrogen systems and renewably sourced chemicals.

At the latest Energy Market Transformation Congress, organized by the German Energy Agency – dena, BDEW boss Kerstin Andreae brought up the issue. She asked the government to clarify which figure was the basis for Germany's 65 percent 2030 target and called for realistic targets when introducing a clean energy quota. To entice capacity increases, Andreae recommended, among other things, that the EEG electricity surcharge be dropped altogether. She said an abundance of concepts are ready and waiting; decisions must be made, mindsets changed.

DRAMATICALLY LOWER COST Meanwhile, Andreas Feicht, director for energy policy at the economy ministry, demands the hydrogen industry join the solar and wind energy sector bandwagon and dramatically reduce costs. He conceded this would necessitate changes in EU incentive regulations. At a dena event, Feicht said he intends to take a closer look at all hydrogen supply chain components, from production to consumption, adding that the picture on the renewables sector differed somewhat, as renewable companies focus more on expanding renewable capacity than on system-relevant consumption.

Nevertheless, Feicht rejects the notion that hydrogen production must come at a high price. If that narrative had taken hold in the PV industry years ago, he noted, the sector would have never grown as big as it is today. On the other hand, Felix Matthes, Öko-Institut's energy and climate policy coordinator, said: "We are fooling ourselves if we think green hydrogen production will be a low-cost venture." In his estimate, the national hydrogen strategy's EUR 7 billion budget must be doubled if the government intends to follow through with its expansion targets.

In the meantime, dena chief Andreas Kuhlmann stated that, scientifically speaking, the sector is in a good position: The government has finally magnified its view from electrons to molecules. ||

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

TRULY ADDED VALUE

Interview with Katherina Reiche, National Hydrogen Council president

After 17 years representing the Christian Democrats in the German Bundestag, Katherina Reiche took on a high-level job at the environment ministry in 2009. Four years later, she held the same position, albeit with the transportation ministry. Then it was time to move on. Between 2015 and 2019, she was lobbyist for and chief executive of the Association of Municipal Corporations – VKU. In January 2020, she became head of Westenergie and in summer 2020, she was elected chairwoman of the National Hydrogen Council. H2-international spoke with the Brandenburg native about her career and future goals.

Fig. 1: Katherina Reiche

H2-international: Ms. Reiche, during your years working for two ministries, you were occasionally involved in hydrogen projects. How does it feel to engage with hydrogen and fuel cell companies once again?

Reiche: My ministry days were some time ago, but as VKU chief executive there were multi-facetted opportunities to interact with the sector. I am delighted with the momentum in hydrogen development. It is now evident that hydrogen is much more than hype. It is the industrial policy approach that can propel the energy revolution forward, expanding from a purely electricity-driven change to a true energy system transformation while retaining supply chains in Germany and Europe. This technology will create durable change in our economy and in our lives.

In 2015, you consciously turned from politics. And went to work in the private sector, becoming VKU chief executive until 2019. What inspired this decision?

Active involvement with energy issues and the energy market transformation has accompanied me throughout my entire career. As a politician, I was able to co-author guidelines for implementing the transformation. At VKU, I was closer to the practicalities, discovering the impact political decisions have on businesses and how they must adjust to them. Now, at Westenergie, I have arrived at the heart of the energy revolution. This is an excellently positioned company with a sharply defined future intent – sustainable, distributed energy supply, and digital, too.

Can you tell us how the national hydrogen council came to be staffed? Did you apply for the position or were you nominated or invited?

The government's decision to establish the NHC was a milestone for lending impetus to the energy market transformation. It is a great honor to have the government call me to the council and a further honor to be elected NHC president. This is an outstanding opportunity to boost hydrogen technology.

In 2006, in the Süddeutsche Zeitung newspaper, you stated renewable energies "are neither up to par with nor as economic as traditional energy sources." Does this still hold true today?

The statement was correct at the time, but it's obvious that times have changed completely. Renewable energy sources have long outgrown their childhood and increasingly proven their economic maturity. They are the future. With bidding procedures making clean energies viable competitors, providers begin to erect larger facilities without the slightest EEG funding. This has the tendency to favor their market integration.

When do you project we will have 100 percent clean electricity?

To answer that, I would need the proverbial crystal ball. The electricity sector is on a good path. Every six years within the past 20, the renewable energy percentage has doubled. We are now called on to lead both the residential and transportation sectors toward climate neutrality. And hydrogen can be a key contributor.

And what's your take on the national hydrogen strategy? Do you feel the goals are too ambitious or too wishy-washy?

The NHS aims to create not only a German hydrogen market but to establish Germany as technology market leader. Hydrogen technology should be a core component of the energy change, decarbonizing production processes with renewables integrated into energy systems. I believe these goals to be valid. The national strategy will create the necessary framework for producing and applying hydrogen.

And the national council? What is its job?

The national hydrogen council advises and supports the government. We provide suggestions and practical recommendations for implementing and improving the NHS. I believe the council's task is to offer hydrogen solutions that contribute to the economy, decarbonizing the industrial, mobility and heating markets.

Do you already have concrete plans for the council?

The government already has several clearly defined measures such as building up industrial-scale hydrogen production facilities that generate a total capacity of up to 5 gigawatts by 2030. This includes the required onshore and offshore wind parks, culminating in up to 14 terawatt-hours of green hydrogen production and up to 20 terawatt-hours of required electricity. When possible, another 5 gigawatts will be added by 2035, or by 2040 at the latest.

To achieve these ambitious goals, we must adjust the framework. We, the national hydrogen council, have already published our statements on this issue. There are, for example, necessary adjustments to be made in the fee and surcharge systems or to regulations ensuring the required infrastructure. Furthermore, the council will address all pertinent issues for instituting a hydrogen economy in Germany.

But not only the council drives hydrogen forward. E.ON and Westenergie have already approved a number of green hydrogen production, storage, distribution and application projects. We are in constant communication with industry partners, municipalities and science. Specifically, at the new research and development project H2HoWi in North Rhine-Westphalian Holzwickede, we will convert an existing public gas pipeline to deliver pure hydrogen in the coming year. This a first in Germany.

Can you give us some insight into or prospects of your personal goals as council president?
We need answers to the multiplicity of societal, economic and political questions, not to mention the practical issues concerning people in the region. My job is to turn the varying skills and interests of national council members to the best possible use for our collective goal. If I succeed, we will truly add value to this vital future technology's progress.

How would you categorize the council? Is it a more economic, scientific or political body?
The council is composed of economic, social and research experts, allowing us views from varying perspectives and of varying needs. This a great chance. Our unanimous goal is to make Germany a hydrogen technology pioneer and the path before us is promising. Even the Coal Commission I served on was intentionally heterogenous, and that proved beneficial.

Have you already established cooperation options with innovation commissioner Kaufmann? Or do you see him more as a lone wolf at the education ministry?
Naturally, as green hydrogen innovation commissioner for the education ministry, Mr. Kaufmann and I work together closely. Our regular exchanges are very important to both me personally and the council. Therefore, we recently decided to meet with Mr. Kaufmann at least once a year. He is also permanently and comprehensively informed of council activities.

Why was finding an appropriate head office so complicated? What kept the ministries from reaching an agreement?
The major issue was creating the necessary infrastructure for the national office's work. Since our efforts are not temporary in nature, we needed an office with long-term, flexible structures. We managed to achieve this and the office is now well underway.

But doesn't the projected distribution among five ministries depend on completely new structures that rather burden efficient work processes?
Besides dena and NOW, head office co-workers will come from ZUG, Projektträger Jülich and GIZ. Thus, each house contributes its specific expertise to the effort. I see this as truly added value for council work.

What exactly will the head office do?
As specified in the NHS, the office will support participating ministries in applying the strategy. Beyond that, the office helps the council coordinate and organize various tasks. The team will also lend its skills to generating progress reports.

You recently requested an "opportunity-opening regulation." What exactly is that? One large energy company's representative hinted you are interested in expanding leeway for current network operators, thereby maintaining old structures.
In our last council session, we delved into national hydrogen strategy item 20. We were agreed the existing infrastructure would play an essential role in the new hydrogen era. To this end, regulations must be adapted. First, hydrogen must be on an equal footing with natural gas in the Energy Industry Act – EnWG. And then it is important that network operators find reliable parameters, as they are already massively investing in future-proof infrastructures.

At the council meeting on Oct. 10, 2020, you broached the topic "EEG surcharges for hydrogen production." You ultimately demanded electricity used in electrolyzers be completely exempt from EEG surcharges. When do you expect this demand to take effect?
Two criteria are decisive: EEG surcharge exemption for electricity used in electrolyzers and secure planning for investors. We at the council promote comprehensive EEG exemption, well aware that we may need to clear up competition-related and constitutional issues. Thus, the council offered the Special Compensation Rules as a possible fallback option. They too will have to be adjusted to ensure long-term planning security and investor and participant diversity. In the short term, however, there are no legal issues.

Thank you for your time, Ms. Reiche.
Interviewed by Sven Geitmann

HYDROGEN RESEARCH NETWORK
In addition to the economy ministry's head office (see p. 21), the ministry has launched a new, funded Hydrogen Research Network. This is the ninth of its kind dedicated to energy. According to Projektträger Jülich, these networks serve the strategic acceleration of innovation transfer in applied energy research within the economy ministry's 7th EFP. Jülich's network coordinator Thomas Sperling told H2-international: "Announced as NHS item 25 and now being implemented, the new hydrogen research network is part of the hydrogen technology research offensive. [...] The network is independent of hydrogen head office activities." Sperling will compile expert recommendations for developing and adapting research and incentive strategies.

HYDROGEN TECHNOLOGY OFFENSIVE
On Dec. 15, 2020, the economy ministry published a call for a Hydrogen Technology Offensive, a contribution to implementing the national hydrogen strategy, immediately inviting submission of innovative ideas regarding hydrogen production, distribution and use, as well as interfacing concepts. Project outlines may be directly submitted to Projektträger Jülich. The ministry specifically encourages small, mid-sized and start-up enterprises to take part, but also universities, research institutes as well as public authorities, clubs, associations and trusts.

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

PUT IT ON THE AGENDA

Interview with NOW chief executive Kurt-Christoph von Knobelsdorff

As of May 15, 2020, the National Organization for Hydrogen and Fuel Cell Technology (NOW) has a new chief executive. Formerly Klaus Bonhoff, who has moved to the German transportation ministry, his successor is Kurt-Christoph von Knobelsdorff. Now is the time to take stock and ask what the future holds.

Fig. 1: Kurt-Christoph von Knobelsdorff

H2-international: Mr. von Knobelsdorff, you have been speaker for and CEO of NOW for around six months. How are things going?
Knobelsdorff: Fantastic! For one, I'm surrounded by a highly motivated team of experts and for another, alternative engines and fuels have gained enormous political momentum. This increases NOW's task spectrum as evidenced by our recent boom in employees. And this is just the beginning, which creates a number of inhouse organizational challenges we nonetheless face with confidence and determination.

Your former years with Jörg Steinbach at the Brandenburg economy ministry also involved activities concerning hydrogen. What particularly attracts you to this area?
Linking hydrogen to the generational task of structural change in the wake of Lausitz withdrawal from brown coal electricity generation. Which ties in perfectly with my work at NOW. For example, Lausitz was chosen as a HyStarter region, and HyStarter is part of our HyLand funding effort that supports establishing a regional hydrogen value chain – from production to gas use in transportation. Or, where NOW is also involved, reviving the traditional Heidekraut train route á la climate friendly.

Looking at last year's sequence of events, the beginning of 2020 proved that interest in hydrogen was enduringly on the rise. Was that one of the reasons you wanted to take on this position?
My interest in hydrogen dates back further. I had already probed deeply into the topic when I was working for Schleswig-Holstein's economy ministry. I am convinced hydrogen is the key to decarbonizing our energy system across all industries. So, making the effort to accompany this transformation from a central position was only logical.

> "Sensible and climate-friendly green hydrogen complements other alternative propulsion methods across all modes of transportation."
> *German transportation minister Andreas Scheuer on PrioritHy*

When you came to NOW, the hydrogen industry was waiting with bated breath for the national hydrogen strategy. Did you take part in shaping it or had the blessing already been given?
It was a long road to enacting the NHS. NOW was intensively involved in preparations and currently plays an important role shaping its implementation. That makes sense, since with the national hydrogen and fuel cell program NIP, we have basically anticipated much of the strategy. Many NHS measures follow approaches NIP had already developed or can be integrated into current projects. Germany's strong position in the global hydrogen technology competition can justifiably be traced back to NOW's NIP coordination.

Last summer, the German government took over the European Council presidency, making hydrogen a focal point. What role did NOW play?
Not only the EU collectively, but many individual European countries have generated a hydrogen strategy. One important aspect, among other things, is applying regional hydrogen to decarbonize energy systems. This is an altogether European approach. We introduced many promising projects at the PrioritHy Conference – jointly organized by NOW and FCH JU and sponsored by the European Council presidency – on Nov. 25, 2020.

What was the conference's focus?
I introduced and explained HyLand activities currently taking place in Germany, such as pushing forward the development and installation of a regional infrastructure. And of course, on a European level, Hydrogen Valley, currently under construction in the Netherlands, and similar projects were presented.

A long-debated issue was who would govern the upcoming hydrogen head office. Fall 2020 let leak that dena and NOW will share the task. Then we heard that not only the economy and transportation ministries were naming agencies but all the other ministries involved as well. How do things stand now?
All ministries will cooperate at the head office. Aside from the two facilities already mentioned, Zug will send two representatives from the environment ministry. We also expect one person from Projektträger Jülich for the federal research ministry. The international development ministry will be represented by GIZ, subcontracted by dena, which means, with eight colleagues, headquarters will be well-staffed.

Why did the decision take so long?
Discussions among the departments involved just took a while, which merely indicates hydrogen's significance for future energy systems. We feel good about the results and are ready to move full speed ahead.

So, the solution is more diplomatic than content-oriented?
Bringing together as much expertise as possible is a good thing. NOW, dena and the other participating organizations are deeply hydrogen-savvy. So far, our collaboration has been trustworthy and good, which is why we have no objections to the solution.

How does that work in practice? Where will the office be and who will direct it?
My colleague Philipp Braunsdorf represents NOW at the head office and will assume the directorship. He will be the office's face and, along with his co-workers, will coordinate activities for the national hydrogen council, their work groups and the department staff committee. We are still seeking premises, but our work has already begun.

Be honest: Do you really think that's a practical solution? I do believe there are doubts in the industry that NOW alone has sufficient expertise.
Thanks for the compliment! But let me reiterate: The collaboration with the other organizations, especially with dena, is trustworthy and truly effective and I am certain it will remain so. And, please, do not confuse the national hydrogen office with the National Charging Infrastructure Center, which has a completely different and broader spectrum of tasks to handle.

Well, NOW has more than enough to do and is rapidly growing. Will you be moving soon?
At the moment, we are renting additional space on Fasanen Street. The National Charging Infrastructure Center has already moved to Tauentzien Street. We will eventually have to consider larger premises. It's quite possible we will run out of space for more desks.

An important issue was and is a new version of the renewable energy act EEG. What do you think needs to change?
Fees and surcharges comprise a large chunk of Germany's electricity costs. To give the business model hydrogen a chance, cost-reduction is a primary prerequisite. An EEG amendment reducing surcharges on hydrogen electrolysis is a core strategy measure to augment hydrogen attractiveness in all application areas – from industrial nexuses to transportation usage, be it on the road, rails or in the air. But that can only be the first step. A comprehensive charges and fees reform must be a top priority following national elections. Neglecting to specify vague legal terms in the EEG amendment, such as energy generation "at point of use," was a missed chance to facilitate regional green electricity for hydrogen purposes. And practically doing away with "load-following capabilities" is in direct contradiction to the national strategy.

RED II is also a hotly debated issue at the moment. What do you think of the current draft?
So far, I am quite critical of RED II suggestions. The economy ministry's approach achieves little to reduce transportation-induced carbon emissions via hydrogen and fuels. For example, integrating green hydrogen in refineries is credited to the industrial instead of the transportation sector. The transportation ministry can't possibly be satisfied with that, as they are the ones responsible for meeting transportation-related climate targets. But the RED II draft also leaves much to be desired from an industrial policy perspective. The level of impetus is far too low to truly propel hydrogen technology forward. It's a looking-glass world when industries are collectively more ambitious when it comes to avoiding GHG emissions than the environment ministry and have to literally beg for stronger legal obligations.

Okay, let's turn from politics and look at the upcoming months. The NIP general assembly will take place at the end of January 2021. What can we expect to hear?
This time around, the general assembly will be consolidated with the German Hydrogen Congress, resulting in a German Hydrogen General Assembly. We're looking forward to two exciting days of high-level speakers and all the current information coursing over the German and international project landscape.

What else is on the agenda for this year? Can you give a short preview?
Since the year's begin, the National Charging Infrastructure Center has been working enthusiastically at NOW premises. I expect a great deal of output, such as preparing the RFP for 1,000 fast-charge network locations that will be installed throughout Germany by the end of 2023. Political efforts are currently targeting technology funding for mass transit vehicles, for heavy-duty trucks and for trains. We're expecting funding regulations to be adopted, which will also impact NOW's work. We need to prepare ourselves.

And finally, allow me a question regarding Berlin and its surroundings. Although many strands converge here, there is no regionwide hydrogen initiative. Why not? After many years, there is finally a state-supported H2Berlin in the capital, but what about Brandenburg? Could you tell us if your former employer is on the ball?
Berlin's hydrogen initiative was constituted in early December 2020. We at NOW have provided initial support, generating a potential analysis for the capital. Gasag, BSR and Vattenfall are also involved. When I was active there, there were many promising discussions with Saxony and Saxony-Anhalt about working collectively, which I still think is the right thing to do. You will have to ask someone else to find out what progress has been made.

Thank you for your time, Mr. von Knobelsdorff.
Interviewed by Sven Geitmann

FIVE MINISTRIES, ONE OFFICE

For the nonce, the national hydrogen office should reside with dena and NOW jointly, Thorsten Herdan, head of the economy ministry's energy policy division, announced during a NOW webinar on Sept. 21, 2020. At the f-cell in Stuttgart late September 2020, von Knobelsdorff confirmed that the office would be jointly led by NOW and the Germany Energy Agency – dena. Particularly the German education ministry spoke out against the economy ministry taking on sole leadership (see H2-international, October 2020).

Prolonged negotiations between the five ministries participating in the national hydrogen strategy ultimately led to all ministries sending representatives to one national office – NOW, dena and ZUG two representatives each; Projektträger Jülich and GIZ, one each. When speaking with H2-international, the German education ministry explained: "Each representative will assume their NHS assignments, especially that of supporting the national hydrogen council." Braunsdorf, until recently program manager for NIP hydrogen regions and with NOW since 2014, will direct the head office.

Category: Policy | **Authors:** Dr. Jan Michalski, Dr. Uwe Albrecht, Jan Zerhusen, Dr. Carsten Rolle, Maira Kusch

HYDROGEN, A GLOBAL PRIORITY

Comparing national policies

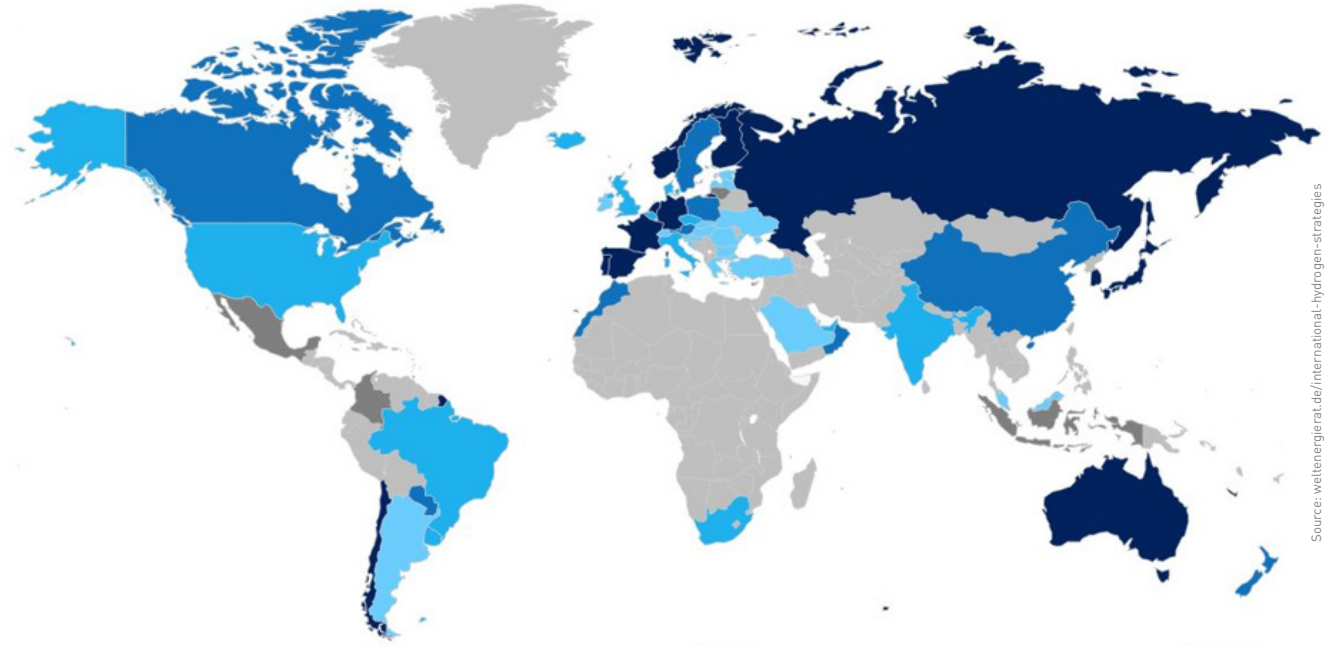


Fig. 1: By November 2020, at least 20 countries had implemented or were planning to implement a hydrogen strategy.

A year rich in change, 2020 brought a host of challenges and opportunities to the fore, as well as a new chance for the hydrogen sector to shine. Captivating both politics and the public, the sector experienced unparalleled dynamic. The industry recently received another boost as governments around the world published national hydrogen strategies, aiming to get in on the ground floor. Some also forged global partnerships to help their countries usher in an era of energy independence.

In collaboration with (and on behalf of) the World Energy Council's German chapter Weltenergierat – Deutschland, Ludwig-Bölkow-Systemtechnik examined, compared and analyzed over a dozen hydrogen strategies, roadmaps and funding programs for a national hydrogen market. The study was published in September 2020.

Following up on hydrogen policies recently introduced in Germany and Europe, the study provides an overview of global governmental activities, describing 17 national hydrogen strategies, their overall goals, preferred markets, infrastructure needs, and policy measures to meet said goals. Past successes as well as lessons learned in politics and industry are also given attention.

GLOBAL MARKET DYNAMICS Starting with the 56 strongest economies, the study indicates a minimum of 20 countries comprising over 40 percent of global GDP have implemented or are planning to implement their own hydrogen strategy. Another 30 or so are officially supporting pilot and demonstration hydrogen projects or have initiated national dialogues with industry stakeholders.

A regularly updated Weltenergierat – Deutschland map (see fig. 1) depicts the hydrogen industry's path to global recognition. Clusters of increased activity are found in Europe, Asia-Pacific, and the Americas. Most strategies, including those drafted by Germany and the EU, were introduced in summer 2020. A series of governments announced their intention to support hydrogen sector investments (see fig. 2), underlining the technology's current appeal to policymakers. Prior to the LBST-Weltenergierat study, only four countries, namely Japan, France, South Korea and Australia, had

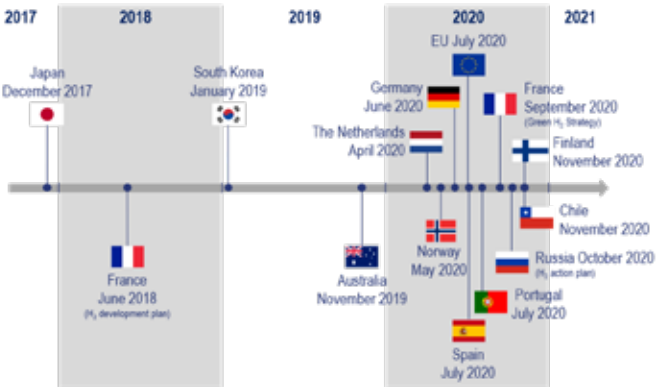


Fig. 2: Last year, prominent hydrogen announcements came in summer and fall.

