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H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

→ FUEL CELL BUSES URGENTLY NEEDED

→ POLITICIANS DISCOVER POWER-TO-GAS

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H2-international

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Cover image Demand for fuel cell buses [Source: Winzenhöler]

HYDROGEN FIRST

Dear readers,

It's been a long time since things were moving forward at the pace they had been in recent months. And it has been just as long since the mood was that optimistic in the energy sector. Wherever you look, you feel as if a new chapter has begun. It certainly feels a lot different than past times of doom and gloom in the fuel cell and hydrogen industry.

Several developments have provided fresh impetus to the sector. Some who once seemed indifferent to the issues of today's generation methods are suddenly debating how to make the energy system fit for the future, while the younger generation has taken an interest in climate and energy matters. And even politicians seem to have realized that business as usual is no longer a viable option but that they will have to explore, and possibly take, new avenues.

One event that recently generated headlines in several parts of the world and has proved the younger generation can be as interested in and committed to something as anyone else is Fridays for Future, a campaign where the students leave their classroom each week to protest climate inaction (see p. 13). They, however, are not the only ones telling everyone what they think of today's climate and energy policy. In the meantime, these peaceful protests have been joined not only by parents but also many scientists and high-ranking politicians (see p. 7).

Things are moving especially fast in the northern German states (see H2-international, January 2019). Just recently, Jan Philipp Albrecht, Schleswig-Holstein's environment minister, said that "this is about nothing less than a transformation from the days of analog coal power production to the digital age in which energy is generated by renewables. Whether we produce green energy from wind or PV, we want to usher in this new era of smart grids by meeting all our energy needs from renewable sources."

The economy minister in the state cabinet, Bernd Buchholz, added that "hydrogen is the key. We now need to take a big leap toward a hydrogen economy as fast as possible. We need to create production capacity large enough to reap economies of scale and take the lead in hydrogen technology. The living laboratories planned by the federal government could help meet that goal, although demonstration is more likely a thing of the past. We need to shift into high gear." Hamburg even saw the founding of a northern German hydrogen business network (see p. 11). The city's senator for the environment, Jens Kerstan, said that at the launch meeting that "we could speed up the energy transformation by a lot if we used renewable electricity in the heat and transportation markets."

Everyone, it seems, wants the same things right now. The German state of Brandenburg is joining the efforts, too, by organizing its first-ever hydrogen conference in Potsdam. Jörg Steinbach, its economy and energy minister, has shown a willingness to support hydrogen and power-to-gas projects, even if he still seems a bit hesitant. At the energy storage conference, he said he first intended to talk to the ministers in other German states before being the only one to submit a petition before the Bundesrat. In the first months of being minister, no one has apparently told him about the many projects that have been launched in northern Germany and in which Brandenburg could readily participate (see p. 12).

The changing mood at the state level, however, has not yet gotten through to the federal parties. H2-international's first survey of the energy policy landscape shed little light on each party's views. Yes, there are some that have shown support for the technology and come up with some intriguing ideas. However, it seems that most party platforms do not yet include thoroughly sustainable energy policy (see p. 42).

Still, after many unheeded calls, there is hope that the government could finally create the regulatory framework needed to implement the energy market transformation: At least, the Coal Commission is opening a path for putting in place concrete measures and laws to turn sustainable energy policy into a reality (see p. 44). And economy minister Peter Altmaier himself stated publicly that "hydrogen was the best way to move forward." (see p. 10)

That's all we needed to hear, isn't? ||

Best wishes

Sven Geitmann
Editor of H2-international

NUCELLSYS REBRANDED

Mercedes-Benz FuelCell

At the turn of the year, NuCellSys, a wholly owned subsidiary of automaker Daimler, became Mercedes-Benz Fuel Cell. Besides the name change, the company announced a shift in strategy. Its chief executive, Christian Mohrdieck, explained that "fuel cells are an integral part of engine development at Mercedes-Benz Fuel Cell. The new name sends a clear message about our focus and underlines how important fuel cell technology will be in the years to come. It also brings us closer to integrating the company into Daimler's corporate structure." ||

HYUNDAI EXEC CO-CHAIRS HYDROGEN COUNCIL

Fig. 1: Eui-sun Chung [Source: Hyundai]

In January, Eiu-sun Chung, the executive vice chairman of Hyundai Motor Company, was named co-chair of the Hydrogen Council. He now heads the organization together with Benoît Potier, Air Liquide's chief executive and chairman of the council since its founding in 2017. Both stressed the import of creating a zero-carbon hydrogen society.

Potier said both were heartened by the level of commitment shown by the council's member companies, which were at the forefront of hydrogen technology development. Additionally, Chung revealed that his company was expecting steadily growing demand for fuel cells, which meant that Hyundai would increase fuel cell production capacity accordingly. ||

PICHLER APPOINTED NEW CEO OF SOLIDPOWER

Fig. 1: Andreas Pichler [Source: SOLIDpower]

On February 12, Andreas Pichler became the new chief executive of the SOLIDpower Group, replacing Alberto Ravagni, who stepped down from his role as CEO of the fuel cell heater maker at his own request. Ravagni had worked for the Italian-based business since its founding in 2007. Pichler is expected to turn SOLIDpower into a globally leading manufacturer of solid oxide fuel cells. ||

SUNFIRE RENAMES NEW ENERDAY

One German fuel cell manufacturer that recently changed its name is new enerday, now known as Sunfire Fuel Cells. Based in Neubrandenburg, the company was acquired by Sunfire, headquartered in Dresden, last fall (see H2-international, January 2019). As part of the deal, Matthias Boltze, who used to be new enerday's sole chief executive, now shares the role of CEO with Andreas Frömmel, vice president of sales and marketing at Sunfire. Their joint aim is to offer a product lineup consisting of LPG-fueled micro-CHP devices for residential buildings and off-grid uninterruptible power supply systems. Carl Berninghausen, Sunfire's chief executive, said that the "restructuring of operations meant moving fuel cell research, development and production to a single location, Neubrandenburg, where we will create the country's first Fuel Cell Center of Excellence." ||

DWV AND DVGW JOIN FORCES

On January 17, in Berlin, the German Hydrogen and Fuel Cell Association, also known as DWV, and the German Association of the Gas and Water Industries, or DVGW, signed an agreement to step up their efforts to help set up a power-to-gas market. At the signing ceremony, which was attended by Thomas Bareiß, who has a leading role in the economy ministry, both organizations said they aimed to "gradually turn today's fossil fuel economy into a climate-friendly energy system" by replacing natural with synthetic gas one step at a time.

Werner Diwald, DWV; Thomas Bareiß, economy ministry; and Gerald Linke, DVGW (from left)

In 2017, the DWV, which has so far been run mainly by volunteer leadership, begun talking to other advocacy groups about creating a shared office that would allow them to coordinate their campaigns and be even more effective in popularizing hydrogen technology. In late 2018, the association's board of directors initially eyed a partnership with the BVES, the German Energy Storage Association, and in February 2018, at an extraordinary general meeting, most DWV members voted in favor of starting talks between the two organizations. At about the same time, the board also suggested a collaboration with the DVGW. As a result of the latter, the DWV and DVWG have now merged operations.

Consequently, the chairman of the DWV, Werner Diwald, called for a swift increase in fuel cell and electrolyzer production capacity and for the establishment of a hydrogen economy involving more than one sector. He said those steps could create 100,000 new jobs, especially in Germany's economically disadvantaged regions.

Bareiß affirmed that the government had to devote more resources to supporting green electricity production from hydrogen and methane and he promised that it would. Gerald Linke, the chairman of DVGW, said he was "relieved to see more and more members of parliament recognizing the opportunities that hydrogen offers for bringing about carbon-neutral energy generation in multiple industries and creating long-term storage options. We consider the statements made by Mr. Bareiß a pledge to move forward on transforming the energy market by using multiple energy carriers, including green gas." ||

POWER-TO-GAS IN AUGSBURG RESIDENTIAL DEVELOPMENT

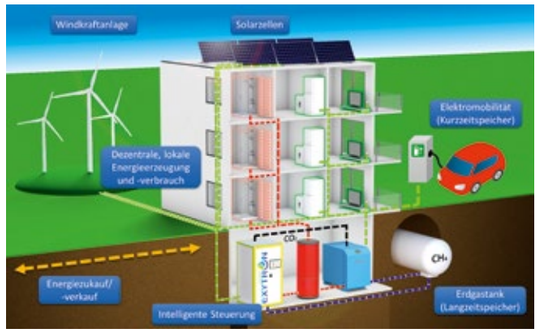


Fig. 1: Energy cycle of a multifamily building [Source: Exytron]

A small, decentralized power-to-gas system was started up in a residential development in Augsburg, Germany, at the beginning of this year. Exytron, the Rostock-based manufacturer of the installation, said it was the first of its kind around the globe to store surplus renewable electricity in synthetic natural gas and extract power when needed. With the help of the company's SmartEnergyTechnology, "the system reduces emissions by 70 percent to 100 percent," said the business's sales director, Klaus Schirmer.

The power-to-gas plant supplies heat and electricity to 70 housing units and uses electric power from a rooftop PV system to make the development less reliant on the public grid. Any power surplus is fed to an electrolyzer, which produces hydrogen that is later turned into methane by adding carbon dioxide. This way, there is little to no impact on tenants' energy bills despite the technology upgrade. ||

NATHALIE RUNS OFF SERENERGY STACK

Fig. 1: It is likely that only a few hundred units of this electric sports car costing several hundred thousand euros will ever be built. [Source: Gumpert Aiways]

On March 5, at the Geneva International Motor Show, Roland Gumpert showed attendees his Nathalie Race, an electric sportscar named after his daughter. The distinctive feature of the coupe, unveiled in spring 2018, is the engine under the hood: Gumpert, who designed Audi Quattro's four-wheel drive, said it had been important to him "to build an electric car that doesn't grind to a halt because the battery is drained but generates electricity during the ride. To achieve this, we used a fuel cell that produces hydrogen from a methanol-water blend." The fuel cell was made by Serenergy, based in Denmark.

Thanks to its four-wheel drive system, the car reportedly accelerates from 0 kph to 100 kph, that is, 62 mph, in 2.5 seconds, making it faster than a Tesla. Its top speed is 186 mph (300 kph), while it has a range of 528 miles (850 kilometers) when traveling at a steady 50 mph (80 kph). A limited edition of the vehicle, to be produced in Ingolstadt, Germany, is slated to arrive by the end of this year. It will be sold under the brand Gumpert Aiways, a joint venture that was set up with Chinese carmaker Aiways after Gumpert Sportwagenmanufaktur, a sports car manufacturer based in Altenburg, Germany, filed for bankruptcy protection in 2014. ||

SCIENCE4FUTURE SUPPORTS FRIDAYS4FUTURE

For months, thousands of students have taken to the streets every Friday to call for a more sustainable energy system. Under the hashtag #Scientists4Future, scientists have now launched their own campaign in support of the #Fridays4Future generation. The organizers' core message is that the young people demonstrating against climate inaction have "valid and well-reasoned concerns. The measures currently taken to protect the climate, the oceans and the soil and conserve wildlife and woodland are wholly insufficient."

Researchers of all stripes are participating in the campaign. "The question of how to build a sustainable society can only be answered by combining research in the human, social and natural sciences, humanities, economics, engineering and law," read a joint statement on behalf of 716 supporters, including professors and postdoctoral scientists such as Carsten Agert, Claudia Kemfert, Volker Quaschning, Stefan Rahmstorf, Michael Sterner, Ernst Ulrich von Weizsäcker and Franz Alt. By mid-March, they had amassed over 23,000 signatures. ||

→ www.scientists4future.org/statement-en-und-es/

UP TO 52 FUELING STATIONS AT TRUCK STOPS

At the FC Expo in Tokyo in late February, Hydrogentle, based in Hamburg, said it would collaborate with other stakeholders in the industry to install a countrywide network of hydrogen fueling stations in Germany to offer drivers a wide range of places to fill up their commercial vehicles. To this end, it signed an agreement with an unnamed partner company about adding hydrogen pumps to truck stops alongside German autobahns. In all, 30 stops are expected to be put up in nearby industrial areas, although the number could ultimately rise to 52.

David Wenger, the chief executive of Wenger Engineering and co-founder of Hydrogentle, told H2-international the project, called H2GO, was aimed especially at those who drive trucks or other commercial vehicles, such as buses, forklifts and StreetScooter vans, around the industrial areas or pass by the truck stops where the fueling stations would be located. He noted Hydrogentle "will not build the fueling stations but buy them," adding that construction in Cuxhaven had started. Four additional stations were scheduled to be built in the state of Lower Saxony. When talking to H2-international, Marco Schmidt, who shares CEO duties at Hydrogentle with Wenger, said the project was "advancing quite well. I think the market for hydrogen is gradually growing in importance." Schmidt is also the head of CreoVis, a Hamburg-based consulting and investment firm that supports a variety of projects and businesses. ||

Category: Conferences & Trade Shows | **Author:** Sven Geitmann

HYDROGEN TO CREATE BUZZ AT HANNOVER MESSE

25th Hydrogen + Fuel Cells pavilion

Fig. 1: WyRefueler, a mobile hydrogen fueling station designed by Wystrach, won't be on display in Hanover. But at the Public Forum, the company's staff will, for the first time, talk about the idea behind it. [Source: Wystrach]

The steadily growing interest in hydrogen and fuel cells will be on full display at this year's Hannover Messe, to be held April 1 through April 5 at Hanover's convention and expo center. This time, the event will shine an even bigger spotlight on integrated energy systems. Its organizers expect over 1,000 exhibitors to unveil new ideas, such as their plans for integrating heat with electricity in industrial settings and storing wind and solar energy as hydrogen and methane or using it to create liquid fuels. Around 180 organizations will reportedly be exhibiting at the hydrogen and fuel cell pavilion, which would mark a new record for the joint exposition on its 25th anniversary.

The Energy show, one of six shows at Hannover Messe, has been renamed Integrated Energy this year. The new name, according to Deutsche Messe, the organizer of Hannover Messe, will underline that "the show will be all about integrating the markets for heat, electricity and transportation into a single energy system." Moreover, it stated that "more renewable energy systems and further opportunities for generating electric power and heat at the point of use make it all the more necessary to change the system. Only if we upgrade the grid will we be able to ensure ample supply of energy at peak times."

The electric transportation area was renamed as well. Known as Electric Vehicle Infrastructure from now on, it provides a platform to discuss charging technology, autonomous driving, new billing systems and solutions for transporting goods and people. As in previous years, it will be located in Hall 27 and will kick off with a speech by Henning Kagermann, chairman of the National Platform for the Future of Mobility, formerly NPE, now NPM (see box). He will update attendees on the state of the electric vehicle market at the Electric Lounge Forum, at booth F81.

HYDROGEN + FUEL CELLS EUROPE It will be the 25th time that hydrogen and fuel cell stakeholders share a large exhibit space at Hannover Messe. Located again in Hall 27, booths B45 through B59, along the main aisle and near the exit to Hall 25, could prove to be the key attraction. Across a total of four stalls, the National Organization Hydrogen and Fuel Cell Technology, better known as NOW, the Brussels-based Fuel Cells and Hydrogen Joint Undertaking, or FCH JU, and multiple other public and private sector organizations will come together to unveil a "road map for the implementation of the National Industrial Strategy 2030 and the country's climate protection goals," as said in in a joint statement. Besides members of the DVGW, DWV and Hydrogen Europe associations, representatives for the Clean Energy Partnership, also known as CEP, H2 Mobility, GP Joule and e.GO REX will be coming to the show to offer attendees the full range of experiences. These will include test-driving and filling up a fuel cell car and listening to experts talk about policy and market conditions.

Under the motto Ride, Refuel & Talk, e.GO REX, based in Aachen, Germany, will display its e.GO Mover model, an all-electric, easily convertible and highly versatile minibus. This Level 4 autonomous bus, which can carry up to 15 passengers, can be equipped with a fuel cell range extender for longer journeys. At Hannover Messe, the company, a spin-off from RWTH Aachen University, aims to unveil a fuel cell prototype with up to 30 kilowatts of power output and storage for 6 kilograms of hydrogen to provide a range of 186 miles (300 kilometers). Jan-Philipp Prote, who chairs the production management department at RWTH, said that a low-volume series, to be used for both (private and commercial) cargo and passenger transportation, could come to market by 2021. The head of sales at e.GO REX, Sharon van Beek, told H2-international that the company considers "fuel cells a future-proof solution for vehicles that are on the road 24/7 and those driven in the countryside."

A visit to this year's Wystrach booth should prove equally interesting. It will be the company's first-ever exhibit on the orange-carpeted area set up by Tobias Renz. At booth E68, the business will showcase its WyRefueler, a containerized large-capacity hydrogen storage solution (see fig. 1) that can be transported by truck or train and serve as a stand-alone system for filling hydrogen tanks. In October 2018, Wystrach unveiled a prototype unit, which it had designed during the EU-funded H2-Share project (see H2-international, January 2018), at an event celebrating the company's 30th anniversary. Because of space restrictions, the WyRefueler system won't be on display at Hannover Messe, but a smaller model system will be used to illustrate its technical features.

Additionally, in mid-February, Nproxx announced that its 500-bar type IV hydrogen tank had been approved for use. The company's chief executive, Reinhard Hinterreither, said getting the product certified showed "that our technical approach is the right one to take and that our products are reliable and ready for the market. We can now go on to market our state-of-the-art carbon fiber pressure vessels and provide additional services." Tobias Gottwald, communications manager at Nproxx, said the company would have a full-size version of its hydrogen storage system on display at booth D52 (see also H2-international editorial, January 2019).