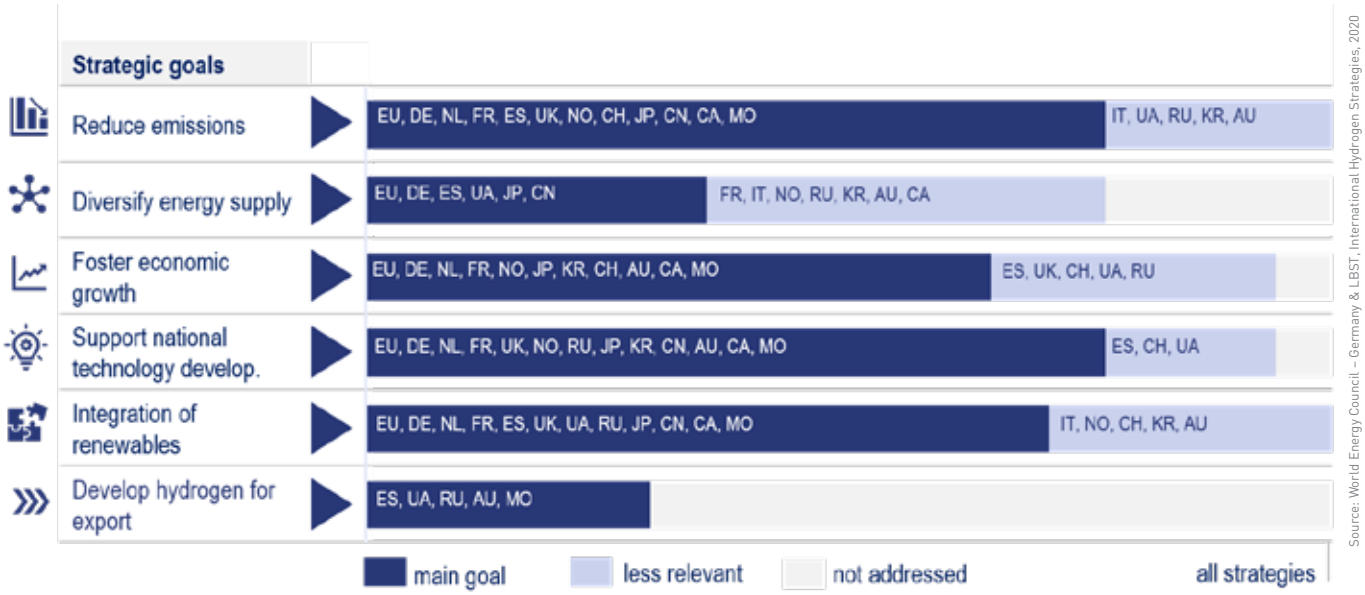


Fig. 3: Climate action and economic considerations are key drivers behind hydrogen market promotion.

presented national strategies or plans for large-scale hydrogen installation and usage.

GOAL: A DECARBONIZED ENERGY SYSTEM Although a roadmap's focus and granularity may differ depending on specific market conditions, all 17 strategies include similar objectives based on the energy carrier's versatility. Typically, a new energy source needs to fulfil three requirements: environmental compatibility, growth potential and ensured supply.

Country-by-country comparisons reveal that most of these hydrogen strategies aim to protect the environment, lower carbon dioxide emissions, ensure clean energy systems integration, and boost national economies and technology (see fig. 3). Supply security, and particularly energy diversification, also plays a role in many strategies, albeit a minor one.

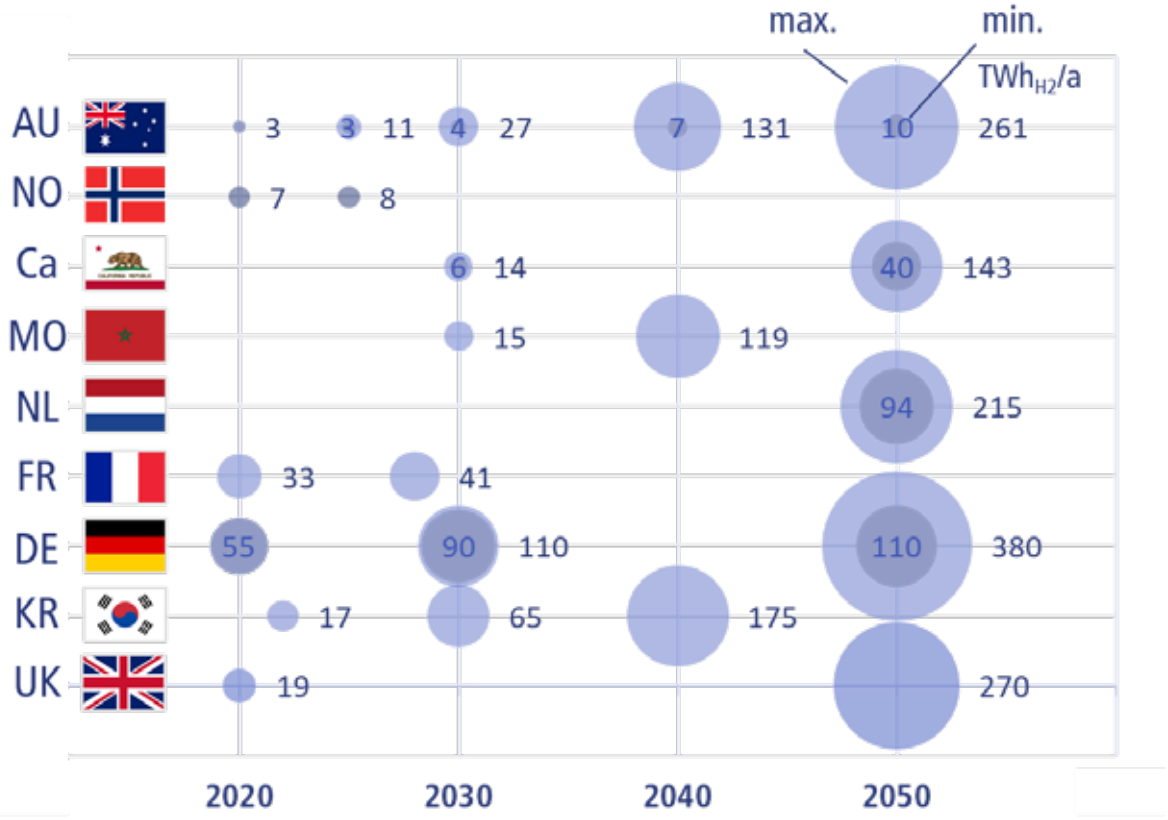
The study focused on countries promising a wider range of uses. Consequently, few of those primarily exporting hydrogen were listed.

All 17 countries and supranational organizations see hydrogen produced from renewables as crucial to decarbonizing their energy systems. More than half, including the European Union, will rely exclusively on the green variant in the long run, i.e., by 2050. Still, low-carbon bridge technologies could provide a cost-effective interim supply, supporting a variety of submarkets.

BRIGHT PROSPECTS FOR INDUSTRY AND TRANSPORTATION Most strategies view hydrogen as a universal energy carrier with multiple applications in industry, transportation, building and electricity generation. Initial major targets are the chemical, petrochemical and auto industries, although priorities may differ from region to region. Fuel cell passenger cars feature prominently in Asian strategies, e.g., Japan, South Korea and China, as well as in California's. In Europe, this submarket plays only a minor role, with countries concentrating on buses and other heavy-duty vehicles instead. Some plans also include clean power-to-liquid synfuels for aviation and shipping. Asian strategies prominently target the building sector as well. Most of the strategies analyzed view hydrogen supporting the electric grid as more of a long-term option.

Combining the figures in all 17 strategies projects global demand for hydrogen by 2030 will be 330 to 380 terawatt-hours a year and 870 to 1,600 terawatt-hours by 2050 (see fig. 4). Scaled to match GDPs, worldwide consumption could come to 9,000 terawatt-hours a year by 2050 – the total amount of clean energy generated around the world today.

Although green hydrogen can increase energy independence, densely populated countries with high energy requirements yet limited clean energy generation potential, such as Japan, South Korea and Germany, will resort to significant hydrogen imports from countries rich in such resources. Within bilateral agreement structures, partnerships and supply chains are already being negotiated. In this respect, >>



Source: World Energy Council – Germany & LBST, International Hydrogen Strategies, 2020

Fig. 4: In selected countries, demand for hydrogen is expected to grow to up to 1,600 terawatt-hours a year by 2050.

hydrogen offers an excellent chance for international cooperation and trade relations along new value chains. Most likely, the high cost of establishing supply chain infrastructure will be shared among the exporting countries and their international partners.

CURRENT POLICIES LACK BITE When implementing policy objectives, most countries intend, first and foremost, to promote traditional research and development. Despite continued R&D relevance, these activities are less important to commercializing hydrogen solutions. However, the majority of strategies mainly focus on national objectives and creating potential uses for hydrogen, rarely addressing practical measures for implementation. The policy instruments as yet available reveal national plans do not live up to the countries' ambitious strategic aims. For the most part, current policies insufficiently trigger strong growth.

Mandatory quotas for eco-friendly raw materials and fuels could generate significant demand for hydrogen in industry and transportation. On the other hand, instead of focusing on CAPEX, promoting suitable OPEX scenarios to lower running costs could help renewable systems operators create sustainable business models. A variety of clean technology approaches across Europe could be developed using EUR 22 billion to EUR 42 billion of the EU's budget.

Countries will also need the funds to create a suitable transport and distribution infrastructure, centrally coordinated planning, standardization efforts and an appropriate regulatory framework. Other decisive factors to ensure success are consumer acceptance and a generally recognized certification program for green and low-carbon hydrogen.

TIME TO ACT A bright, long-term outlook that guarantees safe investment will allow a quick ramp-up of hydrogen markets and ensure lasting success, yielding competitive advantages across an increasingly dynamic environment. Coordinated and targeted efforts to establish comprehensive hydrogen supply chains will also give stakeholders an opportunity to focus operations on certain geographical regions. The time has come for hydrogen to be the center of attention in policy debates and strategic decision-making, a chance all stakeholders should prepare to seize. ||

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LIFT-OFF FOR HYDROGEN-POWERED AIRCRAFT?

Airbus wants fuel cell planes by 2035 – HY4 receives flight permit

Fig. 1: Is this the future of flying? [Source: DLR]

Discussions regarding hydrogen as an optional, exceedingly lightweight aviation fuel are not at all new. One major drawback in switching from kerosene to another energy carrier is the corresponding, complete infrastructure overhaul. Due cause for hesitation. Regardless, some companies are seriously pushing to put hydrogen back on the agenda. Notably, last September, Toulouse-based Airbus announced the intention to bring to market a fuel cell-powered aircraft "by 2035." Many other businesses have also presented plans to launch zero-emission aviation.

As part of ZEROe, Airbus showcases three different concept aircraft, each following another approach to decarbonizing the industry. The first uses a Turboprop propeller engine capable of carrying up to 100 passengers on short-distance flights of less than 1,000 nautical miles. The second is Turbofan, designed for transcontinental flights, seats 120 to 200 people, traveling over 2,000 nautical miles. These two prototypes are powered by modified gas turbine engines that draw liquid hydrogen from tanks installed behind their rear pressure bulkheads.

Sporting a much more futuristic look, the third prototype has more in common with military stealth bombers than civilian planes. It has a blended wing body, with no clear dividing line between the wings and the aircraft's mid-section. This one, too, could carry up to 200 people. Its distinct design allows engineers several options for cabin and tank installation.

Talking to French daily newspaper Le Parisien, Airbus chief executive Guillaume Faury conceded that all three aircraft were still in early development, requiring many more years before coming to market. He said they would be the "world's first climate-neutral, zero-emission commercial aircraft." Airbus wants to have them ready by 2035 and calls on political decision-makers and business leaders to partner up: "The transition to hydrogen as the primary power source for these concept planes will require decisive action from the entire aviation ecosystem. With government and industrial partners' support, we can rise to the challenge, up-scaling renewable energy and hydrogen for a sustainable aviation industry future."

> "This is a historic moment for commercial aviation and we intend to play a leading role in the most important transition this industry has ever seen. The concepts we unveil today offer the world a glimpse of our ambitious, bold vision for the future of zero-emission flight [...] I strongly believe that the use of hydrogen – both in synthetic fuels and as a primary power source for commercial aircraft – has the potential to significantly reduce aviation's climate impact."
>
> *Guillaume Faury, Airbus chief executive*

Revamping airport infrastructure requires, above all, government support. Likewise, increasing research and digitalization funds could expedite retiring less eco-friendly planes.

TURBINE OR FUEL CELL? Just days before the presentation, Airbus posed a question: Which renewable energy carrier can adapt to aviation demands? It is a rhetorical question, of >>

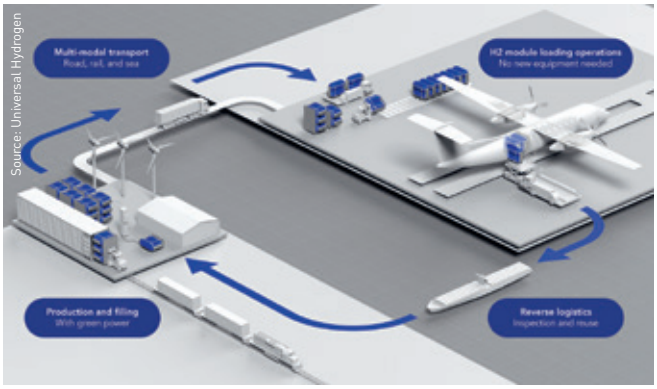


Fig. 2: Universal Hydrogen's fueling approach

Fig. 3: Hydrogen storage units [Source: Universal Hydrogen]

course, the answer being hydrogen. But another question that certainly does require answering, the aircraft manufacturer said, is what pathway to use to power the aircraft. Airbus has identified three ways to use clean fuel in aviation: modified gas turbine engines running on hydrogen, fuel cells driving an electric motor and conventional turbines consuming synfuels.

Airbus expects an exponential increase in research activities to solve the issue, which will require investments in the billions. Glenn Llewellyn, Airbus' vice president of zero emission aircraft development, called hydrogen "one of the most promising zero-emission technologies currently under consideration," adding the company was "exploring all hydrogen options to determine which hydrogen pathway could play a key role in scaling up zero-emission technology to larger aircraft."

ElringKlinger, a supplier based in Dettingen, Germany, is supporting the cause, planning a joint venture with Airbus to develop and validate fuel cell stacks for aviation purposes. The strategic, long-term agreement, intended to run over several years, will grant ElringKlinger a minority stake in the emerging business. In turn, Airbus will have access to ElringKlinger's fuel cell technology, paying a lower to middle eight-figure amount for the honor.

During a global competitive bidding process, ElringKlinger proved to be the "best in class, providing stacks with high power densities and a wealth of expertise in bringing new products to market." Hence, Airbus' choice.

UNIVERSAL HYDROGEN, THE SKY'S THE LIMIT An intriguing electric airplane conversion project made headlines in mid-September last year. A newly minted partnership between magniX, of Redmond, Washington, and Universal Hydrogen aims to retrofit, among other aircraft, the De Havilland Canada DHC8-Q300, better known as the Dash 8, and the ATR 42 turboprops with fuel cell powertrains. The Dash 8 is a 40-passenger regional airplane.

Paul Eremenko, Universal Hydrogen co-founder and chief executive, said: "There is a clear need for a step change in emissions reduction in commercial aviation, and hydrogen-based, carbon-free power is the future of the industry."

Roei Ganzarski, magniX chief executive, stated: "Universal Hydrogen, through its hydrogen transport and distribution infrastructure solution, is on a path to change the way regional flight is achieved and transform it from being powered by decades-old, expensive, polluting technology to low-cost clean solutions. […] Together, we will bring scalable, proven technology to the next level of electric aviation."

Universal Hydrogen is an L.A. start-up founded in early 2020 by Paul Eremenko, Jason Chua, Jon Gordon and J-P Clarke. The quartet is determined to "solve aviation's carbon emissions crisis by making hydrogen the universal propellant for a carbon-free aviation industry." Furthermore, "leveraging the existing freight network for hydrogen distribution with its unique storage and transport methods," the business is intent on removing the primary barrier to aviation's hydrogen use – cost-effective infrastructure for transport and distribution.

Company members do seem to have the know-how to get that done. At only 41, Eremenko has already worked as chief technology officer at Airbus and CEO of its Silicon Valley innovation center. He, along with John-Paul Clarke and Jason Chua, also held leadership roles at former United Technologies, a multinational conglomerate renamed Raytheon Technologies, working out of Hartford, Connecticut. United Technologies subsidiary UTC Power was among those researching fuel cell power systems before the company was sold to ClearEdge Power and later to Doosan.

Eremenko told start-up platform AINonline: "Infrastructure is the main problem, and the solution we're building is a capital-light approach to delivering hydrogen to any airport in the world." Liquid or compressed gas hydrogen will be stored in two-meter-long modules loaded into the back of the plane (see fig. 2). Depending on the type of fuel, the compartment replacing the last two rows of seats should allow a range between 400 (GH_2) and 550 nautical miles (LH_2; around 1,000 kilometers).

magniX aims to provide electric propulsion solutions for commercial aviation and the defense industry, offering two 2-megawatt-class systems. Universal Hydrogen estimates that 2,200 regional aircraft worldwide are suitable for conversion.

Universal Hydrogen's ambitious plan to bring two-capsule hydrogen storage pods, to market will proceed in three phases. During the 12-month phase A, Universal Hydrogen will develop and test the capsules at full-scale with an end-to-end demonstration of intermodal power distribution from the point of production. Other objectives include setting up an "aircraft-scale ground testbed" for fuel cell powertrains.

In phase B, between 12 and 18 months, Universal Hydrogen expects to gain certification for its capsules and demonstrate what the business calls "a capsule health monitoring system." This phase also involves flight-testing hydrogen-powered turboprops, and marketing conversions and long-term hydrogen supply contracts.

Phase C, an additional 12 to 18 months, will see Universal Hydrogen begin capsule mass production, bring hydrogen generation facilities online to supply launch customers and work toward STC to attain FAA certification for a hydrogen-powered regional turboprop.

With additional investments estimated at USD 300 million, the first commercial model could be available by the end of 2024. However, aviation experts doubt the appropriate regulatory framework will be in place by then.

PLUG POWER JOINS THE PROJECT In late September 2020, Plug Power announced its intention to forge a partnership with Universal Hydrogen. Last summer, Plug, of Latham, New York, acquired United Hydrogen (see H2-international, October 2020), and now wants to work with Universal Hydrogen to design, manufacture and certify the latter's engine. The agreement is part of Plug's strategy to broaden the appeal of its ProGen fuel cell systems.

Plug Power CEO Andy Marsh said: "Through this partnership, we are taking our first steps toward establishing a complete ecosystem for the aviation market, from powertrain to hydrogen solutions, ultimately enabling a global transportation system powered by green hydrogen."

Meanwhile, even longtime aerospace suppliers have come around, saying hydrogen provides a way out of today's energy and environmental dilemmas. At the end of September 2020, MTU Aero Engines' chief operating officer Lars Wagner said that hydrogen "should immediately be used as a fuel" in aviation. Unresolved is which production pathway to use, i.e., if fuel cells should produce electricity from hydrogen gas to power aircraft or whether hydrogen should be stored in liquid form and burned in gas turbine engines. MTU said both avenues are possible and will be viable in a few years' time.

DLR TO PRESENT FIRST CONCEPT IN FOUR YEARS In August 2020, MTU entered into partnership with the German Aerospace Center – DLR, which has been conducting research into hydrogen technology for many years. The partners intend to develop and validate a fuel cell powertrain's functionality for a Dornier 228 airplane with an electric MTU propeller engine providing over 500 kilowatts of power.

Rolf Henke, DLR executive board member responsible for aeronautics research and technology, said that "this joint research-industry project is the first of many steps toward zero-emission aviation." MTU chief operating officer Lars Wagner claimed: "As things stand today, fuel cells utilizing sustainably produced hydrogen offer the greatest long-term potential for realizing emissions-free aviation." Especially true for regional, short- or medium-distance aircraft. The Do-228's maiden flight could take place in 2026.

Since the beginning of 2020, a 45-member group led by Johannes Hartmann – EXACT, Exploration of Electric Aircraft Concepts and Technologies – has been working on new efficient, eco-friendly commercial airplane technology at the DLR Systems Engineering Institute. Researchers from 20 different DLR organizations aim to bring a 70-passenger aircraft with a 2,000-kilometer range to technological maturity by 2040.

Pascale Ehrenfreund, who left the DLR in late September 2020, originally proposed devising this integrated concept for eco-friendly aviation. It is not clear yet if her successor, Anke Kaysser-Pyzalla (see p. 5), will announce an even more ambitious goal.

> "With electrically powered aircraft, an engine's practical arrangement, distribution and operation must be rethought from scratch."
>
> *Jan Werner Delfs, DLR Aerodynamics and Flow Technology Institute*

HY4 – TESTS IN SLOVENIA AND GERMANY To achieve their goal, EXACT researchers are drawing on expertise in zero-emission aeronautics at the DLR Institute of Engineering Thermodynamics. The institute developed both the Antares DLR-H2 (see HZwei, January 2013) and a four-seat passenger aircraft dubbed HY4, (see H2-international, February 2016 and March 2017). The latter emerged from a collaboration between DLR spin-off H2Fly, Slovenian aircraft manufacturer Pipistrel and Cummins.

A sixth-generation fuel cell engine, powering the latest HY4 model, was designed by Josef Kallo, Ulm University professor, and his team. Despite the difficult circumstances, not least due to Covid-19 regulations, the H2Fly's plane take-off on Nov. 6, 2020, in Mariboa, Slovenia, was quite a success. Kallo told H2-international: "The system really packs a punch."

His team's perseverance kept the project going despite several delays, including the first flight's postponement >>

Fig. 4: Minister Hermann, project leader Kallo and FSG spokesperson Schoefer (from left) standing beside the HY4 aircraft [Source: H2Fly]

from October to November. Following a three-month quarantine, team members completed a total of 32 take-offs in four days in bad, extremely foggy weather with visibility under 1,000 feet (300 meters), sometimes flying for two consecutive hours.

In late 2020, the HY4 received a test flight permit for Stuttgart. Walter Schoefer, Stuttgart airport management company, FSG's board spokesperson, called it a "great milestone" for the biggest project FSG had ever supported. During the Nov. 11 HY4 presentation at Stuttgart airport, Winfried Hermann, Baden-Württemberg's state transportation minister and FSG chairman, lauded Kallo and his team for their profound commitment and tenacity.

> "HY4 is the future of aviation. [...] It shows that flying carbon-free is possible, presently feasible and has what it takes to change transportation in the long term. [...] Keep up the good work."
>
> *German transportation minister Andreas Scheuer, via video call*

In total, over several project stages, the economy ministry has invested EUR 17.3 million. Since the HY4's maiden flight in 2016, a "mere" demonstration of its general capabilities, Kallo's team has completely revamped the engine's safety features. "All systems now provide redundancy," Kallo noted, adding that, most importantly, the project has shown it is possible to "build an engine providing 1.5 megawatts output for a plane with 40 or 50 seats."