Another topic certain to feature prominently at this year's show, as it had in the past, is electrolysis. Among the 20 electrolyzer manufacturers that will be at the hydrogen and fuel cell pavilion is Hoeller Electrolyzer, based in Wismar, Germany. Its chief executive, Stefan Höller, said the business would showcase "initial prototype stacks representing our new Prometheus line." The stacks will be shown during the famous Electrolyzer Elevator Pitch at the Technical Forum, as well as booth D72.

NEW CEP CHAIR TO DISCUSS CURRENT DEVELOPMENTS One event that is going to be held at the Public Forum on Tuesday afternoon is a panel discussion with several hydrogen pioneers, who will talk about their careers. Holger Grubel, the head of the offshore wind department at EnBW, will be among those sharing their stories about the sector. He became interested in hydrogen as early as 20 years ago and was later employed at a wind power company in Hamburg. Today, he is witnessing things coming together that belong together: wind and hydrogen. A report, including details about his life and career, will be published in the July issue of H2-international.

The panel discussion will also give the new CEP chairman the opportunity to introduce himself. Thomas Bystry, who has managed the CEP, a consortium of companies operating in the industry, since early 2016, is going into early retirement. Expectations are that the organizations will appoint his replacement shortly before Hannover Messe is held. Considering that the current chairman and the previous one worked at oil companies (Shell and Total, respectively), it stands to reason that the new head of the partnership will be someone from the auto industry.

On the morning of the same day, another panel will talk about the creation of an industry alliance for installing 40 gigawatts of electrolyzer capacity. Among the panelists will be Jorgo Chatzimarkakis, known for his clear yet sometimes provocative statements.

The press conference at the pavilion, scheduled to take place at 11:00 am on the first day of the show, will see Bart Biebuyck, who chairs the FCH JU, speak about European, and German, hydrogen regions. Werner Diwald, the chairman of DWV, will not be in attendance. Instead, he is expected to participate in one panel discussion each day from Monday through Thursday.

NORTH RHINE-WESTPHALIA WITHOUT OFFICIAL REPRESENTATION The number of organizations exhibiting in Tobias Renz' space will increase this year partly because North Rhine-Westphalia, or, more specifically, EnergieAgentur. NRW, won't set up a pavilion. In late 2018, it wrote a letter to several organizations, saying the state would not offer a shared space for exhibitors, considering the sharp drop in the number of requests to be part of such an exhibit. Among those that could be found at the pavilion in past years are HyCologne, Wystrach and the ZBT, which plan to join the Hydrogen + Fuel Cells exposition. The state's absence also means that the, widely popular, party that North Rhine-Westphalia hosted each year will not take place either. Nevertheless, EnergieAgentur. NRW will come to the show and exhibit at booth D68, as well as the Decentralized Energy Supply pavilion, at booth K42. ||

NATIONAL PLATFORM NPM GIVES HYDROGEN A CHANCE

When he chaired the steering committee of the National Platform for Electric Mobility, also known as NPE, Henning Kagermann seemed, for the most part, to have little interest in hydrogen and fuel cell technology. Now, in his new role as head of the National Platform for the Future of Transportation, or NPM for short, he might have changed his views, so H2-international asked him again about his opinion:

"Like the NPE, the NPM considers electric vehicles essential to creating a sustainable transportation system and meeting climate protection goals. Combined with the energy market transformation, they lessen the impact of climate change and environmental pollution and improve the lives of people in densely populated urban areas. Battery electric vehicles, or BEVs, are also the most efficient solution, as their round-trip efficiency is nearly 70 percent. But because there are some transportation tasks for which batteries may not be the most appropriate choice, we will need a broad product range that includes BEVs, which use electricity directly, and those vehicles that run on electric power produced during the drive from other sources, such as hydrogen and synthetic fuels. A great deal of energy may be lost when reconverting the latter, but they do have benefits, such as high energy density and great versatility. For example, hydrogen can be stored for a long time and is especially suitable for travelling long distance or transporting goods. Round-trip efficiency, however, is only around 26 percent, which means that hydrogen fuel cell vehicles use less than half the energy BEVs do. Consequently, members of NPM Working Group 2, Alternative Engines and Fuels for Sustainable Transportation, will keep an open mind when taking a look at alternative engine technology and fuels, but will likewise keep an eye on their suitability for a variety of vehicles moving passengers or cargo."

Henning Kagermann,
National Platform for the Future of Transportation

Fig. 2: Hydrogen + Fuel Cells North America 2018

HYDROGEN + FUEL CELLS ASIA

Following the successful implementation of a shared space for hydrogen and fuel cell technology, a tried-and-tested concept for 25 years, in the United States in 2017 and 2018, the idea will reportedly reach Asia in 2019. Tobias Renz and Hanover-based Deutsche Messe will set up their first pavilion on the continent at the CeMAT ASIA show, to be held from Oct. 23 through Oct. 26 in Shanghai. More than 600 organizations are expected to showcase high-tech logistics products at the event. According to Deutsche Messe, the logistics markets in Asia offer many opportunities for growth.

Category: Conferences & Trade Shows | **Authors:** Sven Jösting, Sven Geitmann

HYDROGEN TAKES THE PRIZE

Handelsblatt Energy Summit 2019

Fig. 1: "This is where we need to make use of hydrogen." – Germany's energy minister Altmaier. [Source: Handelsblatt]

From January 23 through 25, many high-profile figures visited Berlin for the Handelsblatt magazine's Energy Summit. Among them was Peter Altmaier, who used the opportunity to deliver a speech detailing what role hydrogen technology could have in a future energy system. And the award for the most innovative business in the industrial sector went to 2G Energy for developing CHP systems fueled by the gas.

Never before did Altmaier seem so committed to hydrogen. In his keynote address, he took a look at multiple options for hydrogen use while painting a relatively straightforward picture of a future energy system. He said that Germany was intent on "creating a state-of-the-art grid. However, this system will not be able to function without the combined strengths of several sectors. And it will, if we aim to store renewable sources of energy, never work by simply adding thousands and thousands of lithium-ion batteries. This is where we need to make use of clean gas, that is, hydrogen. Electrolyzers could produce it from renewable electricity in summer, when much power is generated but comparatively little is used, to store it for the winter. Consequently, we have to ask ourselves how many transmission lines we still require, how many pipelines we can fill with it, and, above all, what the public will think about these changes. Many say they don't want the number of wind turbines to increase fourfold, threefold or even twofold beyond today's numbers. Thus, the transformation of the energy market is far from over. We must continue the debate."

The aim, he said, was not only to create new jobs but also to speed up the planning process and make it future-proof. "Some suggest that, instead of using transmission lines, we produce hydrogen from electricity generated by wind farms in the North Sea and transport the gas in tankers to the coast. It could then be used in gas power plants to supply them with green sources of energy. Vehicles could run off it, as could power-to-liquid. We have recently invited bids for so-called living laboratories. Our goal is to test in four large labs if hydrogen technology could be scaled up and become economically viable," he added. However, he professed that current legislation, for example, Germany's renewable energy law, prevented many of these advancements from taking place.

ATTENDEES LOOK TO JAPAN FOR GUIDANCE The summit's other presentations and panel discussions made clear that transforming the energy sector would only be possible by including renewable hydrogen. The future of the energy system lay in the many power-to-X methods, virtually everyone at the three-day event said. Europe offered good prospects for their use, but their potential had yet to be tapped into. Japan, by contrast, was already preparing for a „hydrogen society," a vision it wants to implement by 2020, when the next Olympic Games are held. The island nation currently imports gas from Australia, where it is produced in coal power plants, even though the country's long-term goal is to create renewable hydrogen at local facilities.

Like Europe, Japan needs to know it can rely on a system producing enough energy at all times. In the past, the country replaced 50 nuclear power plants by their fossil fuel counterparts. Now, the goal for 2030 is to produce 300,000 metric tons of hydrogen, put 800,000 fuel cell vehicles on the road and have 5.3 million residential fuel cells up and running to supply households with electricity and heat. The battle between batteries and fuel cells, raging worldwide, would, in Japan, be decided in favor of the latter, a speaker at the event predicted. Over the longer term, they would be less expensive to produce, since the limited availability of battery materials offered fewer opportunities to cut costs. That is the why the Japanese government has been supporting the expansion of the national fueling network. To date, there are around 100 hydrogen stations in the country, a number that is expected to rise to 320 by 2025.