The flight trials in Stuttgart will continue until May. In 2022, Kallo intends to conduct initial tests with the seventh-generation engine he is currently building in the lab. The ensuing eighth generation will have several hundred kilowatts output to power air taxis. This generation will keep taxis in the air for more than an hour, allowing longer-distance flights. He hopes to realize these ambitions before the end of the decade. Talking to H2-international, Kallo said: "In the start-up phase, we will specify components and systems while also working on the integration concept. That will take about three years. Then we will begin testing integrated functionalities and the plane itself. The next step will be certification. Unfortunately, it takes so long because there are neither technical nor regulatory standards to go on."

To many, Kallo is a pioneer in hydrogen-powered aviation. He has been conducting research on fuel cells since 1998. In 2006, he also began to investigate their use in aircraft. He said he started probing into electric aircraft designs and technology as early as 2014, to get an idea of what will be needed in 20 years to power larger airplanes travelling 2,000 kilometers. In 2019, he remarked: "It's as clear as day, the industry definitely recognizes the potential of electric flying."

E^2FLIGHT
Josef Kallo co-founded the E^2Flight® symposium, set to take place at ZAL in Hamburg on Feb. 25 and 26 this year. The event will be broadcast online.

A BRITISH TWO-SEATER A new entrant to the market, electric aviation powertrain manufacturer ZeroAvia, tested a battery-run aircraft for the first time in June 2020. Initially based in Hollister, California, the business has relocated to Cranfield, UK. In September 2020, ZeroAvia flew its first hydrogen-powered plane over Cranfield, northwest of London, replacing the six-cylinder Lycoming TIO-540 engine with an electric motor and fuel cells to propel a six-seater Piper PA-46-350P Malibu. As part of the HyFlyer project, the prototype received EUR 3 million in UK government funding.

ZeroAvia chief executive Val Miftakhov founded the company in 2017. He noted: "Hydrogen fuel cell systems are currently about four times more energy-dense than the best avail-

Fig. 5: Alérion M1h concept aircraft [Source: Avions Mauboussin]

able batteries, even with compressed gas H2 storage." He also expects liquid hydrogen engines with a range of over 1,000 nautical miles to emerge in the near future and further projects hydrogen-powered commercial flights will commence in 2023.

The company's next step is to complete a 310-mile (500-kilometer) journey taking off from the Orkney Islands, home to one HyFlyer partner European Marine Energy Centre, the other being Intelligent Energy.

BREEZER AND ECAP JOIN FORCES Breezer Aircraft, of Reußenköge, Germany, manufactures ultralight airplanes, serving lower output classes. In January 2020, Breezer announced an agreement with eCap to install fuel cell units in one-seater sport airplanes for the air taxi market. To begin, Breezer will convert a Breezer B400-6 to run on electricity generated by an eCap high-performance battery. Later on, the business will add a fuel cell (most likely from eCap supplier Re-Fire) to provide onboard power.

Dirk Lehmann, who founded electric vehicle conversion company eCap and leads Clean Logistics, said: "In the coming years, there will be growing demand for reliable, safe and environmentally friendly propulsion and aircraft conversion solutions." Bernd Meyer, of IMWS, confirmed there is mounting pressure on the aviation industry to lower its extremely high carbon footprint. He also said that "in the foreseeable future, we won't have a viable alternative to liquid fuel." He prefers waste-to-synfuel over power-to-x, as the latter is "four times as expensive."

Late November 2020, French Avions Mauboussin, a small vehicle manufacturer, introduced partially hybrid-electric, hydrogen-powered aircraft prototypes. The Belfort-based company presented two sustainable transportation solutions for covering short distances, both minimally reliant on infrastructure. The Alérion M1h, a two-seater with an 80-kilowatt hybrid powertrain, is ideal for on-demand transportation, featuring electric take-off and landing with a maximum speed of 155 miles (250 kilometers) an hour. After takeoff, it is powered by an internal combustion engine, later to be replaced with a fuel cell. The first hybrid test flight is scheduled for 2022. The hydrogen-powered maiden flight will follow in 2024. Afterward, the company will build a six-seater Alcyon M3c for a 930-mile (1,500-kilometer) journey to launch in 2026, if all goes well. David Gallezot, who revived the company brand in 2017, said: "In 1928, Pierre Mauboussin founded Avions Mauboussin to provide affordable air travel to everyone. Today, Avions Mauboussin is reinventing itself to reach regions via 21st-century sustainable aviation." ||

HYDROGEN-POWERED AVIATION

In June 2020, the Fuel Cells and Hydrogen Joint Undertaking and the Clean Sky Joint Undertaking published their report "Hydrogen-powered aviation – A fact-based study on hydrogen technology, economics, and climate impact by 2050." H2-international took advantage of the opportunity to ask FCH JU executive director Bart Biebuyck the following two questions:

Does your study consider the Cryoplane study findings, published in 2000 and supported by 35 European institutions?
Not directly, although when compiling the new study we specifically bade consortia to take previous publications and findings into account.

Why the new report?
There are several reasons for conducting a new study. For one, today's cheap clean energy resources and inexpensive electrolyzer technology have greatly reduced hydrogen prices compared to 20 years ago. Fuel cells, too, have made a big leap forward in terms of cost, durability and output. Technological advances have altered both per capita and total cost of ownership. Reliable, accurate and up-to-date cost estimates are most decisive. Also, the new study gave us a unique opportunity to gather all stakeholders together, regardless of their argumentations pro or con hydrogen-powered aviation. To be honest, opinions varied highly prior to the study and I believe it has brought about a much greater alignment. In addition, the European Commission must prepare the next research program. Our study maps out quite specifically the research required to attain renewable hydrogen-powered, zero-emission aviation across the European Union. A most useful route toward funding the right projects.
And then, on the political front, there's the Paris Agreement and the European Green Deal – no doubt, we urgently need bold action.

Category: Energy storage | **Author:** Esther Gebert

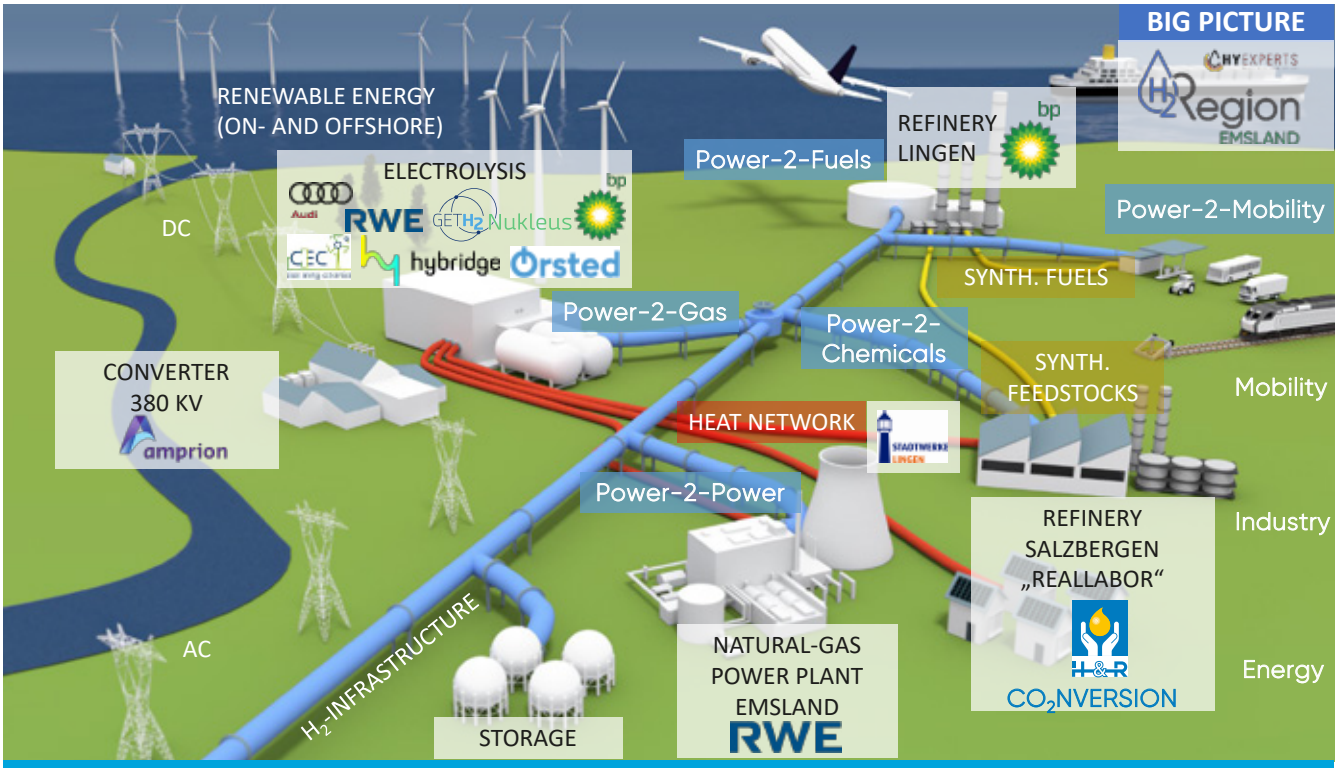
NUCLEUS FOR A EUROPEAN HYDROGEN ECONOMY

Hydrogen Regions, Part III: HyExperts in Emsland

It's no coincidence Emsland has grown to be a leading hydrogen production area in Germany. In 2018, one powerful idea took hold at local business leader's regular meetings: Emsland as a pilot region for generating, distributing and utilizing green hydrogen. Led by Tim Husmann – head of H_2-Region Emsland's partner network and office – and backed by regional authorities and Lingen's city council, the suggestion quickly gained political support. Today, the Emsland reputation for thrusting Germany's energy market transformation forward with green hydrogen is a far-reaching catchword. In 2019, Lingen became a HyExperts region. Fall 2020 exuberantly launched the H2-Region Emsland project, a 15-month drive for synergy between industrial hydrogen supply and transportation solutions.

Emsland's multiple projects prove a functioning hydrogen market is no pipedream. On the contrary, the region confirms that theory can very well be put into practice. Just two examples: the BP and Ørsted partnership building a 50-megawatt electrolyzer in Lingen, including infrastructure, and GET H2 applying for European Innovation funds to build a hydrogen network across Germany. Both projects made national headlines.

Sure, H_2-Region Emsland is home to big, important, industrial ventures, Still, there's plenty of room for smaller systems: the Audi E gas pilot plant in Werlte, which began making renewable hydrogen as early as 2003, and CEC Haren keep coming up with more diverse technological solutions. Emsland authorities expect to see up to 300 megawatts of electrolyzer capacity installed by 2025.



The entire regional supply chain, including (potential) energy sources and uses [Source: H_2-Region Emsland]

A PANORAMIC VIEW

In mass manufacturing, a reliable infrastructure is essential to hydrogen economy success. Home to multiple energy producers, Emsland boasts future-proof generation and distribution networks and the knowledgeable people to maintain them. The region's sophisticated interplay of electricity, gas and industrial components includes 380-kilovolt nodes along an ultra-high voltage network, interconnection points along gas grids and energy-intensive manufacturing processes. Emsland offers multiple opportunities for hydrogen supply chains.

Big businesses, such as RWE Generation and BP Europa, are already planning to install industrial-scale electrolyzers for local hydrogen production. Combined with Emsland's big pool of potential chemical and transportation consumers, the region has what it takes to set up a hydrogen economy, giving the energy industry a truly "panoramic view."

Emsland's energy providers also generate a large annual surplus in clean electricity, an ideal prerequisite for cross-regional hydrogen supply.

The northern German stakeholders have successfully merged multiple centralized and distributed energy concepts into a concept illustrating regional added value. An approach local politicians strongly support. In 2020, H_2-Region Emsland installed a HyExperts management office. Emsland county and Lingen provide the funding, while Tim Husmann, H_2-Region Emsland's longtime contact, provides the leadership (see fig. 1, left).

GOALS: WHICH COMES FIRST? The EUR 300,000 budget from the HyLand program is going toward developing a consolidated hydrogen production and consumption system with integrated transportation solutions. The aim is to devise a plug-and-play concept for fusing regional energy systems with a roadmap for establishing and advancing a green hydrogen economy. The project was broken down into several stages:

Stage One analyzed industrial, energy and transportation data on local hydrogen production and consumption levels. Stage Two will compile and compare regional supply and demand potentials. To this end, project members are currently canvassing large and small companies for estimates on hydrogen use and production capacity. The sum total will also add in transportation demands and miscellaneous needs. To optimally solve the classic chicken-or-egg dilemma when establishing a regional infrastructure, compiled data will specifically analyze site requirements, such as where best to install hydrogen fueling stations to serve transportation needs, to name just one example.

Once sufficient data is at hand, Stages Three and Four will entail validation and feasibility analyses for short-, medium- and long-term implementation scenarios. Both stages should be concluded by late summer this year. During Stage Five and Six, members will generate implementation recommendations, discuss project results and finalize the detailed draft. Project leaders expect to publish their findings in the last quarter of 2021.

COMMUNICATION IS EVERYTHING Compared to other regions' concepts, Emsland's is remarkably unique on several counts. Besides the scientific validity of a holistic energy system, the HyExperts Emsland project incorporates two decisive elements: grid expansion and direct communication with businesses and residents. Project members organize events and launch marketing campaigns, targeting different sections of the population. They hold online seminars on the ABCs of hydrogen, conduct expert discussions and host workshops for a select few businesses. They also organize forums open to the general public.

Fig. 1: At the opening of H_2-Region Emsland's office in Lingen's IT complex [Source: H_2-Region Emsland]

Moreover, H_2-Region Emsland's scientific staff take an iterative approach with a significant benefit – flexibility. Ergo, Emsland hydrogen stakeholders are in a position to take on smaller, freshly conceived implementation and purchase tasks, developing the project with, instead of for, those involved. This early involvement fast-tracks to practical project execution and a prompt closure. For example, at the beginning of the H_2-Region Emsland project term, a group of mass transit experts emerged to study in-depth topics relevant to their sector.

AND THEN... When the HyExpert project ends this year, current and prospective partner organizations will advance further HyPerformer region developments in Emsland. While working closely with other hydrogen regions in Germany, H_2-Region Emsland is also looking to collaborate with its Dutch neighbors. Joint events and regular shoptalk sessions hope to identify direct synergies and establish a shared hydrogen economy across national borders. ||

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Category: Research and development | **Authors:** Dr. Mateo U. de Vivanco, Dr. Hartmut Stöcker, Prof. Dr. Dirk C. Meyer

PYRO-CATALYTIC HYDROGEN PRODUCTION

Improving waste heat recovery

The pyroelectricity phenomenon – crystals converting thermal energy into power – has been known since antiquity. Our ancestors observed that tourmaline thrown into a fire attracted and then repelled ashes. Seventeenth-century scientists began studying the effect in detail, discovering the electric charges are the result of modified crystal structures.

Pyroelectrics are a subgroup of dielectrics, elastic, non-conductive materials that polarize when subjected to an electric field. Such materials include crystalline structures such as lithium niobate and barium titanate, polymers such as polyvinylidene fluoride, and biominerals such as bones.

Pyroelectrics are unique in that changes in temperature trigger polarization. Heating or cooling the material shifts positively charged in relationship to negatively charged atoms. These slight shifts in charges add up along basic cells, giving rise to a macroscopically measurable voltage.

The pyroelectric effect can be used to convert thermal into electrical energy (see fig. 1). Thereby, two electrodes are placed on opposite ends of a crystal, which is then subjected to intervals of temperature changes. To maintain an electrical equilibrium, the polarization shift in the material requires charges to be adapted on the electrodes. Surplus charges flow over an outer conductor to the other side of the crystal, where they generate accessible electrical energy.

PYROELECTRIC CATALYSIS Obviously, the voltage generated via pyroelectric means can also be used in electrochemical processes. When the metal electrodes are removed, surplus or deficit charges can only flow via chemical reactions, leaving one side of the crystal positive and oxidating, while the other would be negative and reducing (see fig. 2). Redox reactions then convert thermal into chemical energy.

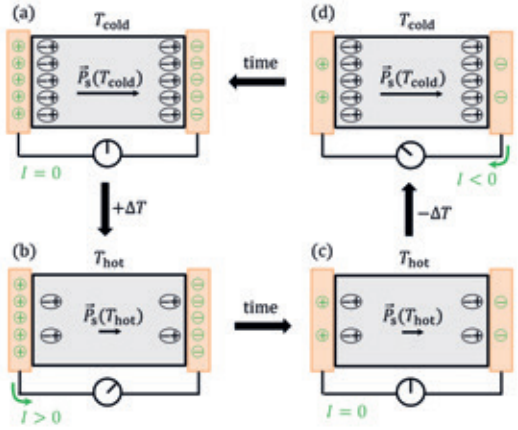

Fig. 1: Electricity generation via pyroelectric effect. (a), (c) Pyroelectric material in electrostatic equilibrium. No current flows. A temperature-induced change in polarization when heating (b) or cooling (d) the material then causes charges to be transferred (current) between metal electrodes (orange).

In principle, a variety of chemical reactions is possible, from directly decomposing organic material to inactivating bacteria to water electrolysis for hydrogen production. The hydrogen is separated from the oxygen with a gas diffusion layer and used either to power fuel cells or as an industrial raw material.

Unlike conventional electricity-sourced electrolysis, pyroelectric catalysis can produce power from thermal waste, even low-temperature heat under 100 °C. This waste heat can be retrieved from transportation, food industry or power plant exhaust gases, to name a few. Since global thermal waste comes to several hundred exajoules each year (according to Forman 2016), these are bright prospects for energy-neutral wastewater treatment and water electrolysis.

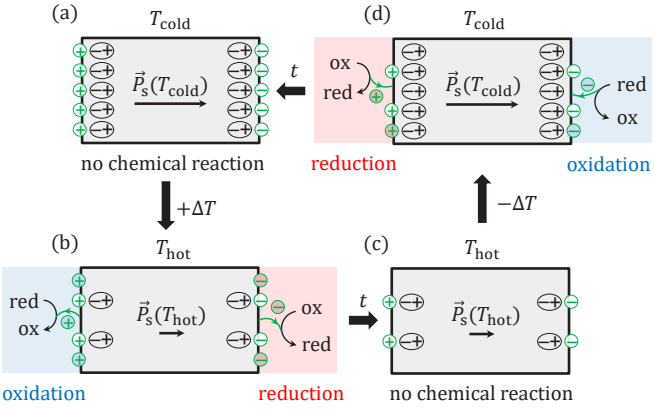

Fig. 2: Simplified model of pyroelectric catalysis that uses compensation charges (green) accumulating on the surface of a chemically unstable compound. (a), (c) Pyroelectric material in equilibrium: no reaction. A temperature-induced shift in polarization by heating (b) or cooling (d) the material then generates a current between the sides of the crystal, possibly prompting redox reactions. Highly reactive excess charges are shaded in red and blue.

PYRO-CATALYTIC THRESHOLD CYCLE How exactly is water split on pyroelectric materials? Which material parameters are decisive? Every small change in temperature induces a flow of charge. However, not every charge flow can split water. Minimum voltage is 1.23 volts plus different overpotentials. The largest overpotential originates in the band gap, as transferring electrons into the medium requires adjusting the valence and conduction bands to match the water's energy level.

For average pyroelectrics, the required electrolysis potential is around 1.5 to 2.5 volts (threshold potential, de Vivanco 2020). All charges transferred prior to attaining the threshold potential are lost. Only those flowing after the threshold potential is attained are chemically active.

The cooling half-cycle begins when the maximum temperature is reached. Then, all processes reverse (see fig. 3) and the material's inner polarization increases again. Shifting charges in the other direction means the crystal's threshold potential must also be reversed. Subsequently, there are no reactions at the start of the half-cycle, until the threshold potential is reached at reverse polarity (see fig. 3). At that point, a charge begins splitting water. The smaller the pyroelectric particle, the greater the proportion of charges that cannot effectively split water. Particles smaller than the critical mass remain out of reach for reactions.

KEY PARAMETERS As a rule of thumb, larger particles are conducive to pyroelectric catalysis, as they provide a higher pyroelectric coefficient, an extended temperature range and minimal permittivity. Still, particle size dependency is more complex than it looks. Although larger particles means larger potential, their active surfaces become smaller despite the same volume, limiting particle dimensions. An optimal value for average materials is 0.4 to 5 micrometers.

The necessary energy flow for heating materials reflects the influence of density and heat capacity. Cycle duration is not a parameter in the physical-chemical model. Abbreviated cycles with an accelerated rise in potential can lead to a (corona) discharge (see fig. 3 on p. 3) without any selectivity involved. Prolonged cycles can cause other compensation mechanisms to kick in, for example, establishing a stable, electrochemical double layer (capacitive regime). This means there is also an optimal cycle duration.

The highest conversion efficiency is the ratio between the energy retrieved from hydrogen and heat input at optimal particle size. Presumedly, cooling to ambient temperature does not require additional energy.

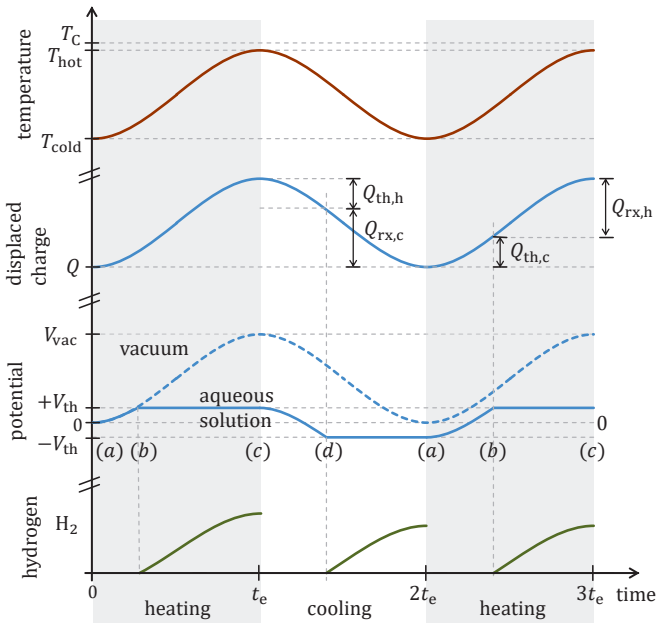

Fig. 3: Schematic diagram showing the course of pyroelectric charge, voltage and pyroelectrically produced hydrogen gas prompted by a sinus-shaped temperature change in a particle. (a)–(d) represent the cycle stages in fig. 1. The periods lost before reaching the threshold potential can be identified on the time axis and on bar. [Source of all images: TU Freiberg]

CONVERSION EFFICIENCY Thus far, conversion efficiency rates are at approximately 1.5×10^{-6} (for $BaTiO_3$, according to Belitz, 2017), a relatively low efficiency rate in light of real-word applications. Nevertheless, blanket use of pyroelectrics could retrieve several terajoules of waste heat a year.