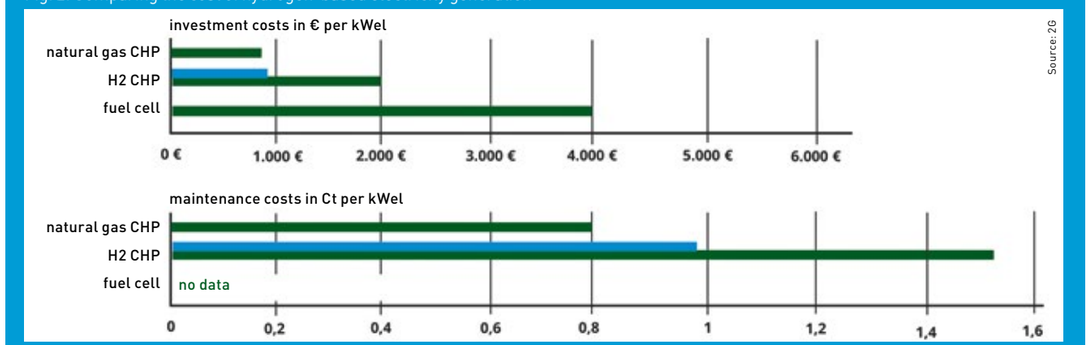
Overall, the impression was that hydrogen and fuel cell technology had been given fresh impetus compared to past years. It also became clear that the entire system to tax energy sources will need a fundamental overhaul. ||

HANDELSBLATT ENERGY AWARD FOR 2G

This year's winner of the Handelsblatt Energy Award in the Industry category was 2G Energy, a stock company based in the German Münsterland region. Its aim is to build efficient and cost-effective hydrogen CHP systems to produce electricity and heat. It uses specially designed gas engines with capacities of between 80 kilowatts and 280 kilowatts.

"Thanks to the piston geometry we developed in-house, we can provide simple and highly customized solutions that can be adapted to work with the compression ratios of multiple gases," Frank Grewe, the head of the R&D department at 2G Energy, said after being presented with the award. The result had been an increase in round-trip efficiency to almost 90 percent, he added. Moreover, the CHP device had the advantage of being much less susceptible to impurities in the hydrogen. Thus, it cost only half as much as a fuel cell module.

Fig. 2: Comparing the cost of hydrogen-based electricity generation



Category: Energy Storage | **Interview Partner:** Heinrich Klingenberg

NORTHERN GERMAN HYDROGEN INDUSTRY NETWORK

Interview with Heinrich Klingenberg, CEO of hySOLUTIONS

Hydrogen is an oft-discussed topic in and around Hamburg these days: In summer last year, the city became the birthplace of the Hydrogen Industry Network in Northern Germany. In November 2018, it was where the economy and transportation ministers of the German states on the coastline met for a conference on a joint hydrogen strategy for the region. H2-international talked to Heinrich Klingenberg, the network's spokesman and chief executive of hySolutions, about the organization's plans and the future role of the city.

Fig. 1: Heinrich Klingenberg

H2-international: In January, the members of the hydrogen industry network already met for the second time in Hamburg. What does the organization do and what is its purpose?

Klingenberg: Actually, it's not a new partnership, but it continues the years-long efforts undertaken in Hamburg and the rest of northern Germany. The entire region is home to a great many renewable energy systems, while elsewhere, local governments still have to make the necessary investments in wind power. The objective of the network is to use that infrastructure buildup to our advantage and add value along the supply chain. We live by the motto of sharpen your edge, in that we could immediately begin implementing a zero-emission economy in the north of Germany while continuing to make optimal use of available infrastructure, such as wind farms.

This is not only a task for research and the private sector but also politics. The relevant departments in the five coastal states are currently drafting a comprehensive hydrogen strategy to complement the network's day-to-day operations and back it up politically. It will help us build an even stronger campaign and exchange a wealth of information. The organization is not yet a legal entity but has established the right kind of environment and clear rules for meaningful and effective collaboration between all stakeholders.

The network is an industry cluster initiative that blends the worlds of business, science and politics and actively integrates vital clusters, such as renewable energies, aviation and maritime transportation. Important decisions on technical, strategic and administrative matters are made by its stakeholder board. Its members come from a wide variety of member companies, be they transmission grid operators, manufacturers or other participants in the market.

The person who invited stakeholders to join the meeting was Hamburg's new senator for the economy, Michael Westhagemann. What do you think was the minister's reason for putting his commitment to hydrogen storage on full display?

Klingenberg: Senator Westhagemann had already stressed the importance of hydrogen for northern Germany when he chaired the Renewable Energy cluster. However, the idea to establish a hydrogen industry network in the region originated with his predecessor in the senate, Frank Horch. And yet, the current senator is following his lead, continuing to push for progress. The objectives are clear: first, focus on climate-friendly solutions in all relevant markets, such as transportation, manufacturing and heat; second, see to it that local companies direct their attention to new, promising application areas; third, continue with the profitable and economically viable use of available infrastructure, from gas pipelines to wind farms; and fourth, collaborate, as well as coordinate, with other stakeholders across the region and do so successfully and on an equal footing.

There was a time when Hamburg aimed at becoming the hydrogen capital of Europe. What's left of this goal?

Klingenberg: I believe that the required economies of scale and rule adjustments can only be brought about if all partners in Germany, or Europe, are acting in concert. It makes me happy to hear that each region wants to lead the field and puts a whole lot of effort into achieving that aim. ||

Category: Energy Storage | **Interview Partner:** Jörg Steinbach

STATE GOVERNMENT TO PROMOTE HYDROGEN

Interview with Brandenburg's economy minister Jörg Steinbach

Among all German states, Brandenburg has had the most trouble striking the right balance between its fossil and renewable sources of energy. Many jobs in the south of state depend on lignite mining, while large wind farms have been put up in the north and around Berlin. The state government, a coalition of The Left and the SPD, has been trying for years to find an equitable solution to its very own energy dilemma. H2-international spoke to Brandenburg's minister for economy and energy, Jörg Steinbach, of the Social Democrats, about the possibility of using hydrogen to combine both pathways.

Fig. 1: Jörg Steinbach

H2-international: Mister Steinbach, last September, you became Brandenburg's economy minister, even though you used to work as a scientist and were the president of the TU Berlin university, as well as a founding member of the Brandenburgisch Technische Universität Cottbus-Senftenberg. Why go into politics?

Steinbach: Unfortunately, I've observed for some time that our society, which was shaped by 60 years of being a representative democracy and helped transform Europe into a beacon of peace, is now at risk of succumbing to nationalism and populism. Politicians themselves are partly to blame for that. When you're offered a chance to fight those tendencies by taking on responsibility and showing others that you can turn the ship around, you just have to say yes, speak up and take a stand.

A crucial date in recent times, I'm guessing, was the day the coal commission published its final report. What do you think of its findings?

I recently heard a journalist say that only a painful compromise is a good compromise. I agree. The commission did the best it could, considering the circumstances. It was a relief for me to see most of its members come out in support of its suggestions to exit coal power production while attempting to retain the economic prowess of German lignite mining areas. After all, the vote on the final version of the report was near-unanimous. What is important at this point is that we use the commission's recommendations to start establishing a reliable set of rules as soon as possible.

> There is no longer any dispute about whether climate change is real. It is. What we need to do now is to reduce carbon and GHG emissions to prevent irreversible damage to our environment.
>
> *Jörg Steinbach*

How will you ease the fears of coal miners, who are worried about their futures and justifiably so?

Their worries will become calculable risks once we pass our legislative package. It will allow them to respond to the transformation of the sector by planning ahead. While that will, no doubt, be a painful experience, I believe the uncertainty in past years has been worse. We will not leave the miners behind. Instead, we can and will use the funding available to us to attract new manufacturing jobs and ensure the successful transformation of local economies. I sincerely believe that twenty years from now, the Lausitz region will be even more appealing than it is today.

How will you create those opportunities? Which areas do you believe have potential to shape the future?

The Lausitz is Brandenburg's economic powerhouse and it should stay that way. We need to replace around 15 percent of economic revenue generated by the state's lignite industry. The energy market will continue to play a key role in that transformation, though I fully expect the 4,000 working at LEAG, a progressive energy service company to still have a job in the future.

I have high hopes for research, too. We have already managed to include two non-academic research institutes in the federal budget for 2019. One is a German Aerospace Center organization, whose staff aims to study low-carbon industrial processes, and the other is the Fraunhofer Institute for Energy Infrastructure and Geothermal Energy. We are currently starting talks on setting up both. By the end of this year, these two new institutes will then start hiring. In Cottbus, the government is also building a federal center of excellence, where it intends to pool expertise on energy-hungry industries. It is scheduled for completion as early as this year. And Fraunhofer institutes, or departments, could develop from the research groups at Brandenburgisch Technische Universität Cottbus-Senftenberg. These groups began to form when I was still president of BTU. Since then, one has grown into the Fraunhofer Institute for Photonic Microsystems. At some point, they will spin off start-ups, which will create jobs and add value to the region. Of course, all this won't happen by tomorrow. It will take 10 years until the new institutes will have achieved a stable organizational structure. By then, however, the Lausitz is going to be better off than it is today.