Pyroelectric catalysis is still in its infancy, promising manifold prospects for improvements. It's up to material scientist to increase output further. One solution may be new kinds of nanostructures, e.g., phosphors. Two-dimensional phosphoric modifications, similar to graphite, have already shown efficiency improvements to 0.228, a five-fold increase over current values (You, 2018). ||

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Category: Research and development | **Author:** Niels Hendrik Petersen

VERY GOOD TO KNOW

Fuel cell stack monitoring

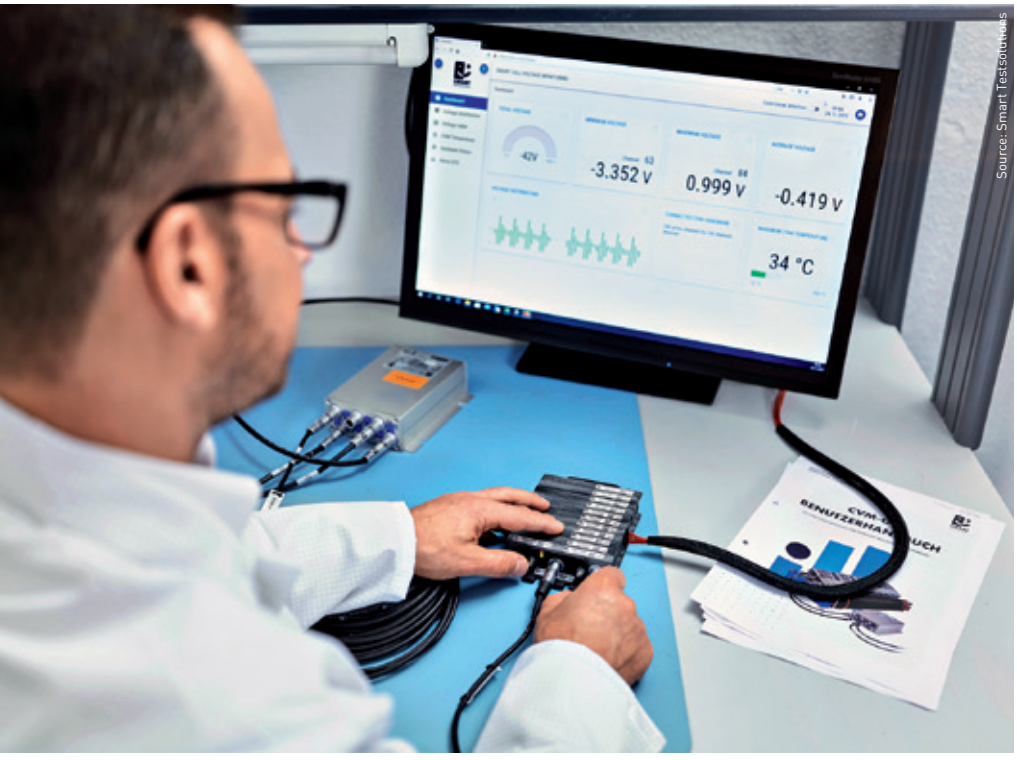
A fuel cell stack is a living organism and individual cell voltages report its vital signs. Which is why fuel cell vehicles are usually equipped with a monitoring system promptly drawing attention to critical operating conditions and enabling immediate response. It is absolutely necessary to reduce system costs before mass production can begin. Automated installations is a good place to start.

If you ask Markus Schuster, business line manager at Smart Testsolutions, Stuttgart, Germany, he will tell you the most important requirement of cell voltage monitoring systems, CVMs, is their availability. "The system must simply function," he stated firmly. The product must be robust, durable and utterly reliable, meeting the highest of technical demands, he said.

Many popular CVM systems monitor the fuel cell stack as a whole, making it impossible to pinpoint the origin of a given malfunction. Monitoring each cell individually allows direct access to a stack's inner workings. The new system signals not only stack malfunctions, but their precise location within the stack as well. You know exactly which cell or cell cluster is complicating matters. "Thus, the CVM data is suitable for operating strategy integration, such as in vehicles. It identifies critical operating conditions and shuts the stack down before irreparable damage can occur," Schuster explained.

HYUNDAI AND TOYOTA ALREADY THERE A Smart Testsolutions measuring device has 1 to 42 voltage sensors with more than 10 channels each, synchronously monitoring up to 420 individual cells in a stack. The greatest CVM challenge lies in the economic viability of a single channel's price, Schuster said. Especially when demands include an 18,000-hour lifetime and the corresponding certification. Costly manufacturer overhead.

There are already several R&D and trial solutions on the market. "So far, these have been proprietary solutions and not available on the open market," said Schuster. But the number of providers is rising. Two large Asian automakers – Hyundai and Toyota – already have ready-to-go solutions.



Source: Smart Testsolutions

SIZE AND WEIGHT MATTERS, FOR CARS Samuel Guesne is systems department manager at the DAM Group, another monitoring solutions provider. "Creating a reliable, affordable and easily integrable CVM is an enormous challenge. All the same, it is essential, playing a decisive role," he confirmed. First and foremost, manufacturers want to know if the installed fuel cell is functioning smoothly. To this end, the CVM measures voltage between the bipolar plates. The collected data can also be used to adjust and improve control commands to the cells. A communication protocol gives drivers real-time operating conditions.

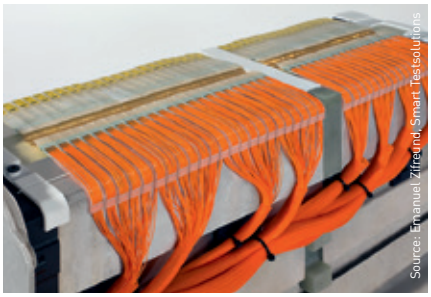

Source: Emanuel Zifreund, Smart Testsolutions

Fig. 2: Cell voltage pickup, CVP, on a model fuel cell stack

The French DAM Group is currently working on a monitoring system that accommodates any number of fuel cells, optimally adjusted to a vehicle's weight and size and relatively quickly installed. The product is in the design and validation phase, with DAM working closely with several partners, Guesne reported.

A CVM efficiently detects weak cells, once specified what comprises a weak cell. "Particularly the peripheral cells, those close to the end plates, need greater attention. In-depth monitoring on both stack ends would be a solution," Schuster explained. Then switching to cluster monitoring in the stack center.

External influences can cause damage as well. A lack of hydrogen can knock out a cell, in which case immediate action is required to nip negative cell voltage in the bud.

No fuel cell is identical to another. Stacks differ in their materials and geometry. Decisive for cell contact is the cell pitch, which defines an individual

Fig. 3: Testing a 95-kilowatt fuel cell suitable for vehicle integration [Source: ZSW]

cell's caliber as well as the distance between bipolar plates. Bipolar plates, in turn, are a key fuel cell stack component, separating gas chambers of neighboring cells.

NOMINAL CELL CLEARANCE IMPEDES VOLTAGE PICKUP Cell voltage pickup, CVP, is a particularly demanding task, as the distance between cells in modern stacks is less than one millimeter. Also, measuring bipolar plate potential is hampered by varying plate architectures. There is no standardization thus far, Schuster said. "Each unit must be adapted to the stack. A fuel cell stack's make-up wholly depends on the selected technological operating principles."

Furthermore, a stack's production and operating tolerances have an impact on its design. "So far, the CVP unit must have a modular structure. To ensure consistent operation, the unit must absorb forces from several directions to balance out differences in length while maintaining secure contact with the bipolar plates. This includes compensating for the shock and vibrations of vehicle application," Schuster noted.

Facing these challenges, Smart Testsolutions has spent the past three years developing spring contacts to improve voltage pickup. The new CVP unit is only 5 millimeters in height and guarantees reliable voltage measurement without extensive manual adjustments following installation. The contacts predominantly center themselves in the cell pouches independently, shortening installation time. This is made possible with double-sided spring placement and a special contact shape. Contacts are made of gilded beryllium-copper wires placed flexibly in modular holders on both ends.

RAPID CVM INSTALLATION Installation and price are important factors in mass production. Currently, installing CVP units is still a primarily manual process – and takes time. The technology must be developed to a point where rapid, automated installation is a reality. According to Schuster, that is the ultimate challenge. What now takes half a day – installing a CVM and voltage pickup – must one day be accomplished in only a few minutes.

Over a year ago, at the September 2019 f-cell, Smart Testsolutions introduced CVM G5S, a monitoring solution developed with economic and operating efficiency in mind. Smart Testsolutions said the single-PCB solution offers improved durability in long-term use as well as cost advantages dependent on unit quantity. As all CVM systems over the past five generations, the measuring components are deployable at ambient temperatures up to 105 °C. They work with a wide range of supply voltages – 4.5 to 32 V – allowing direct service access to 12-volt or 24-volt grids. Thus, a measuring unit can synchronously collect and monitor the voltage of up to 200 individual cells. ||

Category: Research and development | **Author:** Sven Geitmann

THE CATALYST MIRACLE

The growing importance of nickel, tin and copper

New times call for new ideas – and new materials. A global increase in electrification calls for new chemical products. Petroleum catalysts are a major component of the fossil fuel era and must be replaced. The current battle for rare natural resources and chemicals makes it all the more important to invest in research on inexpensive, readily available alternatives. Evidence points to nickel, tin and copper, and their undiscovered properties, as cheaper options. Good news for the electrolyzer and fuel cell industries.

Professor Peter Strasser, leader of TU Berlin's electrochemical energy, catalyst and materials science group, has been researching nickel and iron oxide catalysts used in alkaline exchange membrane water electrolyzers, or AEMWEs. He aims to find an alternative to iridium catalysts in proton exchange membrane water electrolysis, PEMWE. Strasser explained: "PEMWE catalysts are made from iridium, an expensive, extremely rare precious metal covering the anode, where oxygen is extracted from water. To achieve the 2030 capacity targets in the German government's hydrogen strategy, we would need the world's entire yearly iridium supply to meet just a small percentage of Germany's energy demand." (see also H2-international, October 2020)

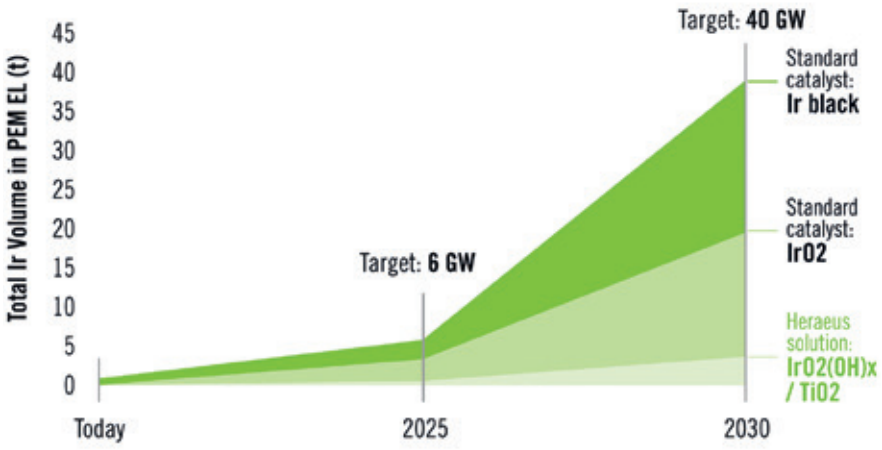


Fig. 1: Iridium required to meet the 2030 targets set in the EU's hydrogen strategy [Source: Heraeus]

Hanau-based Heraeus Group is carrying out similar research. In late September 2020, the German business introduced a new catalyst not only with 50 to 90 percent less iridium but also trebling catalytic performance, according to Heraeus. A far less expensive, far more efficient PEM electrolysis catalyst, the company added.

"Global iridium reserves simply cannot provide sufficient precious metal to supply all electrolyzers necessary for the European Commission's hydrogen targets. We are very proud to have created a product so low in iridium."

Christian Gebauer, hydrogen systems director at Heraeus Precious Metals

Iridium production is currently around 8 tons annually. PEM electrolyzers need about 1 to 2 grams per kilowatt output. The strategy's 40-gigawatt electrolyzer target by 2030 would require 20 to 40 tons of iridium a year if PEM devices provided half the capacity.

In May 2020, TU Berlin researchers published an article in Nature Communications, describing new findings and the molecular dynamics of Ni-Fe catalysts. The team compared experimental data with a new theoretical catalyst model developed in partnership with Purdue University in the United States – a model that fully explains and quantifies the results of TU Berlin's joint experiments with Fritz Haber Institute in Berlin. Strasser said these and similar catalyst research breakthroughs will make a case for water-splitting in "clean, efficient and inexpensive hydrogen production."

COPPER IN PEM FUEL CELLS

Electrolyzers aren't the only devices needing catalysts. Researchers have also spent a good number of years trying to find substitutes for those in PEM fuel cells. Professor Julia Kunze-Liebhäuser, a physical chemist at Innsbruck University, Austria, has discovered that copper is indeed an option despite the metal's commonly assumed inertia. She said: "Our own calculations led us to believe that copper simply can't be a catalyst. And yet, when we conducted our experiment, we detected high electrocatalytic activity."

Substantiating the experiment, Kunze-Liebhäuser cited the Sabatier principle: "The molecules of a good catalyst form neither too weak nor too strong of a bond during reaction. The bond must be strong enough to trigger the reaction but weak enough to inhibit molecules from binding permanently, which would end the process. Unfortunately, the principle doesn't apply to many materials as their molecules bond either too strongly or too weakly. In most cases, you need a substance that allows both stronger and weaker interactions with the surface, depending on the type of molecule."

Referring to observations her team and the Fritz Haber Institute staff made,

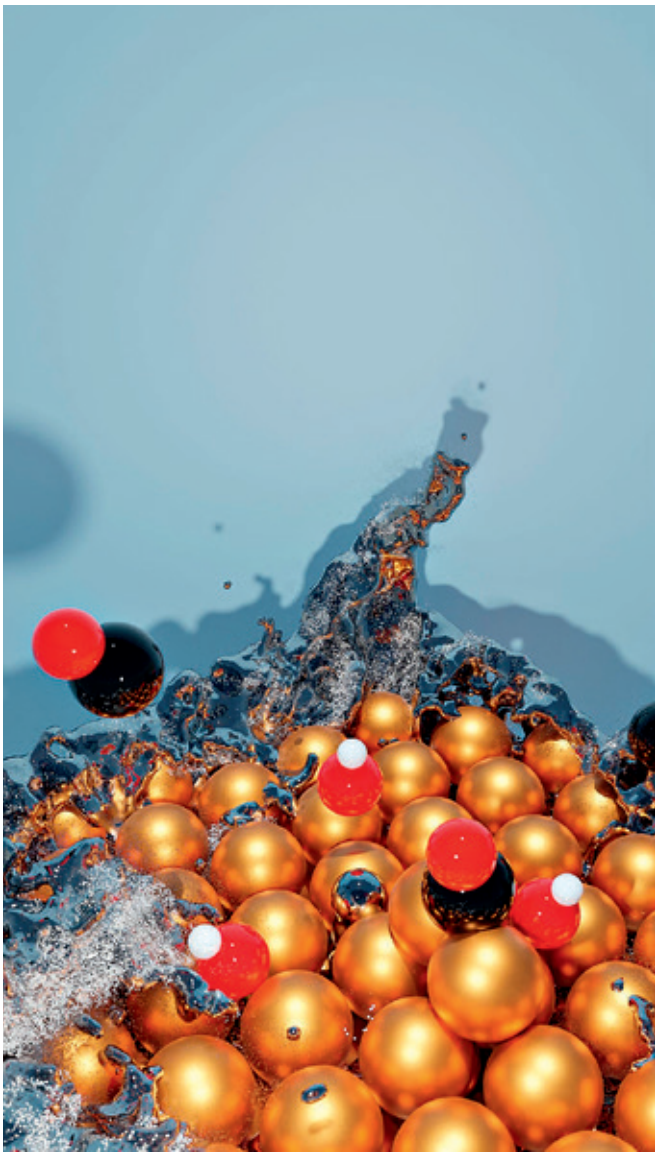


Fig. 2: Catalyst surface dynamics [Source: Andrea Auer]

she said: "We've found that the reaction prompts a change on the copper surface. Small islands of copper atoms form repeatedly. These protruding nanometer-size clusters store highly localized charges induced by molecular adsorption whenever a voltage is applied, fundamentally altering their bonding properties."

Strasser, who researches both electrolyzer and fuel cell catalysts (see HZwei, January 2009), pursues a different approach. He focuses on the cathode, relying on the catalytic effect of single tin atoms embedded in nitrogen-doped carbon, the topic of a Nature Materials article he co-authored. According to Strasser, "most electrocatalysts are made from platinum, iron or gold, which belong to periodic subgroups. Metallic elements in the main groups, such as silicon, aluminum or lead, are often poor catalysts due to their electron configuration. However, the new fuel cell electrocatalyst uses a main group metal, namely, tin."

He elucidated: "Using tin instead of platinum for a fuel cell's cathode could lead to a dramatic reduction in catalyst costs. Tin also has beneficial chemical properties that could increase a fuel cell membrane's lifetime." In cooperation with work groups in the United States, France and Denmark, his team has embedded single tin atoms in a layer-like carbon lattice called graphene, securing them in place with nitrogen atoms.

NEW CATALYSTS FOR SALTWATER TREATMENT In addition, Strasser is investigating the storage and retrieval of clean power in salt-rich brackish water or seawater. When fuel cells generate electricity from that storage, they also produce water of almost freshwater quality. The clean electricity produced in onshore systems installed across Germany doesn't come close to meeting hydrogen production needs. Viable alternative hydrogen sources under consideration are offshore wind farms, transporting hydrogen to the coast via pipelines, or hydrogen imported via tanker from the North African, or even Australian, arid desert zones.

These two options offer an abundance of cheap renewable electricity but a lack of pure water crucial to water splitting. Seeking a remedy, Strasser and several of his peers from the National University of Ireland Galway and the University of Liverpool reviewed the global corpus of publications reporting on successful direct saltwater electrolysis. Their efforts brought forth the most important technological challenges of our day. "Our analysis shows research efforts must be twofold, developing new types of catalyst materials as well as suitable membranes. The membranes commonly used in electrolysis often fail to block out the water's salt content," he explained.

Strasser believes using freshwater for sustainable, diverse hydrogen production, especially in arid, sun-rich regions, is not an option. He favors creating new selective catalysts and special membranes as "important milestones on the way to high-performance saltwater electrolysis." ||

Category: Research and development | **Author:** Michael Nallinger

THE MEASURE OF SUCCESS

Breakthroughs in bipolar plate development

Bipolar plates, or BPPs, are one of the most common components in fuel cell stacks. So, which BPP is put in a stack has a huge impact on functionality and costs. Three research projects, InProPlate, PreCoil and BePPel, funded by the German hydrogen and fuel cell program NIP II, have come up with new techniques that, above all, promise a significant reduction in manufacturing and measurement costs.

Most stacks include either graphite compounds or metallic plates. While metallic BPPs conduct electricity better, they are not very resistant to corrosion. Still, Thorsten Hickmann, Eisenhuth's chief executive, believes ample evidence suggests that passenger vehicle stacks will contain primarily metallic plates. In contrast, trucks, buses, stationary hydrogen systems and other kinds of applications requiring a steady flow of electricity will become the domain of graphite compounds.

As for passenger cars, Hickmann said, two factors play into settling on metallic plates: weight and space. "Neither matter in the commercial vehicle market," he noted. Nearly the same can be said about range extenders in electric vehicles, where the most important factor is economic life.

INPROPLATE: LARGE, THIN GRAPHITE BPPS Eisenhuth, based in Osterode am Harz, ventured into the fuel cell market in 2006 and has since focused on making graphite-based bipolar plates. In 2018, the company joined InProPlate, a collaborative effort between Eisenhuth, Siqens and DLR's Networked Energy Systems Institute. Their shared goal is to design new, innovative production techniques, appropriate testing procedures and equipment by the end of this year, to guarantee the quality of plates, stacks and complete fuel cell systems.

Fig. 1: Large, thin injection-molded bipolar plates [Source: Eisenhuth]

Eisenhuth's project assignment is to produce bipolar plates while improving both production processes and chemical formulas for graphite compounds. Munich-based Siqens' primary objective is to optimize assembly and individual fuel cell components, which entails assuming the consortium's end user role, especially for stationary systems. For its part, the German Aerospace Center – DLR is analyzing project materials and investigating their electrochemical properties.

One challenge InProPlate seeks to address is how to use injection or, at low volumes, compression molding to manufacture large and extremely thin bipolar plates. After all, the project's aim is to come up with solutions for the auto industry, where plates must be up to 700 millimeters long. Currently, many are only 300 to 400 millimeters. "Every additional millimeter raises the stakes," said Hickmann. All plates are approximately 0.7 millimeter thick, an extremely low value for graphite BPPs and soon to be lowered even further, Hickmann believing the limit to be somewhere between 0.5 and 0.6 millimeters.

But thickness and length aren't the only challenges the companies need to surmount. A second stage will focus on polyvinylidene fluoride and polyphenylene sulfide, or PVDF and PPS, compounds. "We've worked with polypropylene compounds successfully so far. The challenge we're now facing is how to apply our knowledge to our new base polymers PVDF and PPS," said Hickmann.

Source: Eisenhuth

"Each additional millimeter challenges the system exponentially."
Thorsten Hickmann, Eisenhuth chief executive

When asked if they will achieve the desired plate dimensions, Hickmann sounded optimistic: "We're making good progress. Using injection molding for large plates was an important

milestone." One key criterium for plate quality is homogeneous design, an aspect influenced by multiple factors, with optimal injection processes being the most dominant. At the same time, efficiency and costs must be consistently monitored. Using the hot molding approach guarantees the least waste plastic per shot, Hickmann noted.

Speaking of costs, he also pointed to the importance of funding. NOW's NIP II program provided nearly two-thirds of the project's EUR 4.5 million budget. "Without those funds, we would never have made such rapid progress."

PRECOIL: PRECOATING METAL COILS The successfully completed PreCoil project focused on devising a new coating technique for metallic BPPs. Unlike the widely used post-forming techniques, the new method coats stainless steel plates before they are shaped. Using the roll-to-roll process, companies can scale precoated, semi-finished products themselves, thereby cutting costs and eliminating time-consuming manual work. Semi-finished goods produced independently of the final BPP can then be delivered to plate producers, creating an intriguing business model.

The new technique also benefits BPP production logistics by doing away with post-coating after bringing plates into form and before sealing them. Until now, this had been a great challenge, especially in high-volume production. Vitali Weißbecker, Precors' chief executive, said post-coating means that "instead of entire coils, parts are sent to stack manufacturers from around the globe." A four-staff spin-off of Forschungszentrum Jülich's Energy and Climate Research Institute, Precors specializes in designing, manufacturing and commercializing new carbon-based materials as well as in devising novel coating methods. Weißbecker said Precors creates materials with functionality, high corrosion resistance and excellent electrical conductivity in mind. In concrete terms, the material has electrical properties that are similar to those of gold, with a 1 milliohm-cm^2 resistivity at standard pressures of about 6 bar. In the fuel cell industry, a resistivity value below 10 milliohm-cm^2 is considered a remarkable achievement.

The PreCoil project, running from early 2018 to June 2020, published a precoating feasibility study and put up a pilot production line for coating plates. Both efforts were NIP II-funded with around EUR 580,000. The two most important project tasks, Weißbecker said, were evaluating the coating material's preforming suitability, which also established its technical specifications, and dividing roll-to-roll fabrication into several continuous sub-processes. "We completely verified each part of the process chain before successfully starting up an entire production line. Customers and in-house staff also carefully inspected the precoated coil material, confirming its quality," he said.

And this although precoated coil material is often riddled with problems. One typical issue is a coil coating rupture during stamping or forming, a hair-line fracture that can lower conductivity and corrosion resistance. With the new precoating technique, the highly elastic layer withstands the forming process without rupture, Weißbecker firmly stated, and can take on an expansion rate of over 40 percent.

"So far, we've coated several hundred meters of metal coils in this way," he noted. The continuous flow process used by Precors comprises four stages: pretreatment, double-sided coating, post-treatment and quality assurance. Afterward, the plates are re-rolled into coils.

The coating material, developed by Jülich's research center, is both eco-friendly and cost-competitive, devoid of solvents and rare, expensive resources. The water-based suspension is applied to the substrate surface wet. Multiple coatings form very thin, insulating layers and layer quality relies on homogeneity. Since layers are approximately 20 nanometers thick, applying the suspension across a material several hundred meters long is a production challenge. To guarantee quality, the material must have an overall homogenous structure and consistent parameters throughout coating.