At the same time as the miners' protests, at which they advocated keeping the coal mines open, another Fridays for Future demonstration took place in Berlin, where students had again left class to take to the streets and call for more concrete plans to protect the climate. What are your thoughts on this initiative?

Regarding the substance of the discussion, I share their worries. That they call on us to provide a future on this blue planet of ours is entirely the right step and understandable. However, their demands and arguments have been a bit one-sided. The complexity of the issue was evident from reading the discussions among members of the coal commission. And although I think that students have a right to protest, they also need to go to school. I believe it is wrong to conflate justified concerns with staying away from class.

Have you talked to some of the students personally? What did they tell you?

I met a few of them at a commission meeting once, though we had little time to exchange personal views. I will gladly invite a group of students to visit the ministry should they be interested in discussing the issues with me. But, please, let's do this in the afternoon, when no one has to miss class because of it.

And what are you telling your fellow party members? Are politicians aware of these protests at all? Is there any discussion about the substance of their arguments or is there simply no time for it?

Of course, my colleagues are aware of the protesters and their concerns. My party welcomes their dedication, but this shouldn't be taken to mean we are in complete agreement with all of their ideas.

OK, let's move on to hydrogen. The German Hydrogen and Fuel Cell Association, also known as DWV, suggested attracting fuel cell and electrolyzer companies to the Lausitz region and using local know-how to design storage technology. Have you heard about this idea? Do you think it could be a viable option?

The upcoming changes to the economy have led to a series of ideas and projects that could provide the Lausitz region with new prospects for growth, without involving coal. As far as I know, the DWV has sent an open letter to the government to ask for its help with establishing fuel cell and electrolysis production facilities, developing a hydrogen economy that reaches across several sectors in Germany, and passing the legislation that could turn these suggestions into a reality.

Current developments at the state and federal level show how important hydrogen has become and how much interest it generates. A fuel cell and electrolyzer manufacturing industry in German lignite mining regions could grow into a key part of our approach to transforming the economy throughout the Lausitz. Creating a hydrogen industry and bringing together the electricity, heat and transportation markets would mean new opportunities for local value chains, such as in fuel cell and electrolyzer production, and jobs in Brandenburg, as well as all of Germany. The implementation of a hydrogen economy is a crucial part of our industrial policy, which combines and utilizes Brandenburg's strengths and expertise of the technology to stay one step ahead of everyone else.

In short, yes, it is a good suggestion and we will definitely leverage the potential we expect it to have.

> FRIDAYS FOR FUTURE
>
> In August 2018, Greta Thunberg, a 16-year-old Swedish student, stopped attending school on Fridays to protest climate inaction in front of the parliament building in Sweden's capital Stockholm. In late 2018, she then held a moving speech at the climate summit in Katowice, Poland, for which she received a lot of praise and support on social media. This January, she addressed attendees at the World Economic Forum in Davos, Switzerland. It was her commitment that prompted the creation of the Fridays for Future movement and inspired students around the globe to leave school early on Fridays and demonstrate in front of town halls and parliament buildings for a better world.

When it comes to hydrogen and fuel cells, Brandenburg has so far little to show for, aside from the hybrid power plant in Prenzlau, the hydrogen fueling station in Potsdam and, shall we say, your hydrogen center of excellence at BTU Cottbus. Brandenburg's infrastructure minister Kathrin Schneider, a fellow party and cabinet member in the state, recently said that she wanted to change that. Are there any concrete plans by now?

The situation is not that bleak. Some projects in Brandenburg are missing from your list. One besides those you mentioned is Uniper's WindGas project in Falkenhagen. It even involves a process that could follow electrolysis: methanation. Likewise, it should be noted that the hybrid power plant in Prenzlau was a world first, turning the company that built it into a hydrogen industry pioneer from which others were able to learn a thing or two.

And even now, progress has not come to a standstill. In addition to some new projects, we are also planning to increase our hydrogen research and development capabilities. For example, this year's Energy Storage Day will be all about hydrogen.

On this day, you will hold a hydrogen conference. Am I correct in assuming that you think of it as being the first of many to come? Should the event be taken as a sign of greater commitment to the industry?

Yes, indeed, this is going to be our first conference dedicated to hydrogen as part of the Energy Storage Day in Brandenburg. However, we discussed power-to-gas at last year's event, so it won't be the first touching on the subject. Our long-held view is that hydrogen could play a key role in the energy market transformation. I hope it will. It would be good for my department if people saw what great opportunities the technology had to offer and made use of them early on. That was why I launched a hydrogen initiative: to analyze the difficulties from the perspective of those responsible for industrial sector policy and to overcome them.

What exactly does the Hydrogen Initiative do?

The aim of the Hydrogen Initiative is to pool state government resources on hydrogen technology and available know-how from research facilities and businesses. Only if we can identify what challenges we are facing can we work together to overcome them. The initiative was set up to facilitate a close exchange of ideas and expertise between politicians and staff at companies, associations and business networks. What it stands for and what its members are working on would later make its way into Brandenburg's hydrogen strategy.

Other German states have energy agencies that deal with hydrogen and fuel cell technology. Your state has ZAB ZukunftsAgentur Brandenburg, which has been renamed Wirtschaftsförderung Brandenburg, or WFBB for short. However, it has done little to improve the situation on the market. In what way is this about to change?

Fig. 2: It would be helpful if we created a business network to complement the hydrogen initiative, the minister said.

WFBB is not just an energy savings agency. It supports start-up companies and business expansion, innovation, internationalization and networking, helps companies fill job roles and train staff, advises in matters of finance and funding and provides guidance on communicating with public agencies. As for savings, it is closely involved in implementing the state's energy strategy, which includes many hydrogen and fuel cell projects scheduled for installation in Brandenburg. By expanding our range of state government measures in support of hydrogen, we also broaden the responsibilities of WFBB.

What do you think about the idea to have the Heidekrautbahn line run on electricity produced from hydrogen?
We, the state government continue to support the idea of powering the Heidekrautbahn with the help of green electricity, available in abundance in the Uckermark thanks to the wind farms installed in the region. We view it as a pioneer project for Brandenburg and the first of many to follow, albeit current legislation only allows funds to come from the federal government.

And what about the Sperenberg multi-energy power plant, also known as MEKS? It was reported that, one year ago, your ministry had published a feasibility study, whose authors saw barely any chance of implementing the project. Is Sperenberg dead?
We have not yet been able to implement the project as planned. This has been due to several factors, some of which still exist today. The feasibility study that we commissioned analyzed these factors and offered solutions to the problems we encountered. There were also some conceptual ideas regarding the design and purpose of the multi-energy plant in Sperenberg. A key aspect of all of them was wind power, which, combined with local PV systems, could produce enough renewable energy to guarantee its economic viability. The mid-2018 ruling of Brandenburg's circuit court against the road map intended for Havelland-Fläming has changed a crucial part of the equation and introduced some uncertainty about how to install wind farms in the area. This uncertainty often causes delays in implementing projects. We, however, are still intent on putting up a multi-energy plant in Sperenberg, and we are likewise pursuing all available avenues to make this project possible.

You are the founding president of BTU Cottbus-Senftenberg. So, how did the university get a hydrogen center of excellence? Were you involved in the decision?
The groundbreaking for the hydrogen center of excellence at BTU took place in September 2010. At that time, I was still president of TU Berlin. While I applaud the decision, I sadly can't take credit for it.

What are your objectives these days? What do you still want to see set in motion in the short time you have left before Brandenburg holds statewide elections on Sept. 1?
We want to advance the digital transformation of our state economy. We have already devised a strategic plan tailored to the needs of local companies. Our second focus is the Lausitz, where we will fight for quickly turning the Coal Commission's suggestions into a set of measures, so that with the help of the federal government, we can launch projects to transform the regional economy. The third item on the agenda is, of course, finding ways to make better use of hydrogen energy, storage and production. This is where we want to utilize the outcomes of the hydrogen initiative, so that we can create an overall strategy for hydrogen.

Last question, if I may. Would you resume your post in a new cabinet, should the SPD agree to govern as part of a new coalition?
Yes, I would. Last September, when I took on the role, I made it clear that I would like to remain and contribute to the growth of Brandenburg's economy well after election day.

Thank you very much for our interview.

"My objective is to find ways to achieve a wider use of hydrogen in Brandenburg. The technology has potential, and we intend to tap into that potential by working together. [...] If we succeed in creating a hydrogen industry, we can provide new value chains and new jobs. [...] The Lausitz has always been a center of manufacturing and energy generation. And the local Brandenburgisch Technische Universität Cottbus-Senftenberg has a wealth of expertise in hydrogen technology."
Jörg Steinbach

Fig. 3: "Hydrogen will help us cope with a changing economy in the south of Brandenburg."