The method draws on everyday oxygen in the atmosphere, so it can also be incorporated into conventional production processes, an excellent asset. Unlike physical vapor deposition techniques, precoating dispenses with (ultra-high) vacuum chambers or inert gas environments. From a manufacturer's standpoint, this significantly influences scalability, costs and mass-market appeal. >>

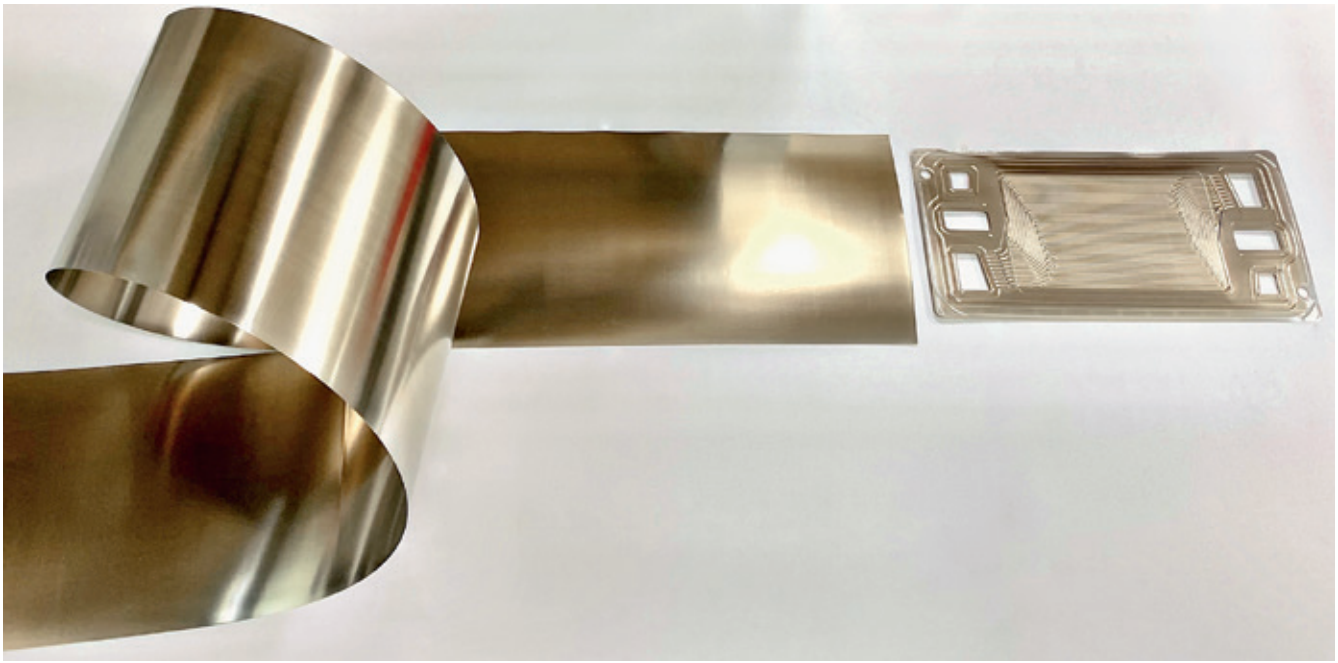


Fig. 3: Precoated coil material [Source: Precors]

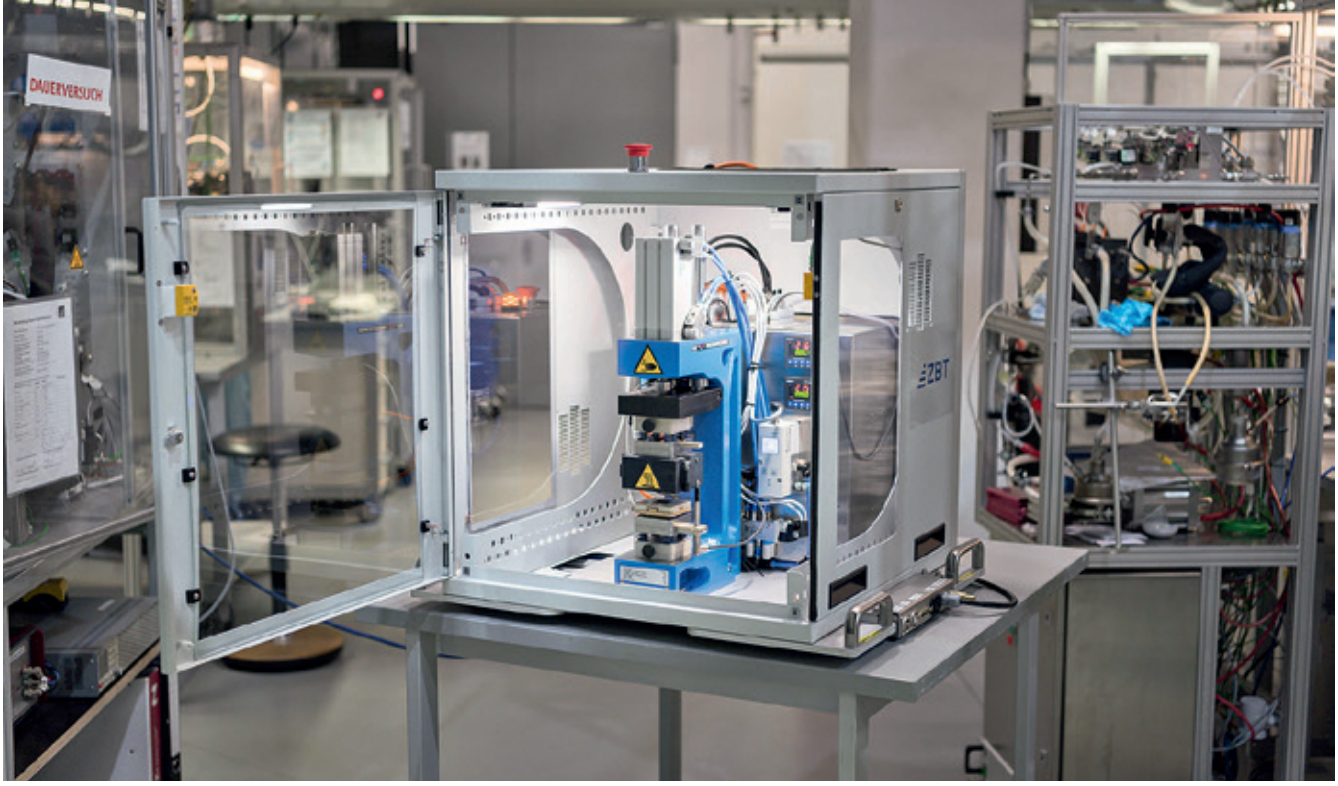


Fig. 4: Measurement system developed during BePPel [Source: ZBT]

These and similar German innovations are what bring about, or maintain, the country's world market leadership, especially in managing complex processes. Yet, it is public funds that make them happen, something Weißbecker deeply appreciates: "We're very grateful for the support we've received. As a start-up company, we would not have the financial means for such research-intensive projects." Funding also expedited bringing new products to market, an opportunity Weißbecker's company has gladly seized, as the company's order pipeline starts to fill. "This year, our customers will complete their long-term tests, which already show great promise. After that, we will increase production capacity so we can offer products in greater numbers," he said in late 2020.

BEPPEL: STANDARDIZED MEASUREMENTS AND QUALITY CHECKS There is a definite lack of uniform electrical property standards for graphite and metallic BPPs in low- and high-temperature fuel cell systems. This means collected data cannot be independently verified. BePPel intends to bridge this knowledge gap. Project leader Nadine Pilinski, of DLR, put it this way: "We urgently need standardized measurements and quality assurance. The industry demands it."

Standards cut costs. They lower inspection expenses. They promote quality assurance. They also reduce plate manufacturing costs. Standards safeguard entire systems, as defective components can be identified and removed before they are integrated into stacks downstream. Standardizing tests for suppliers and stack manufacturers, Pilinski stressed, is crucial to providing reliable, trackable data and to creating transparency.

BePPel, supported by NIP II with EUR 3.2 million, came to be known for its special partnership between several German research institutes, which included DLR, the Hydrogen and Fuel Cell Center – ZBT, the Center for Solar Energy and Hydrogen Research – ZSW, Forschungszentrum Jülich's Electrochemical Process Engineering division IEK-14, and Fraunhofer ISE and ICT. They were joined by over 20 industry partners, mostly BPP manufacturers (providing products and materials for testing), BPP users and stack producers.

The project strived from the end of March 2017 to April 2020 to define and develop standards for measuring physical properties, particularly the electrical conductivity and contact resistance (in-plane and through-plane) of graphite and metallic BPPs. "What we need is a standardized yet inexpensive, industrial-size measuring station," said Pilinski. The first step involved creating an individual measuring station that would be the basis for monitoring future large-volume production. This required establishing presets for continuous manufacturing process control and then transferring the developed measurement method into an industry standard.

Pilinski is pleased with the results: "In a round-robin test among consortium members, we could identify and confirm the need for a new, standardized method to measure electrical conductivity." The new method is based on, among other things, studying the conductivity and the thermal, electrochemical and structural properties of graphite and metallic BPPs. Not only identifying surface structures, aging behavior, and oxide layers, the project also designed measuring equipment to detect material defects and to rate extruded compound material conductivity.

"Throughout the measurement study process, we gained profound insight into measuring absolute values, identifying possible sources of errors as well as into the influence and behavior of materials properties. All of which are essential to creating measurement standards," she said. Other milestones included developing, manufacturing, installing and rolling out a system that provides nearly instant, automated BPP measurements at a predefined pressure and power density. The project also produced guidelines for performing standardized tests of a BPP's electrical through-plane resistance value. Meanwhile, Pilinski is forging ahead: "Following our guidelines will now make reproducible findings possible."

Ultimately, the project's guidelines will be standardized and be made available to the industry. BePPel's industrial and research partners are currently negotiating a suitable agreement, Pilinski said, striving for prompt implementation. Which standard format will apply, DIN or another, is also being negotiated.

When asked if there are plans for EU-wide regulations, Pilinski replied: "Our current focus is a national solution." However, some are hoping the standard will make it onto the global stage and become part of international agreements. After all, one of the BePPel partners was a French company. ||

COMPRESSORS
Energizing the Transition to the
H_2 ECONOMY

NEA COMPRESSORS
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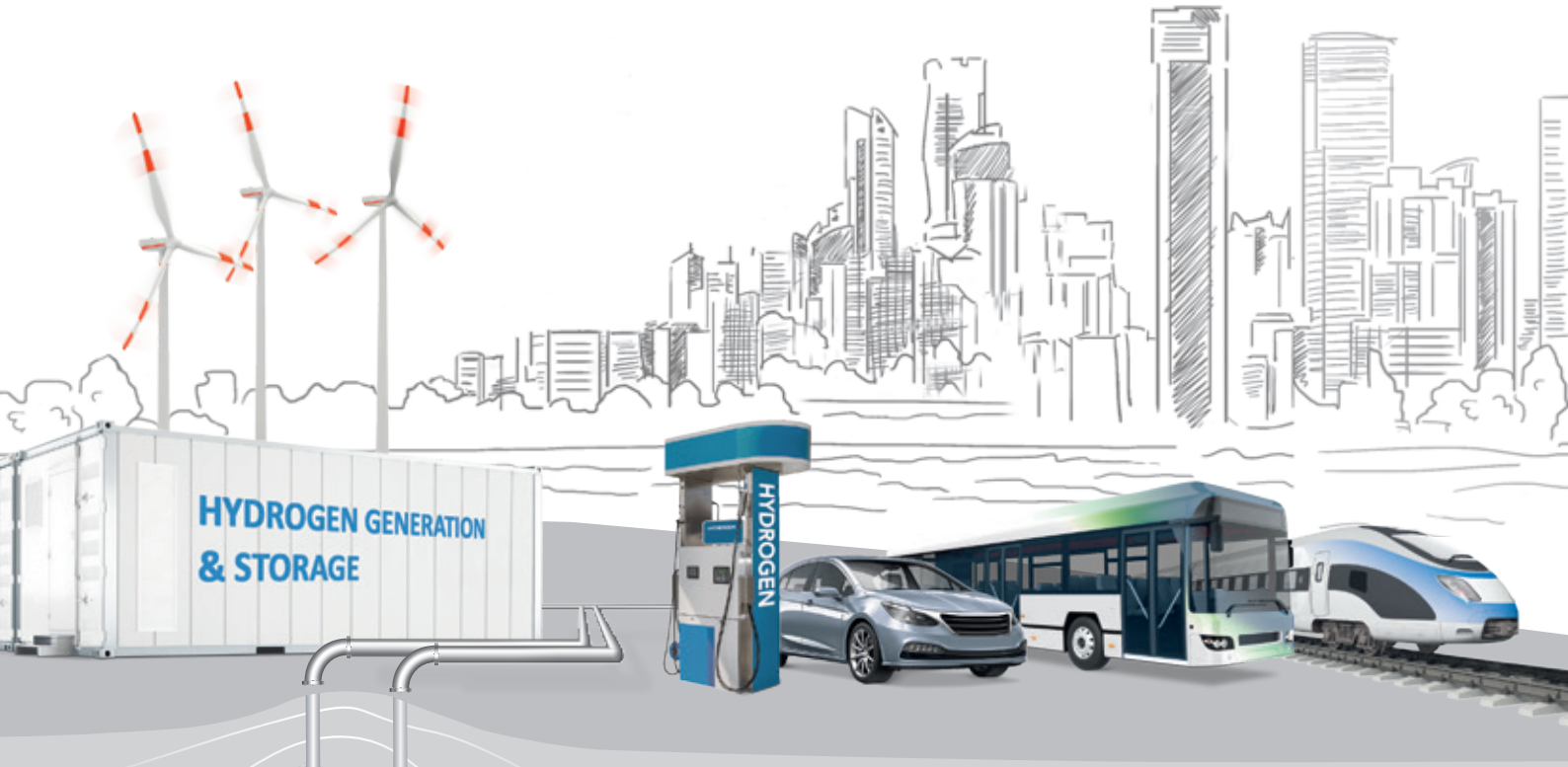

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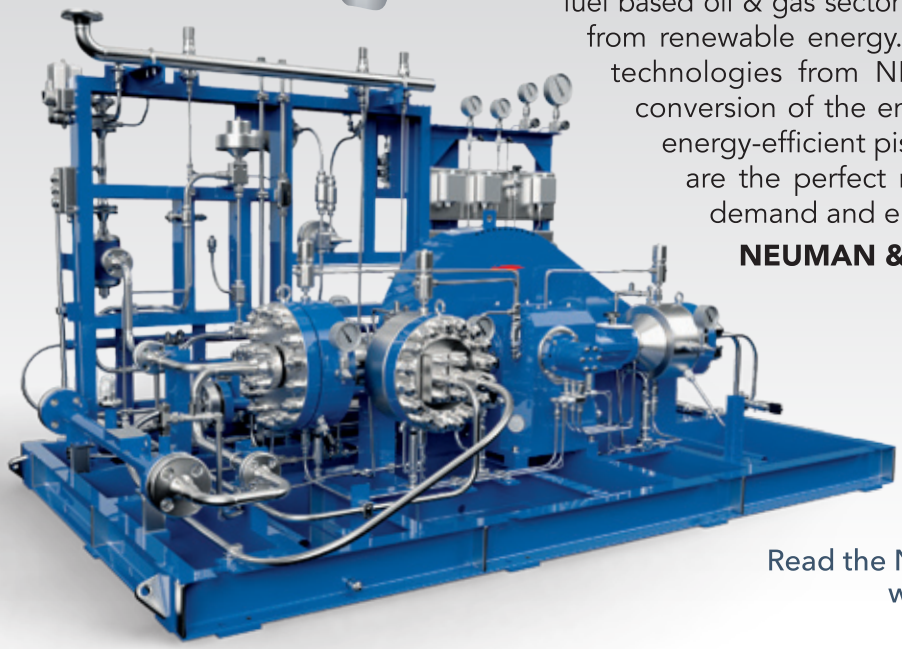

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Category: Research and development | **Author:** Alain Prinzhofer

NATURAL HYDROGEN

A promising source of clean and renewable energy

Natural hydrogen gas is known on Earth since the 1920s. However, its potential interest as an exploitable source of energy has been growing in the past ten years. Early discoveries were either forgotten and neglected (Australia, Kansas, USA, Brazil, Mali) or located in remote areas where little if no economic interests can be devised (Mid-oceanic ridges, mountain chains).

Hydrogen exploration has recently generated a renewed R&D interest for Earth scientists. It is well known that H_2 can be found in mid ocean ridges (MOR), in ophiolites (slices of oceanic crust thrusted onto mountain chains), in continental cratons (very old continental rocks) and in hydrothermal fluids. So far, industrial research projects and potential added value of this resource has been developing mainly in continental cratons. It is indeed in this kind of habitus that natural hydrogen production seems to be more effective with low-cost technologies, and with high H_2 concentrations and fluxes. This document presents two cases, where exploration and business plans are beginning: a hydrogen field in Mali, and an area with active hydrogen systems in Brazil.

THE MALIAN CASE STUDY In 1987, a water well drilled 110 meters deep on the outskirts of the Bourakébougou village (Kati circle) encountered a pocket of gas that subsequently ignited at the wellhead. The well was cemented and abandoned until the Hydroma company re-opened it in 2011, and all the while acquiring block 25 in the vicinity for exploration, with a surface area of 43.174 km². The objective was to carry out exploration operations of hydrogen in the area. "Fairy circles" were observed in the eastern part of Block 25 (similar as the one on Figure 2 located in Brazil), and hydrogen emissions were measured in those superficial structures (Prinzhofer et al., 2018).

Emitted gas in the pioneer well (called Bougou-1) is composed of 98 % hydrogen and the remaining 2 % consists of methane and nitrogen with traces of heavier gaseous hydrocarbons and helium. Shortly thereafter, it enabled the company Hydroma to install a pilot gas exploitation unit, in order to supply the Bourakébougou village with electricity. Since then, much geological, geophysical and geochemical studies have been performed. A seismic reflection survey was carried out in the Bourakébougou area, enabling a mapping of the dolerite that extend in the area and which acts like a seal and could accumulate hydrogen in reservoirs.

Finally, twenty-four additional wells were drilled, devoted to hydrogen exploration. All wells are placed within a circle of 20 km diameter all around the Bourakébougou village. Hydrogen was encountered in all the wells at various depths. The first accumulation is confirmed to occurs at a depth of about 100 meters, and four other deeper reservoirs were discovered. A borehole crossing the sedimentary series to reach the basement showed that it is also impregnated with hydrogen (Prinzhofer et al., 2018).

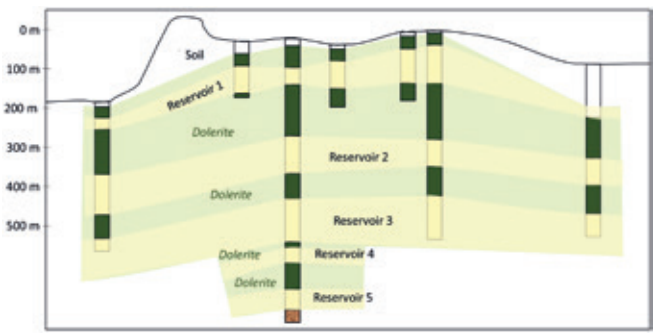
The sedimentary series, about 1,400 meters thick, is intersected by numerous doleritic sills of Triassic age. This sedimentary series represents the oldest part of the Taoudéni basin (Tamboura sub-basin, essentially neo-Proterozoic), which extends over a large part of West Africa. The Paleozoic formations which surmount it are particularly developed in Algeria and present well-known petroleum systems. In contrast, Proterozoic rocks are very poor in organic matter, and these are today considered hyper-mature, with no petroleum potential. This virtual absence of organic carbon probably explains the good conservation of the natural hydrogen produced. Otherwise, the latter would be expected to quickly react with carbon by the Sabatier reaction to form essentially methane.

The importance of these gaseous accumulations makes it possible to envisage in the short term an industrial development of this new energy source. The cost of extracting natural hydrogen, at least in the Malian example, is inferior to the production cost of this gas, especially if the synthesis of green hydrogen, produced by electrolysis of renewable electricity is considered (see fig 1).

As the gas quantities increase almost linearly with pressure and depth, the total amount of accumulated hydrogen is larger in deeper reservoirs, for equivalent reservoir volume and porosity.

The pilot operation of pioneer Bougou 1 well has shown that since 2011, gas pressure at the wellhead has not decreased. As a matter of fact, gas pressure has even slightly increased, which is hardly compatible with a fossil type accumulation of hydrogen. In this case, hydrogen content would be depleted after years of exploitation like it typically occurs in an oil field production with subsequent pressure drop at the wellhead. Several geochemical and physical arguments (in particular the very high chemical reactivity and the high dispersivity of the hydrogen molecule) indicate that hydrogen gas, when encountered in a given geological context, has not been generated nor accumulated for long. In fact, estimated time of generation/ migration/preservation/accumulation of natural hydrogen is between 10 and 100 years, short and compatible with a human renewable valorization.

A thorough monitoring of wellhead pressures would provide a better knowledge of the geometry of the reservoir, combined with a more precise quantification of the flow of generation and migration of this renewable naturally occurring gas. The surface measurements in Brazilian "fairy circles" example, also seem to imply a production flow compatible with such short time cycled characteristics.



Source: Prinzhofer et al., 2018

Fig. 1: Synthetic cross-section of the Boukarébougou hydrogen field, with the superposition of five gas reservoirs.

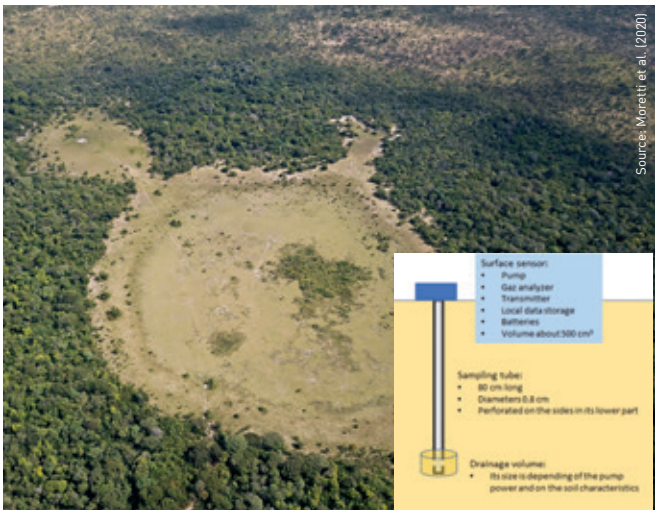


Fig. 2: One of the monitored "fairy circle" located in the Sao Francisco Basin (Brazil) and sketch of the measurement principle at a 1m depth. The diameter of the larger circle is about 600 meters.

A BRAZILIAN CASE Brazil is a country where numerous evidences of hydrogen seeps can be noted. Among them, we studied an area in the Sao Francisco Basin, located in the states of Minas Gerais and Bahia. The basin is Neoproterozoic and hydrogen has been quantified in large concentrations through many oil and gas drilling wells. An ongoing ENGIE research project attempts to evaluate the long-term hydrogen exudations in different zones of the basin. Semipermanent H_2 sensors have been placed in the ground to geochemically monitor two "fairy circle" structures during two years (Prinzhofer et al., 2019; Moretti et al., 2020; see fig. 2).

Hydrogen emission data into the atmosphere are not constant neither spatially nor time wise. Figure 3 shows that for a given spot in the structure, a large pulse of H_2 occurs sporadically during 24 to 48 hours (reaching several percent of H_2 in the soil). The large spike is followed by a relaxation phase with smaller daily pulses. Concentrations can reach up to several hundreds of ppm for several weeks. Interestingly, it is found that at the scale of fairy circle, observed large pulses occur very often but are not measured in neighboring sensors, i.e. gas seeps appear as meter-scale localized.

Important large H_2 emission appears to correlate with a H_2 release from deeper horizons. Daily oscillations could correspond to the release of remaining H_2 in the soil, favored for example by the atmospheric pressure variation between day and night (Cathles and Prinzhofer, 2020). This study proposes a better assessment of real exudation flux of hydrogen in such structures, estimated in this Brazilian case to be around 0.02 to 0.04 $m^3/day/m^2$. This is a key parameter to quantify the gas generation in a hydrogen system and to estimate how rapidly hydrogen accumulations are renewed.

CONCLUSIONS After several years of R&D on the occurrence of the following can be said of this new source of energy: Hydrogen geological systems are observed through superficial exudations, presenting circular depressions called "fairy circles". These structures are generally associated with Proterozoic rocks, and are the first guides for this resource exploration.