Category: Energy Storage | **Authors:** Johanna Gegenheimer, Dr. Simon Verleger, Dr. Frank Graf

HOW TO OPTIMIZE POWER-TO-GAS

MethQuest: Efficient creation of renewable methane

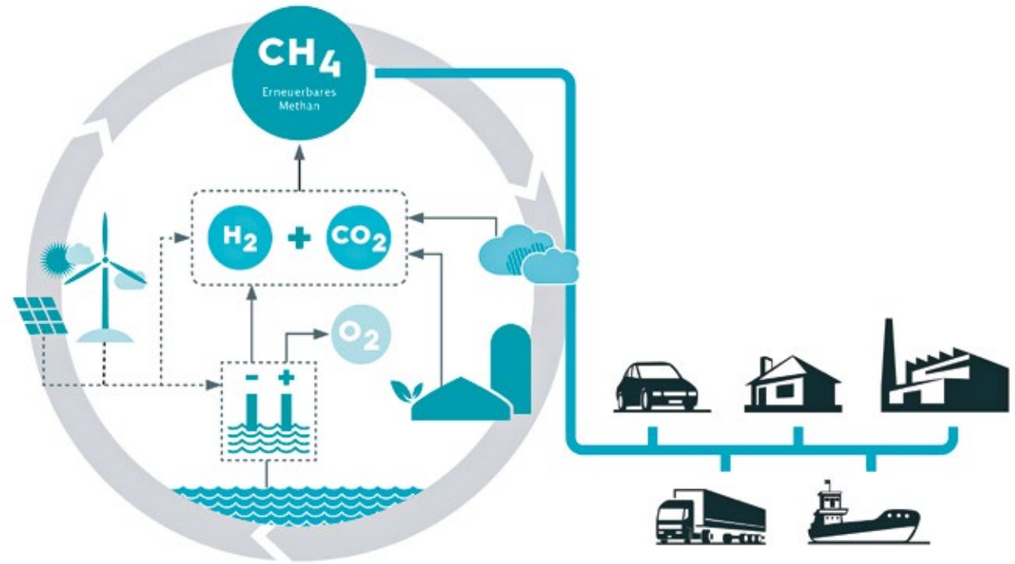


Fig. 1: Creating synthetic methane by using electricity produced from renewable sources of energy or non-fossil carbon. [Source of all images: MethQuest]

The MethQuest project investigates the creation of methane from renewable sources of energy and its use in stationary systems and vehicles by studying the entire value chain of the gas. This holistic approach promises technological advances in areas that range from production and methods such as electrolysis to the required infrastructure and end use of the gas.

Using renewable methane to advance the transformation of the energy sector is the central aim of researchers working on the MethQuest lead project, launched on Sept. 14, 2018, and funded by the German economy and energy ministry with EUR 19 million. Renewable methane, a sustainable energy carrier, has the advantage that technologies powered by methane are ubiquitous, with millions of devices up and running today. Additionally, the existing pipeline system provides a comprehensive and high-capacity infrastructure to transport, distribute and store the gas and increase the utility of volatile renewable sources of energy.

One focus of MethQuest is transportation. Many vehicles and vessels can, even in the long-term, be powered only by chemical energy carriers. One example is high sea vessels; another is heavy-duty trucks. The benefit of renewable methane is that, compared to alternative liquid fuels, the needed technical procedures are simpler, while the gas can be converted much more efficiently, which has a positive influence on production costs and the demand by renewable energy generation facilities.

Another advantage is the uncomplicated substitution of fossil fuel-based compressed or liquified natural gas, that is, CNG or LNG, by compressed or liquified renewable >>

Fig. 2: The lead project MethQuest, coordinated by MTU Friedrichshafen and the DVGW research office at the Engler-Bunte-Institut at KIT has six subprojects.

MethFuel:	Ensure efficient and demand-responsive production of renewable methane
MethCar:	Make gas engines fit for future transportation challenges
MethPower:	Produce electricity and heat in innovative CHP systems
MethMare:	Reduce emissions in the maritime industry by using novel gas engine technology
MethGrid:	Integrate heat networks with electrical grids and gas pipelines locally
MethSys:	Determine the impact of renewable methane in the transportation and energy system

methane to ensure that existing power plants and engines can be used in the future. As the ratio of renewable methane to fossil gas can be increased gradually, there is no need to change fuels in the short term and appliances will not have to be replaced either.

MethQuest contributes to advances in transportation by designing and studying technologies for the efficient production of renewable methane and use of the gas in passenger vehicles and ships. This involves a redesign of CHP systems or upgrades to them. Another focus of study in MethQuest is what impact the introduction of renewable methane will have on Germany's energy system in terms of infrastructure requirements, costs and environmental benefits. An integrated energy system is seen as key to using available resources as efficiently as possible. Additionally, the Rhine Harbor Karlsruhe project is developing concrete solutions for designing micro-grids to supply river or sea ports with energy. MethQuest responds to these challenges with a holistic approach supported by 27 partners from the worlds of science, manufacturing and energy.

METHFUEL: REDEVELOPING HYDROGEN ELECTROLYSIS

Whether renewable methane will become readily available on the market depends mainly on how efficient and cost-effective its production can be. As producing the gas is (still) highly expensive, the primary objective of the MethFuel subproject is to improve the manufacturing chain, known as power-to-gas. The project partners have taken on the role of component developers to perfect the technologies required for the process, namely water electrolysis, carbon dioxide injection and methanation.

Those improvements and redesigns mainly concern the devices used in the process, their energy efficiency and environmental impact, and their management, adjusted to more accurately meet the needs of volatile sources of renewable energy. To find other sources of carbon, the project partners are likewise studying the extraction of carbon dioxide from air. The power-to-gas technologies are not only investigated separately but also studied and optimized in combination.

Renewable hydrogen produced via electrolysis is one of the two core components of the power-to-gas process, but it is also the primary cost factor in the equation [1]. This is why a great deal of resources are being directed to experimental and theoretical studies of several water-splitting technologies, namely PEM, SOEC and salt water electrolysis. These have so far been developed to differing degrees.

The advantages of **PEM electrolysis** are short, dynamic response times, small balance of plant, a wide variety of operating conditions, great efficiency and high gas purity. The MethFuel partners are implementing innovative ideas to provide the process with a much greater degree of flexibility, that is, 25 percent above that of state-of-the-art equipment. In more specific terms, they intend to develop and run a 1-megawatt PEM pilot system with full overload capabilities. Compared to a conventional 2-megawatt plant, it could, should it be connected to the primary market, attain higher nominal full-load hours and considerably reduce the investment in the stack and BoP.

High-temperature electrolysis operates at much higher temperatures, ranging from 750 °C to 850 °C, than PEM and conventional alkaline electrolysis. This means that water needs to be fed to the system in a gaseous state. That water is then split inside solid oxide electrolysis cells, or SOECs. They have improved kinetic properties and consume less electrical energy. However, more energy is required to turn the water into steam before it can be fed to the SOEC. The process heat needed for generating steam can be produced by connecting the SOEC to the exothermic methanation process used to create renewable methane. Some estimates have shown this kind of connection to increase power-to-gas efficiency to over 80 percent. So far, only small, less efficient, pilot plants with a maximum of 100 kilowatts of capacity have been started up.

To be able to manage large SOEC systems in the future, the MethFuel project partners are testing SOEC cells by different manufacturers in the laboratory and use the experimental findings to draw up a model cell. They then employ a numeric simulation to improve the operating conditions of a cell and, based on those results, create a model stack. The findings from modelling the stack are later integrated into a production process for renewable methane to determine the operating conditions most suitable for the system while integrating, for example, heat generated by exothermic methanation.

Salt water electrolysis enables the use of salt water, a resource of enormous advantage in the long run, as the world's fresh water sources make up only 2.5 percent of total reserves. Salt water electrolyzers could produce renewable hydrogen near offshore wind farms. The salt in sea water consists of foreign ions that are dissolved in the fluid, and the competing reactions pose great difficulties for electrolysis. Thus far, very little research has been devoted to this kind of electrolysis. This means that during MethFuel, a feasibility study should be carried out to explore the possibilities of using salt water for the process. This would involve studying the influence of different membranes, commercial catalysts, porous transport layers, the pH value, and the salt concentration, particularly in regard to the degradation behavior of individual components. These investigations would allow the development of a durable and thus economically intriguing electrolysis cell.