Natural hydrogen may be encountered in various geological settings: mid-oceanic ridges, ophiolites, cratons, and hydrothermal fluids. Among these different habitus, cratonic environments seem the most promising and valid.

Cratonic hydrogen seems to be often associated with geologically old rocks, generally of Neoproterozoic age. This geological period corresponds to a moment of de-oxygenation of the Earth atmosphere, which may be associated with the reducing property of the H_2 molecule.

A hydrogen system features, like a hydrocarbon system, a generation kitchen, a migration conduit of gas up to the surface, with possible porosity contrasts in layered rock, implying accumulations.

Natural hydrogen characteristic time in the subsurface implies that it is a renewable resource at human time scale. This renewable property, associated with the non-polluting compounds of hydrogen combustion (product is water) makes it a very interesting new potential source.

Natural hydrogen occurrences are widespread in every continent, allowing to imagine a decentralized relation with this source of energy and breaking the paradigm of fossil energies, which were centralized because of their concentrated geological occurrence.

The complete understanding of hydrogen systems is far from finished. The generative processes taking place at depth, gas migrations velocity and flux, a balance of generated/accumulated and consumed/dispersed hydrogen should be further investigated.

Several industrial projects are underway today in different countries, allowing to better assess the potential of this resource in our future energy needs. ||

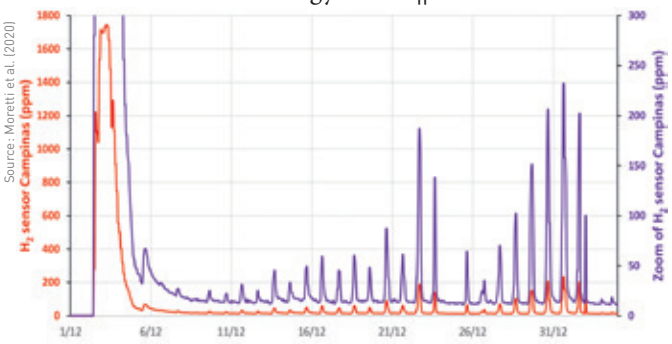


Fig. 3: Evolution with time, during one month, of a hydrogen pulse monitored with one sensor. After a large initial peak (red scale) and a couple of days of quasi absence of emission, regular daily pulses are releasing smaller quantities of H_2 (violet scale).

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

A NEW DAWN FOR HYDROGEN

Sven Jösting's stock analysis

Fuel cell and hydrogen stocks are riding a wave of popularity as a new megatrend sweeps the market. So far, every single one of these stocks has exceeded expectations. But how long will the love affair between investors and the industry last? Will analysts and shareholders use new methods to evaluate business models, prospects, backlogs, submarkets and revenues, and, above all, the potential for profit? And will the market separate the wheat from the chaff? I'd say yes, that will definitely happen.

What the relevant companies need is proof of real sustainability. No greenwashing, no constant drip of buzzwords to spike their stocks. If you use renewable resources, recyclable products, and low-waste fuel cell and stack manufacturing techniques, shareholders will have your back. These days, large institutional investors are paying special attention to sustainability. Following an environmental, social and governance strategy, they can offer businesses tons of cash, propelling them to stock market fame.

Fig. 1: Historical prices of the stocks discussed in this issue
Retrieved Dec. 22, 2020 [Source: wallstreet-online.de]

BALLARD – BOUGHT DEAL RAKES IN USD 400 MILLION

Fig. 2: Tony Guglielmin

In what is known as a bought deal, an underwriter syndicate co-led by investment bank Raymond James has offered Ballard Power [Nasdaq: BLDP] fresh capital for shares. The offer was so popular, the initial USD 250 million target was quickly raised to USD 402.5 million: In late November 2020, the companies agreed on USD 350 million in stock, with an option on another USD 52.5 million, all selling at USD 19.25 per share. Ballard has since exhausted those resources, though more could be on the way soon.

Third-quarter figures were at the lower end of expectations. With total revenue at USD 25.6 million, net loss came to USD 11.2 million, or USD 0.05 a share, mainly because of high R&D expenses and a USD 2.8 million investment in manufacturing facilities in China. Covid-19 has been everything but good for business, the company said, allowing only essential travel and making customers apprehensive of placing orders. Still, Ballard is in a good position. Via an at-the-market program, the fuel cell company raised USD 250 million by Sept. 30, 2020, bringing cash reserves to USD 361.7 million. Factor in another USD 32.7 million that will be added in the fourth quarter and the price of the stock sold in November, and you'll get to around USD 800 million in cash and cash equivalents at the end of 2020, minus fourth-quarter costs.

During Ballard's quarterly earnings call, Tony Guglielmin, the company's then-chief financial officer, said his decision to retire was difficult, even more so because Ballard "stands at an inflection point." I'd say those who thought the stock reached its peak last year will be in for a surprise.

One indication that there's more to come is Ballard's partnership with Mahle, a global auto supply heavyweight with revenues exceeding USD 10 billion a year. Over half of all vehicles registered around the world are built using components manufactured by the group, such as temperature sensors or air filters. Ballard's role in the partnership is to deliver fuel cell systems for commercial vehicles. Turning a collaboration like this into a joint venture may be the next logical step.

AUDI EXIT HELPS BALLARD Ingolstadt-based Audi was once Ballard's ideal partner when developing passenger car stacks. The H-Tron concept study is a direct result of their collaboration. What's more, the German automaker has spent USD 50 million on Ballard IP. Though the partnership is said to continue, it seems to me as if both companies are ready to go their separate ways. Ballard just received, you might say, a missing

license for integrating FCgen-HPS stacks, which have so far been used in trucks and buses, into other automakers' passenger cars. Audi's, and thus also VW's, exclusive right to Ballard technology is gone. Meanwhile, the fuel cell maker is free to pursue other ventures.

The companies' recently signed patent license and technology development agreements, I think, prove Audi intends to collect license fees but has no longer any interest in using Ballard stacks in-house. That's a good thing for the fuel cell business. Basically, Ballard can now sell FCgen-HPS stacks to anyone on the market – for the right price, of course.

> "We don't have enough carbon-neutral hydrogen available today and we won't for decades. As a result, I don't believe there will be a mass market for hydrogen-powered passenger cars."
>
> *Markus Duesmann, Audi's chief executive*

In my view, the above quote expresses a sentiment shared by most automakers. Their sole focus is on all-electric vehicles, not least because of generous public incentives. VW also doesn't want to confuse consumers by offering several drive concepts at once. The only automakers not following suit, Toyota and Hyundai, are based in Asia.

News to me was that the Canadian fuel cell maker might also invest in electrolysis. Getting a foot in the door requires Ballard buy another company, strike up a partnership or enter into a license agreement with someone in the industry. CEO Randy McEwen said the business is "perhaps a number of years ahead of a number of electrolyzer companies that work on things like electrolyzer MEAs," noting that MEAs make up two-thirds of PEM electrolyzer cost.

China, for one, is very committed to growing the hydrogen and fuel cell sector. The Chinese government doesn't just pour money into sectors left and right but allocates funds based on a clear set of rules. In all, 36 regional and big city councils can apply for generous financial support as long as they can prove their projects drive the sector forward. One requirement is that local authorities map out a hydrogen and fuel cell strategy that covers everything from suitable technologies and applications, e.g., in mass transit or transportation in general, to hydrogen production, storage and distribution.

The Chinese government knows as well as anyone that it will take years until we see fuel cell passenger cars come to market. Consequently, China has turned its attention to the commercial vehicle sector, intent on seeing 100,000 hydrogen-powered trucks, vans and buses hit the road by 2025 and as many as 1 million by 2030. That's an enormous potential Ballard and Chinese partner Weichai can start to tap this year and use to grow in 2022 and beyond. Chinese orders alone will keep Ballard-Weichai's joint venture busy for a long time to come.

My key takeaway from all this is that Ballard will have to spend a lot more cash to defend its position in the marketplace and post regular profits. The company has indicated 2020 revenue of USD 100 million to USD 120 million, a less than impressive amount considering the USD 800 million Ballard has in the bank. Investing in electrolysis will likewise open up new opportunities. This year, Ballard should be able to pull in orders of 100, 500, 1000 or more bus stacks, instead of 5, 10 or 20, increasing revenue and earnings. Based on the company's 40-40-20 strategy for the world market, a European stack factory is a done deal, I believe. A joint venture could soon be in the works as well. In short, there's no way around Ballard in the hydrogen and fuel cell industry. My price targets for 2021 and 2022 are respectively USD 30 and USD 50 (or more).

BLOOM ENERGY – WHAT A RALLY!

As third-quarter results faded in the rear-view mirror, Bloom Energy stock rebounded with a vengeance following a temporary slump. Natural disasters, including storms and floods, prevented the completion of 41 projects, pushing revenue below the anticipated USD 225 million to USD 200 million, And yet, the company's USD 12 million in the red means Bloom [NYSE: BE] performed much better than expected. The net loss was "only" USD 0.09 per share instead of USD 0.16 and including non-recurring revenues, that loss shrank to as little as USD 0.04 a share.

Bloom took advantage of the good mood to raise fresh capital via green convertible senior notes, aiming to redeem a portion of already issued high-interest bonds. This included a call on some senior secured notes, which were converted into shares, turning debt into equity. With Bloom paying a premium, it was a sweet deal for stockholders. Adding in restricted funds, the business now has USD 504 million in the bank. dramatically lowering interest costs. The increase in equity, on the other hand, will nicely prop up the company's balance sheet.

A while ago, Bloom presented new "skids" for improved energy box handling, making them easier to install, and announced plans for a USD 50 million to USD 75 million increase in production capacity. On Nov. 18, 2020, Bloom unveiled a new, more efficient electrolyzer. The company further stated its long-term intention to sell and produce greater hydrogen quantities, with annual revenues from this submarket expected to hit USD 750 million by 2025. According to some estimates, prices for either green or blue hydrogen will drop below USD 2 a kilogram in the next five to 10 years. Additionally, Bloom said the new electrolyzer equipment will make servers up to 50 percent more efficient.

My conclusion is that Bloom will benefit from the growing concerns over global warming. The company provides fuel cell plant technology to tackle the challenge. And the incoming US government will do its part to promote the sector, having already announced a USD 2 trillion climate plan. A boon, to be sure, though the firm's success doesn't depend on the plan passing. The company said there is large potential for growth in all corners of the globe. In my view, Bloom is one of the fuel cell industry's most underrated stocks. Sooner or later, shares could well reach USD 35 or more.

FUELCELL ENERGY – HIGH-FREQUENCY TRADING PROMPTS STOCK SURGE

FuelCell Energy's quarterly results weren't the reason for the year-end price surge from around USD 2 to over USD 11. At times, more than 200 million trades were concluded in one day, which exceeds the total shares outstanding. I believe we're witnessing the impact of high-frequency or day trades or swarm-like investor activity via, e.g., Robinhood. >>

Fig. 3: Row of GenDrive units [Image: Plug Power]

Right before the rally, Heights Capital Management reported the purchase of 19 million FuelCell shares, giving the private equity firm a 6.7 percent stake in the fuel cell business.

There are rumors that a competitor is interested in acquiring FuelCell [Nasdaq: FCEL]. Pure speculation at this point. The business's convertible preferred stock with a cumulative 5-percent dividend, highlighted in an earlier article, has meanwhile risen from USD 380 to more than USD 640. While traded infrequently and part of a narrow submarket, the shares should be gradually moving toward USD 1,000 and FuelCell needs to buy them back to lower the high cost associated with the offering – a 5-percent dividend adding up to USD 50 per USD 1,000 nominal value, assuming shares are traded at USD 580. Moreover, the preferred stock can be converted into common stock. FuelCell stated its intention to purchase some of that stock in a recent investor note in connection with J.P. Morgan's placement of 39.6 million shares for USD 6.50 apiece. FuelCell gets money for around 25 million of them, while 14.7 million were sold by existing stockholders. The last part doesn't look so good. Even though I can't be sure about investors' motives, it seems like some just wanted to make a quick buck.

Orion Energy Partners is now getting back money loaned to FuelCell. The private equity firm did well on options and warrants. But Orion was also the one providing FuelCell with funds when times were tough. Sadly, much of the cash from the capital raise will not remain with the manufacturer. Still, equity replacing debt is a good thing for balance sheet purposes.

PLUG POWER – SEIZE THE DAY

That was fast. First, Plug Power [Nasdaq: PLUG] raises around USD 840 million issuing new shares at USD 22.25 apiece. A felt five minutes later, the company is offered a USD 1 billion bought deal, perfectly exploiting the stock surge to collect massive capital. Plug must now have over USD 1.7 billion in the bank, thanks to the company's growth prospects targeting hydrogen.

Third-quarter results showed a non-GAAP loss of USD 0.04 a share, a nice surprise since a loss of USD 0.07 was expected. But GAAP showed a per-share loss of USD 0.11, whereas analysts expected minus USD 0.07 on average. The market founded the distinctly higher stock price on non-GAAP earnings, less indicative in my opinion.

Throughout the year, insiders sold USD 100 million worth of Plug stock. On Nov. 12, 2020, Plug's chief financial officer Keith Schmid reportedly divested USD 1.9 million worth of stock at USD 22.84 per share, just a few days before the above-mentioned capital raise. In my eyes, a first warning shot.

The warrants granted to Amazon and Walmart are interesting. Each corporation guarantees Plug USD 600 million to convert forklifts. These warrants are issued in exchange for USD 50 million in purchases. Amazon can exercise two tranches of warrants at USD 1.19 a pop, while the price for additional warrants is USD 2.55 apiece. At the end of 2020, Amazon had around 35 million warrants, with another 20 million to arrive in the coming years. Already unrealized gains over USD 700 million, according to a Seeking Alpha article.

The same goes for Walmart's 13 million warrants at a price of USD 2.12 per share, potentially. Another 42 million warrants will follow as long as purchases hit USD 50 million. My conclusion: Plug is drawing computably large orders. How high-margined they are is beyond my judgement. But should the warrants become shares, it's a decided stock dilution for existing shareholders.

So, what are the two corporations going to do? Will they secure profits through warrants, shorting stock? Amazon and Walmart orders reportedly make up 50 to 70 percent of Plug's total revenue.

We can call Plug's business model sustainable when it produces hydrogen via electrolysis, which is the company's clear intention. I believe once industrial-scale water-splitting is underway, hydrogen will be a lovely, consistent profit-maker. Still, I am leery of a USD 12 billion market cap. And it raises the question what Plug intends to do with its enormous cash cushion. Acquisitions? Let's cross that bridge when we come to it.

NIKOLA MOTORS – GM BOWS OUT

The hammer fell on Nov. 30, 2020. General Motors will not buy into Nikola. But according to the new memorandum of understanding, GM still wants to work with Nikola on battery and fuel cell technology. Consequently, the Badger pickup truck will not emerge from GM's assembly line as planned. And the originally projected USD 2 billion investment is also rendered moot. As a result, Nikola stock plummeted.

Betting on falling prices, investors sold over 50 million shares short. If the GM partnership had gone through, the massively shorted market would have made for a perfect squeeze, bringing USD 40 to USD 50, or more. For the nonce, short sellers can be pleased with themselves. Meanwhile, Nikola partners Bosch, Mahle and Iveco see no reason to abort cooperation, proof that the company's business angle is not just hot air.

We can assume Nikola [Nasdaq: NKLA] is now seeking another partner for the Badger. My speculations tend toward FiatChrysler due to its lack of electric cars on the road, allowing Tesla to provide regulatory credits. And with the stock price so low, investment banks can supply the USD 1 billion Nikola needs for its own plans – the perfect plunge. Especially considering today's intense interest in fuel cells on the trucking market.

PASSING REVIEW For Nikola Motors, 2020 was a year of high flying and crash landings. Fraud accusations leveled by a short seller hit the company hard, costing Nikola not only dream partner GM for Badger production but also a major contract for 2,500 battery-operated garbage trucks. The company founder left the enterprise announcing he hoped that would repair the damage. His departure, though, had the opposite effect, making it look like the short seller was right. Going from bad to worse, Nikola's strategic partner Bosch reduced holdings to below 5 percent, ditching 4 million shares on the stock exchange the very moment GM withdrew its bid.

It can't get any worse. The stock price slump is an appropriate response. Meanwhile, much of the stock, especially the founding shareholders', is up for grabs, with the PIPE lock-up agreement expiring on Dec. 21, 2020. What now? Is there light at the end of the tunnel? If you ask me, I'd say yes. I draw my optimism from a December article in the German Süddeutsche Zeitung newspaper. Titled "Auf Achse," the report claimed Nikola had the right software concept to put fuel cell commercial vehicles on the road – with battery and hybrid versions to boot.

The truck design was acquired. Another company seems to have simply copied it. Prototypes have already arrived in the United States, according to a spokesperson for Iveco, a CNH Industrial subsidiary that is working with Nikola out of Ulm, Germany. CNH owns around 6.7 percent of Nikola. At the same time, an e-truck factory is under construction in Arizona. There is said to be USD 900 million in the bank, >>

Fig. 4: ITM Power solar hydrogen station [Image: ITM Power]

but will it also be enough to refund Badger deposits? So much for the – basically negative – updates.

PHOENIX FROM THE ASHES? Now for the 2021 prospects: Investors have shorted over 50 million shares. When will they buy in again? They've made their profit through the massive price slump. What will they do when there's some good news? What if CNH decides to increase its Nikola holdings? CNH could also use the technology for agricultural equipment. And what if FiatChrysler catches the ball GM tossed away and produces the Badger?

Let there be no doubt, the future belongs to hydrogen-powered trucks. Many countries, as well as the state of California, have developed solid prerequisites to lower trucking carbon emissions in the coming years. Nikola has a promising strategy to generate the missing hydrogen infrastructure: To build its own fueling station network with partner Nel Asa. Certain oil corporations (seem to) want a piece of this pie. I can imagine a few gas companies as partners, too: Linde, Air Liquide or Air Products.

In short, 2021 could be the year Nikola and its stock make a comeback. To be sure, it will be a bumpy ride, so buckle up. Share volatility is here to stay – short sellers will see to that. There's also the multiple class action suits costing money, but they could just as easily be laid to rest. Furthermore, Tesla's intention to bring its own battery-powered truck to market in 2021 or 2022 ignites an exciting competition between battery and fuel cell approaches. Until just a few years ago, Tesla, too, was merely a business with a vision.

I'm with the trade analysts at J.P. Morgan, who announced in a memo on Dec. 28, 2020, that next year will "turn generally positive" for Nikola. Their new price target is USD 35 (down from USD 40).

A fitting stock market truism: Buy on bad news. Just when things are looking their worst, the tides of fortune change.

ITM POWER

Auto suppliers, transmission operators, gas manufacturers: Big corporations are shifting their positions toward the growing hydrogen market, buying into companies that possess key expertise and technology, such as electrolysis. Linde, and most recently, Italian grid operator Snam, invested in ITM Power, with Snam spending EUR 33 million on the stock acquisition. In total, ITM [London: ITM] intends to raise around EUR 165 million. A current market cap of over 2 billion is a good valuation for the company. Those betting on electrolyzers should take a closer look at Ballard and Bloom.

TESLA JOINS S&P 500

It may seem contradictory, since joining an important market index is a very good thing, requiring funds to adjust their holdings. In Tesla's case, I see at least USD 8 billion would have to be invested through them. I tend to doubt this will automatically lead to a massive increase in valuation. Index funds may already have positions based on a variety of investment vehicles, such as options that can be turned into shares without any relevant influence on the price. Perhaps out of pure contrariness, the stock could turn sour when things are looking their best because analysts, investors and the media see only rising prices, completely ignoring the risks.

There have been a slew of companies accepted into a major index and despite high expectations, their stock has fallen, not risen. It may well be that Tesla and its shareholder community's prayers have been answered, but that's not a guarantee shares will rise. Buy the rumor – sell the fact. Also, the amount

WIKIFOLIO BZVISION – PORTFOLIO JUMPS MORE THAN 400 PERCENT

Quick as a flash, FuelCell Energy went from around USD 2 to nearly USD 11 with an immense volume of over 200 million trades on some days. For a 50,000-share portfolio, the ideal basis for truly high price gains. When stocks were down, I gradually bought in, completely sold on the fuel cell story. Since such turbulence results in profit-taking, I had no doubts about divesting 30,000 shares in several tranches before parting from the last 20,000. Too early, in hindsight, but okay all the same.

I used the money to buy Bloom, Ballard and Nikola shares, plus "new" Tesla puts from Société Générale, at a strike price of USD 600 and a Dec. 17, 2021, expiry. FuelCell has excellent prospects, but the stock is getting too far ahead of itself for me. I'm expecting a consistent upward trend for Bloom and Ballard, the target for both being USD 30 this year. With extremely convincing business models designed for the medium-term, they promise massive company and, eventual, profit growth. My Nikola investment speculates on the firm's successful battery and fuel cell approach for commercial vehicles. GM is out of the game, so someone else can step in. With Tesla, I have until December 2021 to bank on declining prices, time enough. The position also serves as insurance in general should the US stock market shift into reverse. In that case, the pressure would be on shares with which many investors have amassed extraordinarily high profits that can be realized in a bearish phase. It's quite possible that declining fuel cell stock will be more than compensated by a rise in put options. Exercising the options will then provide fresh capital for purchasing fuel cell shares – just in case. This strategy paid off in early 2020, and I see quite a bit of evidence that this year could do the same. You'll find my BZVision portfolio at wikifolio.com.

of short interest, 45 million shares, is downright ludicrous, a mere 6.2 percent of the free float. And it's even less when you calculate Tesla's total stock, including CEO Elon Musk's, coming to well over 1 billion shares, after the five-for-one split.

Fans had hoped Tesla's entry into the index would trigger a short squeeze, pressing short sellers into covering their positions, causing a price surge. However, shares are already at an all-time high of around USD 650, bringing Tesla's market cap to over USD 580 billion. Where will it end? Shouldn't Tesla first deliver convincing financials, i.e., sustainable high profits?

ANALYSTS AT ODDS While Goldman Sachs set a new USD 780 target price, analysts are arguing about where the stock will go after witnessing the 2020 hike from around USD 300 to USD 3,800 (non-adjusted for the stock split). With a share price in the neighborhood of USD 460, several people thought of as insiders started selling stock. Tesla's chief financial officer gave up 1,250 of 19,000 shares, some directors sold between 1,000 and 5,000 – one even 155,000. You could argue these are negligible amounts, but the number of leading employees cashing in are not. As far as I know, there are no inside buyers. Meanwhile, J.P. Morgan analyst Ryan Brinkman raised his target price from USD 80 to USD 90, saying "Tesla's valuation is difficult to conceive in any imagined scenario."

With a profit of USD 0.76 instead of USD 0.60 a share, third-quarter non-GAAP results were better than predicted. The more conservative GAAP figures looked altogether different. Analysts forecast USD 0.50 earnings per share, but the actual EPS came to USD 0.27. Revenue was USD 8.8 billion, about USD 500 million higher than projected. Cash and cash equivalents improved to more than USD 14 billion due to a USD 5 billion capital raise. What may look like a healthy cushion is not all that fat considering investment plans of over USD 10 billion, plus the multi-billions in debts and obligations.

Net income was USD 331 million, thanks to USD 397 million in regulatory credit sales. In the last three quarters, the credits allowed Tesla to post revenues to the tune of USD 1.2 billion. Windfalls, you could say, that have little to do with business operations.