OVERALL ASSESSMENT OF POWER-TO-GAS

The progress achieved in comparison to state-of-the-art equipment for all three electrolysis technologies under study forms the basis for an overview of practical power-to-gas process chains. Separately considering each key power-to-gas technology will not be sufficient if the objective is an optimal use of resources. Only an evaluation of the entire power-to-gas process chain will bring to light the interplay between the technologies. That is why MethFuel also includes the conceptualization and technical, as well as economic, assessment of several power-to-gas process chains. The findings will be used in the other five subprojects of MethQuest, which is scheduled to run for three years. The subprojects address the use of renewable hydrogen and methane in stationary and vehicle applications. Together, they will facilitate the creation of a unique database to allow detailed analyses of a complex energy system and its inner workings. ||

→ www.methquest.de

THE DEVELOPERS BEHIND THE ELECTROLYSIS TECHNOLOGIES

PEM electrolysis
Areva H_2Gen GmbH *(stack development)*

Fraunhofer-Institut für Solare Energiesysteme ISE *(stack research)*

iGas energy GmbH *(pilot plant construction)*

Infraserv GmbH & Co. Höchst KG *(pilot operation)*

SOEC electrolysis
ElfER - Europäisches Institut für Energieforschung

EDF-KIT EWIV *(cell tests and model of power-to-gas process chain, including stack)*

Institut für Technische Chemie und Polymerchemie am KIT *(stack modelling)*

Salt water electrolysis
Die elektrochemische Katalyse-, Energie- und Materialwissenschaften-Gruppe an der TU Berlin *(development of electric cell and construction of lab test stand)*

Fraunhofer-Institut für Solare Energiesysteme ISE *(construction of test stand)*

[1] U. Albrecht, M. Altmann, et al (December 2013). Analyse der Kosten Erneuerbarer Gase. Bochum: Ponte Press Verlags GmbH.

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INTEGRATING RENEWABLE GASES

SMARAGD project findings

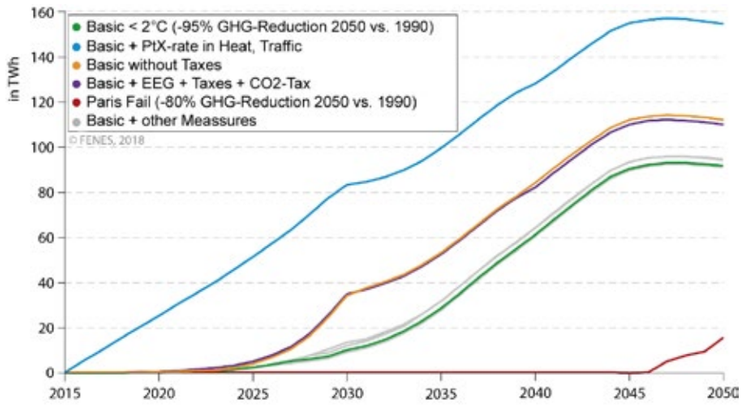

Fig. 1: Contribution of power-to-X to energy generation in Germany [Source: SMARAGD]

Renewable gases or power-to-X are essential to meeting climate protection goals because they provide cost-effective solutions for reducing GHG emissions from vehicles, heat generation devices and power production systems, for storing energy long term or for using the final products as chemical raw materials. German laws, however, have yet to include effective means to reduce those emissions to the required degree. This lack of measures and thus, pricing strategies, is still preventing the widespread use of low-emission technology.

As part of the 2015 Paris climate accords , 180 countries worldwide agreed to limit the human contribution to global warming to 1.5 °C or notably below 2 °C compared to pre-industrial levels. To reduce the expected high costs incurred by environmental damage and lessen the geopolitical impact of climate change, the agreement requires a profound and timely transformation of the global energy system. This provides a great challenge to Germany, as well as other industrial nations, which need to design a GHG-neutral economy by 2050.

Based on what we know to date, as well as according to an estimate by the Bundesrat [1], renewable gases will be essential to the transformation because they offer cost-effective solutions for lowering emissions, especially from goods and passenger transportation, industrial processes and electricity production and could be used for long-term storage and for supplying heat, in particular in residential developments and neighborhoods that are equipped with decentralized energy systems.

PROJECT AND METHODS For the SMARAGD [2] project, which was funded by the German Gas and Water Industries Association, DBI Gas- und Umwelttechnik partnered with Becker Büttner Held, the gas and water association's research department at the Engler-Bunte Institut of the Karlsruher Institut für Technologie, the OTH Regensburg university's FENES, and the Gas- und Wärme-Institut Essen association to devise suggestions for rules that could help advance the cost-effective integration of renewable gases. The researchers involved in this project had a look at Germany's energy legislation to determine possible barriers to the use of renewable gases before providing a total of 26 detailed recommendations. These were then analyzed for their impact from different perspectives:

- Business analysis from the perspective of green gas producers
- Business analysis from the perspective of consumers, by considering their freedom of choice
- Economic cost-benefit analysis based on an optimized combination of technologies

The researchers chose, from all three analyses, those measures that seemed to be the most apt solutions for a cost-effective promotion of market opportunities and an expansion of renewable gas capacity. These measures were then subjected to a detailed analysis regarding ideas for cost allocation and its impact on consumers.

RESULTS The analyses have shown that the present legislative framework in Germany provides no effective methods for reducing emissions to a degree required to achieve climate protection goals. As a result, there is also no pricing policy to incentivize low-emission technologies. This means that without implementing additional measures, it will not be possible to achieve the required increase in renewable gas quantities across the energy system. The situation could change if prices of fossil energy sources in the electricity, heat and transportation markets were to experience a considerable increase. However, current predictions do not support such expectations. For this reason, the authors of the SMARAGD study have suggested making use of different policy instruments, such as a green gas quota, a temporary exemption of renewable gases from all taxes, surcharges and fees, and carbon pricing combined with exemptions from surcharges on renewable gases owing to renewable energy legislation and from the electricity tax, as well as the creation of green gas allowances in cap and trade.

The findings of the **business analysis from the perspective of synthetic gas producers** indicate that a complete exemption of renewable gases from surcharges, fees and taxes has the largest impact on electricity generation prices. Based on the assumptions made in this analysis, large power-to-gas systems could become economically viable in this way in the foreseeable future, that is, between 2030 and 2050.

The **business analysis from the perspective of consumers** made clear that implementing individual regulatory measures with little influence on the supply and use of green gases has a marginal effect on consumer prices. This means that individual policy instruments targeting the gas network have little effect. However, if several incentive measures were combined, enough momentum could be gained to turn biomethane or a comparable or less expensive option to traditional sources of energy into a serious alternative.

From an economic standpoint, and based on the assumptions and conditions contained in this study, the most effective instrument to expand and utilize power-to-X capacity seems to be the implementation of a power-to-X quota in the markets for heat, transportation and chemicals, starting with a minimum quota of zero percent in 2015 up to 5 percent in 2030 (see fig. 1). This quota will provide a timely impetus for power-to-X-technology. It will lead to a final energy production of around 155 terawatt-hours from power-to-X by 2050. In comparison, the final power-to-X quantity for both other concepts analyzed in detail, namely the complete exemption from all taxes, fees and surcharges and carbon pricing, would result in about 115 terawatt-hours by spending nearly the same cumulative amount of funds between 2015 and 2050. Learning effects and mass manufacturing will then cut the costs of power-to-X technologies beyond those years to a point at which the industry can survive on its own.

The strongest driver of renewable gas production is an ambitious climate protection policy inspired by the Paris climate accords and its goal of a 95 percent GHG emissions reduction by 2050. However, detailed plans need to be drawn up to achieve that aim. It will be important to exploit the potential of all renewable sources of energy by increasing generation capacity and improving energy efficiency overall. In addition, gigawatts of power-to-X capacity will need to be installed in every sector to meet the Paris accords' climate protection goals and ensure the reliability of the energy system and its supply security. In addition, there will be high demand for renewable gas and power-to-X from abroad.

RECOMMENDATIONS AND OUTLOOK The findings of the legal, business and economic analyses have led to the following recommendations:

Efforts need to be undertaken to adapt the gas network for use with renewable gases, namely biomethane and synthetic fuels, as quickly as possible to become a leading market for the technology, have a positive impact on the national job situation and create export opportunities. In addition, operators of gas networks and electrical grids require a reliable framework for planning ahead and the certainty that their investments in expanding and converting energy systems, for example to accept higher concentrations of hydrogen, will pay off. This is due to long depreciation periods of up to 50 years and more. The German Bundesrat has come to the same conclusion (see box).

Furthermore, most biogas systems that generate electricity on site will no longer be funded via the Renewable Energy Sources Act somewhere between 2025 and 2035. Converting these systems to inject gas into pipelines or repowering existing biomethane plants are key options for keeping all of them in operation.

To help increase the use of renewable gases, wholesalers should become subject to a binding quota, to ensure that a minimum quantity of renewable gas is injected into the national pipelines. The findings of the economic analysis show that a quota required in the markets for heat, transportation and base compounds could bolster the power-to-X technologies power-to-gas, power-to-liquid and power-to-chemicals and guarantee the use of biomethane potential.