Some analysts see the stock rising further. Others, like Citibank and J.P. Morgan, are rather at USD 120 and USD 90. I hover in the middle at USD 250 to USD 350 when it comes to my expectations of 2021. Which is good for fuel cells and hydrogen, although Tesla and the analysts, too, are ignoring that. Let Tesla build the world's largest battery factory in Grünheide, supported with EUR 3 billion to EUR 5 billion in government funds, including the European Union's share, and let Elon Musk announce he could very well imagine working with an established automaker. I allow myself to be skeptical. Meanwhile, Tesla [Nasdaq: TSLA] seized the day once more, as an ATM program is expected to generate another USD 5 billion for the electric car manufacturer, the second USD 5 billion within just a few weeks. Wonderfully euphoric. But things could get grim when Tesla disappoints. I've been expecting that for some time. ||

Fig. 5: Tesla joins the S&P 500 [Image: finanzen.net]

RISK WARNING

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

Category: Market | **Author:** Sven Geitmann

THE BIGGER PICTURE BRINGS GREATER JUSTICE

Future accounting calculates sustainability

Money makes the world go round. Companies seek to maximize profits, countries their GDPs. In both cases, we are dealing with figures in dollars, euros or some other currency. But what about values or services without a price tag? Such as employee health. The advice and expertise of colleagues freshly retired. What is the long-term cost of cutting down a forest? How expensive is sustainable (or industrial) farming? So far, most accounting revolves solely around financial issues. Social or environmental aspects are rarely mentioned, unless a company publishes a separate sustainability report. As a result, many conventional technologies are still considered economically viable simply because their long-term impact is ignored. Gray hydrogen is a prime example. Produced from natural gas, it is much cheaper than hydrogen from clean energy sources. Yet, the latter option is far more sustainable. A new, holistic approach to accounting could balance out the difference.

According to the IMF website, a "GDP measures the monetary value of final goods and services – that is, those that are bought by the final user – produced in a country in a given period of time." The OECD describes it as an "aggregate measure of production equal to the sum of the gross values added of all resident institutional units engaged in production (plus any taxes, and minus subsidies, on products not included in the value of their outputs)."

In short, monetary values tell you what people are worth and how much they contribute to society. We live in a meritocracy, opting into its downsides.

Long before Covid-19 engulfed the world, people have been debating about the rightness of the policy instruments we use to remunerate a given person's true contribution. Following the Fall of the Berlin Wall, discussions zeroed in on what numbers to assign GDR citizens' lifetime achievements so the government could allocate the correct amount of retirement funds. Since then, similar issues have arisen regarding housewives' contributions as well as those of people caring for the elderly.

Many parents know first-hand just how exhausting childcare can be – not that they get paid for it. Overall, it is not easy, and sometimes even impossible, to assign monetary values to people's work.

A REVOLUTION DAWNS IN FARMING AND ENERGY PRODUCTION A German group of companies called Regionalwert recently devised a method with the potential to revolutionize accounting in the agricultural industry and possibly the energy sector as well. With the help of software giant SAP, the idea conceived by Christian Hiß is now moving from initial regional experiments to the mainstream. An imminent breakthrough could have far-reaching implications, especially for the energy industry, as Regionalwert's sustainability assessment could uncover the "real" value of green hydrogen.

Many moons ago, Hiß, a gardener by trade, began his quest to determine agricultural work's factual contribution to society. He believes farmers have accumulated a wealth of knowledge, sometimes at great personal cost, that has never been recorded on a balance sheet.

Fig. 1: Christian Hiß: "They key is to change the way we account for profits and losses."

SOCIAL AND ENVIRONMENTAL IMPACT ASSESSMENTS It's been more than 15 years since Hiß hit on his idea while filing his taxes. He realized any bookkeeping method tallying nothing but euros will fail to given an accurate account of all contributions made that year. He began to design a multi-stage approach including important sustainable farming parameters, such as soil fertility, farming expertise and employee satisfaction.

Using the method first captures all social, environmental and human business contributions and rates them accordingly. This data is then interpreted prior to assigning monetary values to each item. The result can be likened to a sustainability index, or, more precisely, a sustainable value balance sheet. Hiß himself calls it a "radically" new approach to accounting.

> "Standard accounting has no columns for vital assets such as soil fertility, biodiversity and expert knowledge. They have no monetary value on a company's balance sheet. We believe this is a fatal flaw in the system, a source of great social inequality, environmental harm and risk."
>
> *Excerpt from Regionalwert's company pages*

Hiß envisions a balance sheet with social and environmental contributions as fixed assets. This also means a company's liabilities would include, for example, money reserved for meeting sustainability targets. One example he gave was: "If you use hybrids in farming, that's a business risk."

His aim is to have financial statements reveal the enormous investment required to uphold sustainability. So far, accounting departments do not generally specify these invest-

ments, balance sheets recording them as liabilities, despite their environmental and societal benefits that also support a resilient, regional supply chain.

DO ALL OF THE MATH Between June 2018 and November 2019, Regionalwert Freiburg staff teamed up with Agronauten association members for a project called "Farm the Math" ("Richtig Rechnen in der Landwirtschaft") to generate a blueprint for new accounting principles. The project's results are the basis for Regionalwert's sustainability assessment, what the authors call the "first market-ready accounting tool providing data to list and rate social, environmental and local economic contributions in agricultural businesses."

The method may take some getting used to, but it allows companies to finally factor in non-quantitative parameters. Regionalwert staff members have analyzed over 170 social, environmental and local economy performance indicators, including sowing open-pollinated seeds and wildflower strips, the nitrogen balance and carbon sequestration, the percentage of apprentices and staff turnover, fair wages, social engagement and regional added value. A cleverly designed and comparatively well-structured online platform then displays all these factors on screen, as well as the company's sustainability rating.

QUARTAVISTA INNOVATION PROJECT Regionalwert also conducts a support project, "QuartaVista – A roadmap for value-oriented businesses," funded by the German labor ministry. Launched in November 2018 and scheduled to run until February 2021, the endeavor has evolved into a collaborative effort between four researchers, several Regionalwert staffers and multiple partner organizations. Together, they are mapping out a new rating system. Jenny Lay-Kumar, who leads Regionalwert Freiburg's research department, noted: "The QuartaVista project demonstrates how our innovative methods for measuring sustainable farming success can be applied to many sectors. This will be significant to both businesses and policymakers."

Project member Johanna Saxler explained that the name QuartaVista refers to the four factors upon which success in future businesses will hinge – environment, knowledge, social justice and finances. She said: "We are specifically looking at the risks incurred by non-sustainable operations." Balance sheets will reflect both objectively verifiable indicators, i.e., the United Nations' sustainability goals, and subjective criteria, including expert knowledge and societal consensus.

QuartaVista also aims to set up a fund to compensate partner businesses' social and environmental achievements. In the long run, a larger fund could support companies in the energy industry and other sectors.

BANKING AND CONSULTING SOFTWARE After years of in-house development, designing and testing, the Freiburg-based company released an online tool to its member companies in July 2020. The Regionalwert Sustainability Assessment targets banks and agricultural advisors, the ones weighing and rating credit risks, which means they dig into an applicant's sustainability claims. Therefore, Hiß was not surprised to hear Germany's financial regulator BaFin is moving in this direction.

Hiß, Eichstetten's Regionalwert founder, explained: "For several months now, we've been observing a shift away from reporting on sustainability toward accounting for sustainability. In December 2019, BaFin published a note on how to handle sustainability risks, stating that such risks must be reflected on a bank's balance sheet if they stem from business operations. This means financial institutions will need to develop new methods and tools. This is where our Farm the Math and QuartaVista projects come in. They provide organizations with a knowledge base on which they can build their own solutions."

ECB BOSS LAGARDE SPOTLIGHTS GREEN BONDS Hiß is confident his approach will make the leap from the banking sector to other industries. During a United Nations event in October 2020, ECB President Christine Lagarde wondered if her >>

REGIONALWERT FREIBURG

Even before Germany's renewable energy law EEG took effect, community wind farms were already a market staple. They prove the feasibility of large energy generation projects when a good number of local residents support them financially, sharing costs and risks. Community stock companies follow a similar approach and can be found in a wide variety of areas including agriculture, brewing and real estate, to name a few.

Founded in 2006, Regionalwert Freiburg is one such community-owned business. It aims for sustainable and reasonable economic activity in the farming and food industries. Even though this ownership model carries a risk of total investment loss, many people lined up to support the company, some investing as high as six figures.

Eichstetten am Kaiserstuhl, Freiburg county, Germany, was the first to try out the new concept. Local partner businesses can boast of a very committed, highly motivated staff full of ideas – which is not surprising, as they know they are working for a good cause. In the past several years, similar initiatives have sprung up in Munich, Hamburg, Berlin, and in the Rhineland and Brandenburg regions. The idea even made it to Austria's capital Vienna, whose social enterprises are not directly related to those in Germany. The Austrians simply licensed the name and the concept. Five more community stock companies are currently in the works. One such community in the German Münsterland region submitted an application for European Union funding. Other regions will follow soon.

In August 2020, Regionalwert Impuls, formerly Regionalwert Treuhand, became the parent company to all German Regionalwert organizations, working from an office in Bonn to bring the regional initiatives closer together. The Impuls advisory council is made up of subsidiary board members and is led by Hiß. Stefan Gothe leads the parent company.

As opposed to cooperatives that collect money for their members, social enterprises – shareholder-owned, citizen-funded – primarily raise cash for business operations and individual projects. Still, they can pay prettily eventually. And while cooperatives follow the rule of one person, one vote, social enterprise shareholders receive a number of votes based on their stake in the company.

Regionalwert said that a distinct German community stock company advantage is that ownership cannot be terminated. In extreme cases, when several people withdraw from a cooperative simultaneously, the organization is forced to sell shares to partner organizations. This simply can't happen with the Regionalwert approach, thereby forming a long-lasting business network of value-creating partner companies that can rely on steady, long-term equity.

Fig. 2: Ulrich Martin Drescher, Regionalwert Freiburg chairman

bank should purchase more green bonds in light of the market's "failure" to address environmental concerns. She went on to say financial markets are not always reliable when it comes to determining and pricing risks without supervision. If we left it up to them to put a price on climate change, she added, we may well regret the decision.

Hiß emphasized that Regionalwert pioneered social and environmental ratings. On Dec. 1, 2020, he presented a new tool, the Regionalwert Performance Calculator, available for EUR 500.

SAP COOPERATION Born in Southern Germany, Hiß is very proud that his small, regional initiative has the opportunity to work with software giant SAP, headquartered in the state of Baden-Württemberg. As a globally operating IT corporation developing multifarious business software, SAP has shown interest in integrating the Regionalwert method into its accounting modules. A commercial about Regionalwert was produced, and in early 2020 SAP caused a buzz by spotlighting QuartaVista at the World Economic Forum in Davos.

Hiß, however, is already thinking ahead. As the European Green Deal includes installing Europe-wide accounting rules, Hiß imagines Regionalwert's SAP partnership prompting EU leaders to make his approach part of their deliberations. "Experts say our approach is the most future-viable," he said.

Now, SAP is fully committed to promoting Hiß' sustainability method. As Reiner Bildmayer, SAP director of the QuartaVista innovation project, told the German Liberal magazine: "We rely on approximately 500 parameters developed by our partner Regionalwert Freiburg. With their expertise, we can offer ratings recommendations for just about anything, down to a chicken's health in relation to the land area it roams." Asked whether he can assure businesses the method will pay off: "Yes, it will. And QuartaVista accounting will also improve your standing in the community. Verified sustainable entrepreneurship not only appeals to customers; it also improves your access to funding, since sustainability is an increasingly significant factor in bank loans. BaFin, too, seems to think it is an important topic."

ZEIT MAGAZINE AWARD Further recognition for Hiß and Regionalwert's positive impact came later in September 2020 when they were presented with the "Be bold, be sustainable" award by the German ZEIT Wissen magazine. The award honored their deep commitment to the cause and their role model status in society. Hiß said: "I am overjoyed by this. […] It gives us the support we need to open people's eyes to a new form of sustainable, regional production."

Jörgen Beckmann, chairman of Die Agronauten, added: "We urgently need a future-proof economic concept for more than just farming and food processing. As a basic form of economic production, farming can teach us how to conserve natural resources and secure our existence for coming generations. Christian Hiß recognized this long ago and made the first move."

ACCOUNTING EFFICIENCY Although the approach was initially tailored for the agricultural sector, Regionalwert Freiburg's idea is, by far, not exclusive. Sustainability ratings could also be used to assess the value of energy generation or energy system efficiency.

As mentioned at the beginning of this article, today's balance sheets are based on purely monetary factors, disenfranchising new and advanced technologies that require a greater funding upfront. But it would pay off to take a more holistic view and consider a technology's mid and long-term benefits to humankind and the environment. Even today, there are numerous studies indicating that a radical switch to carbon-free energy generation will be much more expensive than a gradual exit from fossil fuel production.

Current balance sheets of gray and green hydrogen production reveal little about which resource has a real future. All the same, some managers and politicians compare the two costs as a basis for long-term decisions. And yet, we already know that investing in gray hydrogen is as dubious as installing an oil heating system just because it's cheap.

There are similar issues with efficiency calculations that simply divide output by input. Essentially, they only account for energy content. However, like financial reports, where some things cannot be measured in euros or dollars, not all thermodynamic values have a kilowatt-hour symbol next to them. Using the new accounting principles, efficiency and energy production calculations would also reveal key performance indicators such as resource consumption, pollution and waste disposal requirements.

Regionalwert Freiburg said it is seeking to develop an integrated approach, even though the company is currently focused on the agricultural sector. When H2-international asked Hiß about Regionalwert's plans for entering the energy market, Hiß conceded outright: "We don't have any yet. We simply lack the resources." But he is looking for partners to join Regionalwert's business network.

FARMERS ALSO PRODUCE ENERGY Sustainable agriculture and clean energy production often go hand in hand these days as, in the changing nature of agricultural practices, farmers are (inevitably) becoming energy producers. Many agricultural businesses are already taking care of their energy needs. Just look at the PV systems on countless barns. But we are still a far cry from fully renewable heat and transportation.

Obviously, though, energy production on farms must become even more sustainable. Meeting the Paris Agreement goals necessitates changes in how we provide farmers with energy while keeping them in operation. Farms need partners to help them make the switch to solely renewable sources. And government, research and business leaders should throw their full support behind accessing that untapped potential. ||

"In the last years, loosely knit accounting principles have created gaping holes now stuffed with economic inefficiencies."

Christian Hiß, Regionalwert Freiburg

"Inextricably linking a company's financial statements with the United Nations' Sustainable Development Goals is the key to this century's economic activity. Christian Hiß and Regionalwert Freiburg's Farm the Math project provide the foundation for this endeavor. What is successful in farming must also be possible in other industries."

Professor Ernst Ulrich von Weizsäcker

Category: World | **Author:** Girana Anuman-Rajadhon

THE COST OF CLEAN HYDROGEN-GENERATED ELECTRICITY...

... and the challenge of going mainstream

This article will review the cost of clean, hydrogen-generated electricity based on the levelized cost of energy, grid parity, baseload, and intermediate and peak load. The question to answer is, what power prices can consumers and industrial customers expect at the point of use?

The LCOE specifies the per-unit cost of electricity over an energy-generating asset's lifetime. The LCOE is calculated dividing the total energy generated by the asset's net present value, which includes the initial investment, operation and maintenance costs, fuel prices and the cost of capital.

In 2020, the LCOE of utility-scale solar was already lower than that of brown coal in Germany (see fig.1).

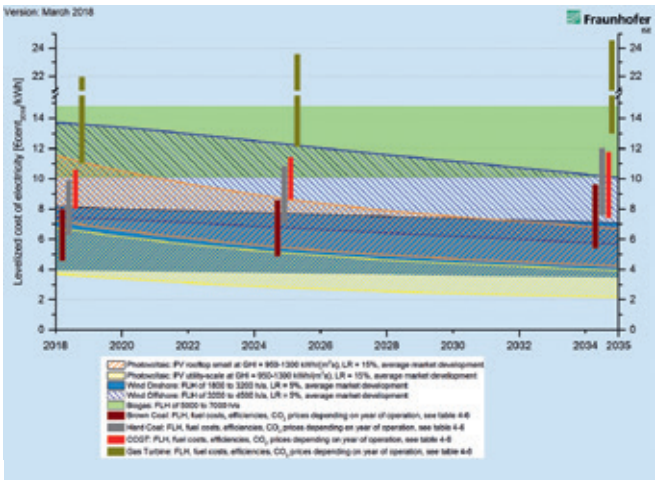

Fig. 1: Learning curve-based LCOE estimates for renewable and conventional power plants in Germany by 2035, taken from Fraunhofer ISE's March 2018 study "Levelized Electricity Cost – Renewable Energy Technologies."

The levelized cost shows the point where average revenues allow a project to break even. Often, the LCOE is calculated by a given plant's operating term, which usually is 20 to 24 years.

Grid parity, or socket parity, is when an alternative energy source generates electricity at an LCOE less than or equal to the price of grid power. The term is most commonly used when discussing renewables, notably solar and wind. The results depend on whether one is calculating from the utility's or the consumer's perspective. Grid parity is one of the most misused concepts in clean energy debates since, due to varying wind speeds, sunshine hours and available baseloads, the same technology can give highly diverse results.

Wholesale prices are paid to electricity producers. Retail prices charged to end customers reflect the full cost of delivering power 24/7. Note, however, that generation, the largest expenditure, accounts for only 44 percent of the total cost. [1]

ABOUT LOADS Even if solar breaks even with fossil fuel and nuclear sources, grid parity is just one factor in clean energy making a meaningful contribution to the grid. Many conventional energy sources are also used to provide a steady supply of electricity, but baseload plants cannot raise or lower output efficiently. Intermediate power plants, however, like natural gas combined cycle stations, can. And peak-load systems can be started up and shut down quickly to meet demand when it is highest.

Mark Febrizio, a policy analyst at the GW Regulatory Studies Center, draws this conclusion: "Grid parity sounds nice, but it does not mean that solar will play a large role in electricity generation. For the electricity grid, it is far more important to have on-demand power day and night than cheap power in the middle of the day. Sources of energy that can produce electricity independent of the weather or time of day are crucial to keeping the lights on." A very true statement. As we all know, this is the challenge, or barrier, that clean energy will face before it can go mainstream, regardless of how cheap solar and wind power has and will become.

Solar and wind will not replace conventional sources around the clock unless energy can be stored and distributed when needed. One solution to this problem is electrolysis, the use of water-splitting, and green hydrogen produced from renewable electricity, to store vast amounts of clean energy that can be tapped at any time.

CLEAN HYDROGEN-GENERATED ELECTRICITY The following is a description of a factual green hydrogen electricity system installed at a conference center in Thailand and used primarily midweek. Project calculations reflected total costs of the solar roof, electrolyzer, fuel cells and tanks used to generate electricity from hydrogen. The installation runs independent of the grid, receiving its power from the 35.1-kilowatt PV roof.

The first step involved measuring or estimating the center's load profile to obtain a detailed daily demand curve that accounted for seasonal weather variations and daily PV production. Subsequent calculations showed the energy needed for fuel cells to ensure a continuous supply of electricity, including four days' worth of backup energy in the case of heavy rainfall during the day.

The roof was designed to produce a power surplus around noon. The electrolyzer used the surplus from Saturday to Tuesday to produce clean hydrogen that was then stored in tanks. Midweek, when demand exceeded the available PV output, the fuel cells retrieved hydrogen from the tanks to generate electricity. While supercapacitors were used to respond to rapid changes in demand, the fuel cells provided power for longer periods. Although today, fuel cells can be started up in seconds, supercapacitors for evening out short spikes are still less expensive.

The PV component proved sufficient to supply the conference center's annual average baseload power, as electricity was not required at night but mainly afternoons from Wednesday to Friday. The backup unit – several hydrogen tanks >>

storing up to four days' worth of energy – only jumped in if the sun did not shine and the installation could not generate enough electricity.

PROJECT DETAILS [Source: Enapter]

PV Energy	
Installed Available PV Power [kW_p]	35.1
Average Daily Available PV Energy [kWh]	122.1
Load Energy	
Average Daily Energy Consumption [kWh]	63.0
Low Daily Energy Consumption (Weekend) [kWh]	10.8
High Daily Energy Consumption (3 x per week) [kWh]	124.5
Energy Storage System (High Energy Autonomy)	
Enapter AEM Electrolyser Size [kW]	12.5
Fuel Cell Size [kW]	10
Size of Tank [m^3]	5.5
Equivalent energy storage of the H2 tank [kWh]	252
Autonomy in days assuming average load	4
Size of Supercap [kWh]	10

The solar-hydrogen electricity system comprised an electrolyzer, a dryer, a water treatment unit, fuel cells, hydrogen tanks, supercapacitors and auxiliary components. The values specifying minimum and optimum system performance were electrolyzer and fuel cell output, tank storage capacity and the number of days the installation could run on backup energy.

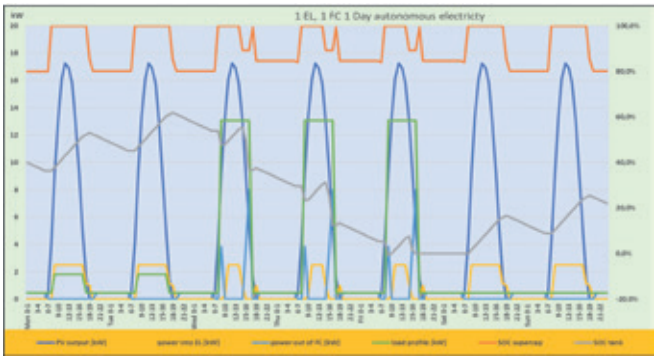

Fig. 2: Solar-hydrogen system providing a day's worth of backup electricity [Source: Enapter]

The average weekly demand and electricity profiles illustrated in figure 2 indicate the solar-hydrogen system would provide just enough power for the center, with output declining sharply on Fridays (see gray line). This means, following two sun-less days, not unusual during the rainy season, the system would no longer fully meet demand. Thus, design improvements were made to prevent unforeseen weather events from affecting performance.

The optimized solar-hydrogen system comprised five electrolyzers, four fuel cells and a sufficient number of tanks to provide four days' worth of backup electricity. The average weekly load as depicted below shows the new system provides the center with sufficient and consistent electricity.

COST OF SOLAR-SOURCED HYDROGEN As a next step, the cost of an optimal solar-hydrogen electricity system in 2020 was calculated. After many discussions with producers, these calculations were based on a 2026 cost-cutting scenario in-

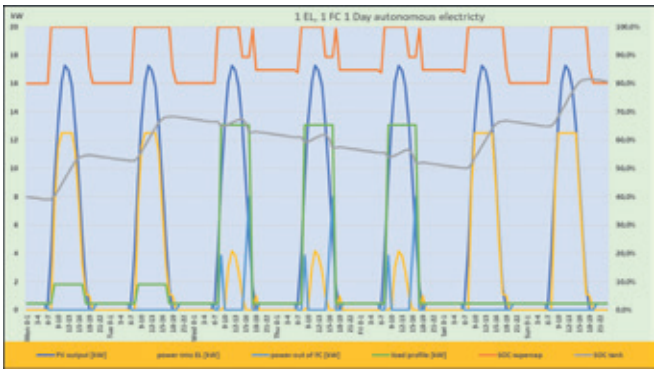

Fig. 3: A solar-hydrogen system providing four days' worth of backup electricity [Source: Enapter]

volving Enapter's Model T and the assumption that fuel cells and tanks will see a 50 percent reduction in price, while other costs will drop by 30 percent.

Project budget (EUR)	2020	2026
System	5EL,4FC, 4 days	5EL,4FC, 4 days
Electrolyser Equipment Cost	66,700	29,300
Fuel Cell Equipment Cost	44,500	23,000
H_2 Storage Equipment Cost	25,000	12,500
Supercap Equipment Cost	22,500	11,250
Auxilliary Parts and Components	9,000	4,500
Equipment Cost EXW Subtotal	**167,700**	**80,550**
Complete Solar Hydrogen System		
Solar Hydrogen kWh production	63	63
Enapter System lifetime in hrs	30,000	40,000
Daily Hydrogen usage in hrs	4	4
System usage in years	21	27
EL OPEX in kg	2.80	2.75
Total kWh production	472,596	630,129
Euro/kWh	**0.355**	**0.101**

Table 2: Average per-day costs of a 63-kilowatt-hour solar-hydrogen electricity system based on the achievable optimum of four days' worth of backup energy

Enapter provided the electrolyzer cost estimate, figuring in an additional 30,000 to 40,000 hours for its T unit. The device is scheduled to come to market around 2025. Factors not included in the calculation were PV roof cost and hydrogen system installation, plus the electrolyzer's low OPEX.

Considering the electrolyzer and fuel cell markets are still in their early stages and prices will drop as efficiency and economies of scale rise, we could see a substantial decrease in system costs, from EUR 0.36 per kWh in 2020 to EUR 0.10 per kWh, or lower, by 2026.

The above project is a good example of how to provide power for office facilities, as there is little demand for electricity at night. On the other hand, a residential system needs consistent fuel cell-generated electricity over a longer period of time, which would increase project costs to around EUR 0.12 per kWh.

LCOE BY 2026 So, let's compare retail LCOEs of different electricity generation systems: Brown coal plants generate power for as low as EUR 0.05 per kWh. Utility-scale PV is even cheaper, adding up to EUR 0.03 per kWh. In contrast, a solar-hydrogen system comes to EUR 0.10 per kWh. But compared to hard coal-fired power stations' EUR 0.07 to EUR 0.11 per kWh, CCGT plants' EUR 0.09 to EUR 0.12 and gas turbines' EUR 0.12 to EUR 0.22, solar-sourced hydrogen electricity seems to be on its way to being cost-competitive by 2026.

This quick summary demonstrates the difficulties in calculating LCOEs for solar-hydrogen electricity systems. Each project design must incorporate detailed load profiles and backups. The LCOE of one and the same solar-hydrogen project could be between EUR 0.08 and EUR 0.11 per kWh, depending on the number of days the system is expected to run on backup energy. In other words, tying together intelligent demand side management, peak solar or wind output and a computerized unit integrating all energy management components could help create smaller, much more affordable solar-hydrogen devices, sparking the interest of residential real estate or microgrid owners.

CONCLUSION Is there a solar-hydrogen electricity system cost-effective enough to replace conventional baseload or intermediate power plants? Absolutely! Hydrogen is well-suited to smooth out solar and wind volatility. Although one could argue that hydrogen-generated electricity is twice as expensive as brown coal, it is still cheaper than every other conventional power source. Plus, the technology is already a viable option for off-grid installations and microgrids in remote areas.

One barrier to implementation is the substantial upfront investment and a lack of bank financing. We are now at the same crossroads we were with solar power plants 15 or 20 years ago. However, there are hopeful signs that solar-sourced hydrogen electricity systems will very soon be incorporated into typical solar and wind projects (i.e., in 2021).

Last, but decisively not least, LCOE calculations completely ignore the benefits of improved air quality and a healthy environment. If we included those, solar-hydrogen and all other kinds of renewable energy systems would be mandatory by now and a mainstay of electricity markets worldwide. ||

Girana Anuman-Rajadhon is an investor in Enapter and presented her calculations at the company's financial workshop in October 2019 in Bangkok (see H2-international, February 2020).

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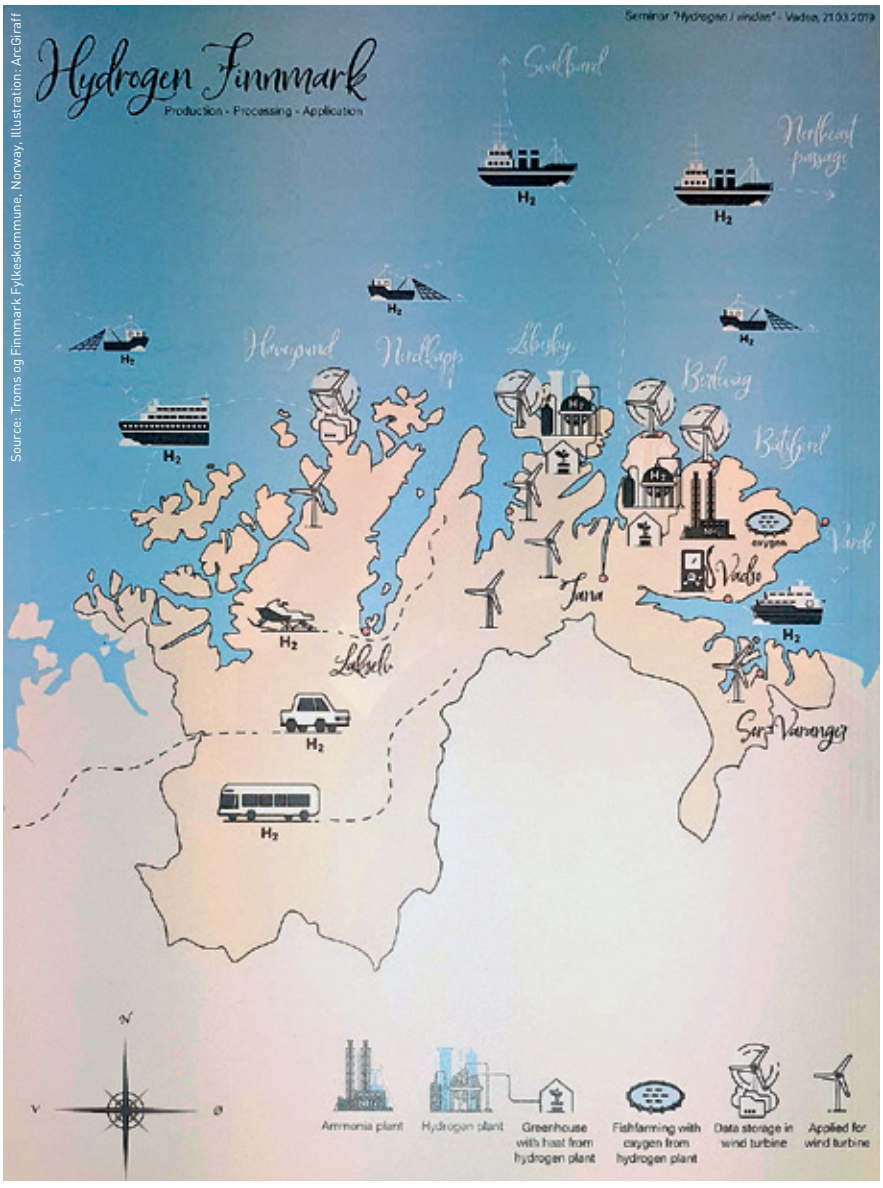
TOWARD 'HYDROGENEWABLES' IN NORWAY

H_2 projects in Norway, the Netherlands, Portugal and France

In June 2020, the German government adopted a national hydrogen strategy, spelling out clear ambitions, concrete targets and a solid plan of action for the next 20 years, including an increase in production capacity to 5 gigawatts by 2030 and 10 gigawatts by 2040. Overall, the country will invest EUR 9 billion in new business and R&D ventures. By 2050, hydrogen produced in Germany could cost less than EUR 1 per kilogram.

Other countries in Europe and worldwide have since followed suit. Portugal approved its own national strategy, aiming to pour EUR 7 billion into the sector by 2030. In the Netherlands, discussions have centered on converting the Magnum power plant into a 1.2-gigawatt H_2 production facility. And two Dutch provinces, Groningen and Drenthe, announced a EUR 2.8 billion plan to set up a Hydrogen Valley in the north of the country. Worldwide, many countries have either announced their hydrogen strategies or are preparing them. For example, very recently, Canada has announced its hydrogen strategy, together with Hydro-Québec announcing plans to construct a 90 megawatt-electrolyzer facility to supply green hydrogen (11,100 metric tonnes) and (88,000 metric tonnes) oxygen annually to the Recyclage Carbone Varennes plant project in Québec.



Meanwhile, as part of REFHYNE, ITM Power will construct the world's biggest electrolyzer at Germany's largest refinery, Shell Rheinland Raffinerie in Wesseling. Once complete, the 10-megawatt PEM system is expected to produce around 1,300 tons of green hydrogen a year. The project will allow stakeholders to perform key economic, technical and environmental impact assessments, craft new business models, analyze the technology's implications for policy, and make project findings available throughout the EU.

In France, Siemens and Engie will build a EUR 15 million power-to-X-to-power facility that will use clean grid energy and electrolysis to produce and store hydrogen gas. Another project called HyAMMED, or "Hydrogène à Aix-Marseille pour une Mobilité Écologique et Durable," will see Air Liquide construct Europe's first 700-bar fueling station for long-haul trucking. After coming online, the station will reportedly produce 1,000 kilograms of hydrogen and allow for 20 fill-ups in 24 hours.

EUROPEAN GREEN DEAL Truly, July 8, 2020, was a day for the history books. Not only did the European Union launch "a hydrogen strategy for a climate-neutral Europe" as part of its Green Deal but also announced two other important initiatives – the Energy System Integration plan and the European Clean Hydrogen Alliance, or E2CH2A. The overall goal is to establish a European hydrogen economy and to make the euro the currency of choice on the global market. The industry-led E2CH2A will promote investments in hydrogen production and application, help get large projects off the ground and speed up decision-making, as well as address challenges and barriers to innovation [2].

All three initiatives offer a unique opportunity for using wind- and PV-sourced renewable hydrogen (RH_2) to supply fuel and chemical feedstock throughout Europe and to store energy in salt caverns. Clean hydrogen production capacity is projected to grow to 1

million tons by 2024 and 10 million by 2030, that is, 6 and 40 gigawatts by 2024 and 2030, respectively. Adding in 40 gigawatts produced in neighboring countries, 2030 capacity will reduce CO_2 emissions by 100 million tons.

The total cost of kick-starting a European hydrogen economy is estimated at EUR 430 billion, with initial EU investments coming to EUR 96 billion. The money will go toward electrolyzers (13 percent), offshore (47 percent) and onshore wind (25 percent) and solar PV (15 percent). The aim is to produce 4.4 million tons of RH_2 in the EU. An additional EUR 91.5 billion will be spent producing 4 million tons in Ukraine and North Africa.

A European electrolyzer industry will create an estimated 170,000 jobs. As for hydrogen infrastructure, EUR 120 billion will need to be invested in the EU and North Africa to supply RH_2 for fuel and materials production, e.g., for making kerosene and steel, and to fund hydrogen manufacture in the transportation, heat and power markets [2]. Moreover, natural gas pipelines and storage systems are expected to serve an important electricity interconnector function across Europe, while hydrogen could provide more grid flexibility.

The European Commission's strategy for rapid market growth involves three stages [2]:

- Stage 1 (2020 to 2024): Produce 1 million metric tons of RH_2 and kick-start electricity generation.
- Stage 2 (2025 to 2030): Increase energy production capacity, produce 10 million tons, and decarbonize most of Europe's energy markets and industry.
- Stage 3 (2030 to 2050): Modernize and transform hard-to-abate sectors, e.g., shipping and aviation.

Overall, an EU-wide market for hydrogen promises significant value-adds within a multi-billion-euro high-tech environment. Hydrogen production, storage and distribution will drive innovation, growth, jobs, trade and transportation throughout the European Union. The technology's competitiveness will hinge on the swift delivery of new, innovative and sustainable solutions promising efficient, on-demand power. These solutions will be vital to meeting societal demand for reliable, clean and efficient energy generation and smart, green and integrated networks. By 2050, a continent-wide hydrogen market could generate EUR 820 billion in revenues, provide 5.4 million jobs, and avoid 560 million tons of CO_2 a year. Supporting innovative production techniques is thus crucial to facilitating the establishment of a hydrogen economy.

WIND ENERGY AND HYDROGEN IN NORWAY Norway is the world's third-largest natural gas exporter. It meets around 25 percent of EU demand, i.e., 1,200 terawatt-hours annually, via pipelines to Germany, Belgium, the UK and France. Nearly all oil and gas produced on the Norwegian continental shelf is exported. Valued at over EUR 50 billion, oil and gas supplies generate half of Norway's export revenues each year [3,4].

Furthermore, virtually all electricity used across the country (98 percent) is generated from renewables, hydropower being the most potent source with a yearly generation potential of over 200 terawatt-hours, followed by wind and thermal power. Today's green electricity production comes to 130 terawatt-hours annually. Norway is part of what is known as the Nordic electricity market, which also includes Sweden, Finland and Denmark. This market is integrated into the European power sector via interconnectors to the Baltic countries, Germany, the Netherlands, Poland and Russia. Two new interconnectors to Germany and the UK are scheduled for completion this year.

Small island communities in Norway are now contemplating whether to become energy independent via wind-sourced hydrogen gas. In 2004, an off-grid wind-hydrogen demonstrator was started up on Utsira island. At the time, it was the world's first system producing two to three days' worth of off-grid power, used by 10 households on the island [5].

There is also REMOTE, or "Remote area Energy supply with Multiple Options for integrated hydrogen-based Technologies," a 4-year project conducted under the auspices of the EU Horizon 2020 program. Its aim is to demonstrate the technical and economic feasibility of two fuel cell-based hydrogen storage solutions with the help of four systems put up in Ginostra and Ambornetti, Italy, in Agkistro, Greece, and on Froan Island, Norway. Regarding hydrogen safety, a project called SH2IFT is investigating potential barriers to introducing hydrogen to various sectors due to a lack of harmonized regulations, codes and standards, considered a major hurdle to commercializing hydrogen and fuel cell technology.

Theoretically, Norway's wind energy potential is huge, amounting to around 1,000 terawatt-hours a year onshore and 14,000 terawatt-hours offshore. The country is spending more than EUR 1 billion on wind farms and constructed a EUR 1.1 billion wind energy system, Europe's largest, between 2016 and 2020. This centrally located 1-gigawatt installation, owned by Statkraft, TrønderEnergi and Nordic Wind Power, consists of six interconnected wind farms reportedly generating 3.4 terawatt-hours a year. ||

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GO EAST, HYDROGEN

What's up in the Czech Republic, Hungary, Poland and Russia

Central and eastern Europe are no newcomers to the hydrogen market. Pertinent chemical and refinery industries can draw on a wealth of expertise. Poland, the region's most important economy, was one of the European Union's top three hydrogen countries in 2018, producing a total of 1.3 million tons. Unfortunately, much of the hydrogen is fossil fuel-sourced and not available on the open market. Still, efforts to make chemical companies and refineries part of a new hydrogen economy are underway.

Half the chemically synthesized hydrogen produced in Poland issues from Azoty Group factories, primarily from subsidiaries Puławy and Kędzierzyn. Sales to partner businesses are increasing, with a current total of 600 tons a year. In summer of 2020, the Azoty Group – also involved in fuel cell development – announced ambitious plans for greatly expanding production capacity.

Another key player in Poland is Orlen, the country's largest oil corporation. Orlen steam-reforms natural gas to make hydrogen, nearly all of which is used in Poland's industrial sector. The Lotos Group, an Orlen acquisition, is currently building a hydrogen purification plant near Gdańsk to supply buses and other fuel cell vehicles.

Also, in early summer 2020, Polskie Górnictwo Naftowe i Gazownictwo, PGNiG, a Polish natural gas supplier, launched a EUR 6.6 million investment program promoting a hydrogen economy, having already erected both a power-to-gas system in Odolanów and a research facility, New Fuel Lab. PGNiG now plans to produce green hydrogen from solar sources and offshore wind energy generated on Poland's Baltic Sea coast. The gas will be distributed via company-owned pipelines.

CZECH REPUBLIC FUELS UP Major energy corporations, primarily government-owned, support central and eastern European national hydrogen strategies and initiatives. However, not all follow the EU's strategy to emphasize green hydrogen production. Also missing is a sufficient infrastructure for manufacturing and distributing the gas.

Getting a head start, the Czech government published a National Action Plan for Clean Transportation in 2015. The plan aims to improve hydrogen infrastructure, especially in transportation, and to construct six to eight new fueling stations by 2023. One program partner is Orlen subsidiary Unipetrol, which will reportedly build three fueling stations in Prague, Brno und Litvínov.

HUNGARY, THE NUCLEAR RENEWABLE A similar constellation is at work in Hungary, where the country's major energy corporation MOL dominates the hydrogen sector. In early 2020, MOL launched a new climate initiative encompassing a recycling program, increased renewable capacity and the acquisition of Goldi Mobility, a hydrogen-powered, mass-transit bus manufacturer (see H2-international, August 2020). Hungary has also created a national platform for hydrogen technology transfer bringing together industry managers, researchers and project leaders.

Then, last summer, Hungarian officials made a surprising statement. They claimed hydrogen produced from nuclear power is a renewable source of energy. Péter Kaderják, Hungary's energy and environment minister explained:

"In the long run, nuclear-produced hydrogen will play a decisive role in Hungary's economy and energy mix. Thus, we think nuclear-sourced hydrogen needs to be recognized as a renewable." At present, nuclear power stations already meet a third of Hungary's electricity needs. Completing Pak 2 plant expansion will double the share.

In late September 2020, Ukrainian energy suppliers Naftogaz and Energoatom signed a partnership agreement, joining forces to enter the hydrogen market. Naftogaz' pipeline system can optimally deliver the energy carrier and the company's natural gas reserves can produce additional quantities of hydrogen. Energoatom, a leading nuclear energy supplier, has tons of generation capacity. As Polish energy industry news site BiznesAlert reported, Naftogaz and Energoatom also conducted initial pipeline tests in October 2020 to determine how much Ukrainian hydrogen could be blended into the natural gas network.

RUSSIAN COLORS: YELLOW AND TURQUOISE HYDROGEN
Russia's hydrogen strategy aims to hold on to the country's strong global energy supplier position. To all intents and purposes, Russia is still bringing up the rear in technology, barring a quick or mid-term switch to a hydrogen economy. Reportedly, Gazprom is focusing on turquoise hydrogen via methane pyrolysis (see H2-international, May 2020).

Russia is also considering producing natural gas and hydrogen blends distributed through the pipeline system. Gazprom said conventional pipelines could deliver blends of 20 percent hydrogen, while long-distance networks, such as Nord Stream, Nord Stream 2 and Turkish Stream, could deliver up to 70 percent blends.

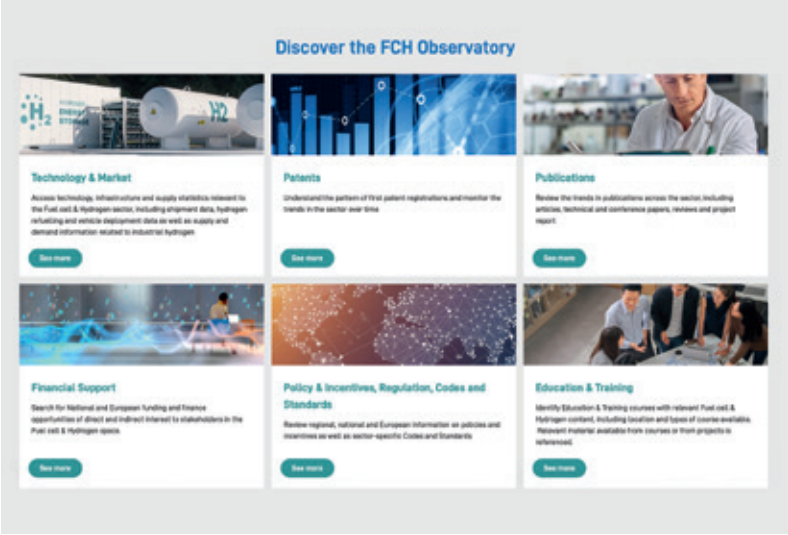
Russia's national strategy puts Rosatom in sole charge of producing yellow hydrogen, sourced from nuclear energy. Novatek will purportedly concentrate on the blue variant, produced from natural gas via carbon capture and storage. ||

Category: World | Author: Diana Raine

THE FUEL CELLS & HYDROGEN OBSERVATORY

The go-to resource for all things fuel cells & hydrogen

Where do you go to, to get curated facts on all things related to fuel cells and hydrogen? You could spend several hours searching project information or browsing company sites, digging around to find anything useful, or you could go straight to the fuel cells and hydrogen observatory (FCHO), a portal launched in September 2020 as the go-to resource for anyone wanting to find statistics, data and information about the sector. The Fuel Cells & Hydrogen Joint Undertaking awarded the contract for the development and operation of the online portal and information source to the energy transition and strategy consultants, E4tech who worked with a team of industry actors to deliver this resource.



E4tech project managed the delivery and continues to manage operation of the portal, working with seven expert organisations to source and validate the datasets which hold a wealth of information on all aspects of sector and market development. With IT solutions provider Inycom, an innovative user experience was designed to present information in clear, objective and user-friendly formats. Up to date data is essential to providing information for decision making, which is the foundation of success of the observatory and its users. Datasets are therefore continually being researched, consolidated and validated by subject matter experts, using only data that is owned or primary sourced, to ensure that it is current and reliable.

The main part of the FCHO is structured along a series of chapters. The technology and market chapter enables users to view and analyse the numbers of fuel cell shipments per year across geographies and application areas. The observatory has links to the Hydrogen Availability System to enable displaying the availability and number of hydrogen refuelling stations in Europe, as well as links to the European Alternative Fuels Observatory (EAFO) to display information on fuel cell electric vehicle deployments. There is also a section on the supply and demand landscape for industrial hydrogen which will form the baseline for monitoring the transition to green hydrogen.

Chapters on patents and publications tracks the trends in both these activities going back to 2014, providing an indicator of the evolution of research and development in the sector. The chapter on policies provides users with up to date information on EU policies and how they apply to fuel cells and hydrogen. National policies are also depicted, using a database which identifies those policies that promote or hinder the development of the market for hydrogen and fuel cells. This national policy database has been assembled using the FCHO's network of national correspondents who keep the data within this evolving landscape current.

An extensive database of regulations, codes and standards has also been constructed and users of the FCHO are able to search for current standards or those in planning, relevant to their particular areas of interest.

The financial support chapter allows searching for current funding mechanisms relevant to a particular project idea or theme. The resource is kept up to date by accessing an artificial intelligence (AI) search mechanism which scours live funding streams for compatibility with input criteria.

The latest chapter to be launched is on Education and Training Chapter, which went live on Nov. 24, 2020, during Hydrogen Week. Here users can find information on courses related to hydrogen and fuel cells in institutions across Europe. The chapter also provides a signposting function to point to relevant and interesting materials on the topic. At the launch event, Diana Raine, E4tech managing consultant and FCHO project manager, called upon stakeholders to get involved and support the efforts of the FCHO.

The FCHO is the first of a kind information source and aims to educate, inform and help stakeholders become more data-driven and to aid decision making. Whilst it is early days the potential for the FCHO to expand further is significant. The project team hope to be able to make links across the chapters to demonstrate impact of actions on the progress of development as the fuel cell and hydrogen market accelerates toward commercialisation. In these changing times for the sector, the existence of a reference to monitor developments and progress will be increasingly important. ||

Sources: www.fchobservatory.eu, www.h2-map.eu, www.eafo.eu

Organisations involved: Hydrogen Europe, Inycom, NEN, Hydrogen Europe Research, Concepto, Innovation Loop, HGF

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

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

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www.fcexpo.jp

World Hydrogen Fuels Summit
Accelerating Hydrogen Policy, Strategy & Projects
March 9 to 11, 2021, online, Netherlands
www.worldhydrogenfuels.com

IRES, International Conference for the Storage of Renewable Energies, March 16 to 18, 2021 – digital
www.eurosolar.de

ACIEUHydrogen & Fuel Cells Energy Summit
March 17 to 18, 2021, in Porto, Portugal
www.wplgroup.com

World Online Conference on Sustainable Technologies – WOCST March 17 to 19, 2021, online
www.wocst.org

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

Hydrogen Online Workhop (HOW)
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www.hydrogen-online-workshop.com

APRIL

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

H2 Forum Green Hydrogen 2025 – Fueling Europe's Industry and Mobility April 27 to 28, 2021, online, Germany, *www.h2-forum.eu*

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HyVolution – Hydrogen event for energy, industry and mobility, May 4 to 5, 2021, in Paris, France
www.hyvolution-event.com

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www.zeroemission.show, H2 Hydrogen & Fuel Cells

Energy Storage World Forum organized by Dufresne
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www.energystorageforum.com

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