Besides a detailed study of binding quotas, further research should focus on the idea of a complete exemption of renewable gases from taxes, surcharges and fees and a combination of certain sets of measures in regard to their impact, concrete implementation and boundary conditions. These further studies would need to consider limits on power-to-X capacity additions and other restrictions as well. The findings would then make it possible to introduce a suitable concept for increasing the capacity of power-to-X and integrating the electrical and gas grids, as well as supplying all sectors with green gases, as called for in a recent Bundesrat decision (see box). ||

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BUNDESRAT CALLS FOR PROMOTING POWER-TO-GAS

The Bundesrat states in his decision from Feb. 15, 2019 [1] that integrating the electrical grid with the national pipeline system via water electrolysis is essential to the success of the energy market transformation, although electrolysis has not yet become economically viable. It thus calls on the federal government to set up a support program to promote the installation of large-scale electrolytic hydrogen production systems with more than 50 megawatts of capacity to "scale up the technology, improve manufacturing methods, and integrate the devices into the national grid by 2030." The German government is later asked to examine what EU-compliant changes to energy legislation are suitable for achieving those aims. These changes would then be introduced as soon as possible within the current legislative session.

ENERGY STORAGE

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

A TRUE PIONEER GOES OFF-GRID

A visit to Hans-Olof Nilsson in Sweden

Fig. 1: The house has run entirely off solar power and hydrogen since March 2015.

Hans-Olof Nilsson from Sweden is an electrical engineer who used to work in the refrigeration and telecoms industries and now co-manages a clean energy consulting firm focusing on off-grid solar power and hydrogen storage solutions. A few years back, he decided to go off-grid, by storing solar energy in summer as hydrogen to keep warm in the cold Swedish winter. One day, he invited me to visit his house, which has more than 5,380 square feet (over 500 square meters) of space and is just 6.2 miles (10 kilometers) away from Gothenburg.

Our tour of the property began outside his house, where it became clear the project was a continuous work-in-progress. He wanted to put a carport on the east side of it, while the remaining area was to be levelled and covered with grass. That is, all of it except for the driveway and parking space close to the house: They would be paved with concrete and asphalt. At the time, the building had been almost five years in the making and was basically finished, with a few of the technical installations to be upgraded in the near future.

Fig. 2: Hans-Olof Nilsson is the senior executive partner of the Nilsson Energy consulting firm, which he co-founded in 2017.

The exterior walls have been covered with ceramic tiles by Tonality, a German manufacturer. The tiles have been mounted on vertical metal rails while leaving about an inch of space between them and the insulation material behind the wall cladding. This space provides good ventilation and avoids moisture buildup during construction. When touching the tiles, they feel surprisingly cool, despite the warmth of the midday sun. This is by no means accidental. Nilsson chose them because they provide superb air circulation and function as a heat repellent in summer, reducing the need for cooling the interior of the building – a climate shield that is virtually maintenance-free.

ONE LARGE ROOM, 23 FEET HIGH When Nilsson and I stepped into his home, his wife was sitting at her work table on the balcony on the second floor – in a building that is almost one single space only. She is the architect who designed the layout and oversaw construction of the house. The living room extends around 23 feet (7 meters) or so up to the angled ceiling, where large, slowly rotating fans ensure that all sections of the huge room are kept at an even and pleasant temperature.

Many questions start popping up as one takes in the magnitude of Nilsson's project, the most evident being how many and what kind of installations are required to run a house this size off the grid? Also, how much does it cost to become energy-independent? It seems I was not the first to ask, as Nilsson responded almost immediately by saying:

"A typical high-rise building in Sweden costs, on average, 32,000 Swedish crowns, or USD 3,690, per square meter. Ours came to 15 million in total. It has 500 square meters, so that makes 30,000 crowns a square meter."

That's an impressively low number considering the high-quality materials used throughout, plus the PV and thermal panels, as well as a significant number of controllers, inverters, tanks and other pieces of equipment. Almost all units and appliances are interconnected, by wires or tubes or both. In all, there are 9.3 miles (15 kilometers) of the latter and 93 miles (150 kilometers) of the former. All switches and sockets lead to control cabinets, of which there are seven, with a central unit located in the basement. Each can be individually programmed and is monitored by a KNX system.

We move on to the indoor garage, which supports 592 square feet (55 square meters) of the first floor. Here, a BMW i3 was parked for charging. The Nilssons own two electric cars, the BMW and a Renault Zoe, which they use for daily commutes and errands, and a conventional combustion engine Volvo for longer trips. The house produces enough electricity so that both electric vehicles can be charged daily. Nilsson said he was planning to replace the Volvo with a fuel cell vehicle, a Toyota Mirai.

Once inside the garage, we took the spiral staircase to the basement, the heart of the house's energy system. Things will get a bit technical from here on. Nevertheless, it will be an exciting journey, which will take us into the realm of advanced energy management and production.

Fig. 3: Chargers and inverters (gray) on one side of the wall...

Fig. 4: ... and batteries on the other.

1. THE ELECTRICITY GENERATION DEVICE The central unit of the system, fed by photovoltaic, or PV, power. It distributes that energy to batteries, water electrolysis and the building's internal electrical system. The yellow boxes house a combination of inverters and chargers. They charge the batteries when surplus PV electricity is available and draw from them to feed AC power into the electrical circuit when it is not. These batteries have been placed on the other side of the wall. Each box can be charged at up to 8 kilowatts of effective power.

Above right are gray boxes with a capacity of 12 kilowatts each. They are inverters only, not chargers, and meet immediate AC power needs. When enough PV power is available, any surplus is channeled to the yellow boxes charging the batteries. Each gray inverter is linked to three of the yellow boxes and represents a redundant system. In this way, both inverters work independently of each other to supply the building with energy. The red box is a 3-kilowatt inverter, connected to the PV panels that are part of the facade. These panels feed directly into phase two of the three-phase AC system in the house.

The energy storage, made up of lead-silicon batteries with a capacity of 144 kilowatt-hours, can power the building for 5 full days, including heat but excluding electric car charging. When the state of charge is at 85 percent, electric power generated by the PV system is redirected to produce hydrogen through water electrolysis. When it drops below 30 percent, for example, after a couple of cloudy days with low PV production, a fuel cell is used to convert hydrogen into electricity to recharge them. These kinds of batteries are sealed, that is, they do not release gases or accumulate layers on the cells, in contrast to many lead-acid batteries.

2. PRODUCING, STORING AND USING HYDROGEN In 2018, the prototype alkaline electrolyzer in the building was replaced by a new, more efficient, PEM one, a HyProvide P1 unit by GreenHydrogen, a manufacturer based in Denmark. It was put inside the lower cabinet and produces 2 normal cubic meters of hydrogen an hour by using 5.5 kilowatt-hours of electric power for one normal cubic meter. The energy content (calorific value) of 1 normal cubic meter is 3.3 kilowatt-hours. It takes 1 liter of deionized water to produce this 1 normal cubic meter, which can be used to generate 1.5 kilowatt-hours of electricity and 1.5 kilowatt-hours of thermal energy (heat) in the fuel cell. The heat produced by the fuel cell is then injected into the hydronic heating system of the house.

Annual hydrogen production s around 3,000 normal cubic meters. In the house, around 2,200 normal cubic meters are consumed to generate electricity and heat. Nilsson said that he intended to use the remaining 800 to 1,000 normal cubic meters as fuel for a Toyota Mirai. The car can go around 6,200 miles (10,000 kilometers) on that amount of hydrogen. Pure oxygen, also produced by electrolysis, is about half the amount of hydrogen. At the time, it was discharged into the atmosphere, but it could be used for the ventilation system to help create an indoor climate that is richer in oxygen.

Recently, a new and more efficient heat-powered metal-hydride compressor by Hystorsys, based in Norway, was installed too. It has no moving parts and works based on temperature differentiation. It requires 0.5 kilowatt-hours for compressing 1 normal cubic meter of hydrogen at 300 bars.

Like the electrolyzer, the previous prototype fuel cell system was replaced by a commercially available product, the powerful PS-5 unit by Swedish fuel cell maker PowerCell. Besides electricity, the fuel cell produces water at 65 °C to 70 °C for space heating and hot water, generating up to 5 kilowatts of both electric power and thermal energy. Heat and electricity are produced simultaneously when the fuel cell consumes hydrogen.

Outside the house, there was the storage facility, a pack of interconnected high-pressure bottles, with a capacity of 12 cubic meters. It can hold roughly 3,600 normal cubic meters of hydrogen compressed at 300 bars, more than enough to meet the energy needs of the household and provide the fuel for the hydrogen vehicle the Nilssons intended to buy.

3. CONTROLLING AND MONITORING ELECTRICITY Using the main cabinet, Nilsson is able to control, time and program all switches and main plugs in the house. KNX products have been used for creating a smart and integrated control solution. If part of the system fails, one of the redundant inverters takes over. In all, there are seven control cabinets and 67 continuously running energy monitors to log electricity consumption, with 14 Kamstrup monitors to log information on hot water and space heating, as well as 10 parameters being transmitted by a rooftop weather station. Nilsson gathers all this data to conduct simulations of energy flows and consumption patterns for projections of energy use and design ideas, offering both to those who aim to go off-grid as well. >>

Fig. 5: PEM electrolyzer (left in lower cabinet) and one of three 1,000-liter hot water storage units (in the middle)

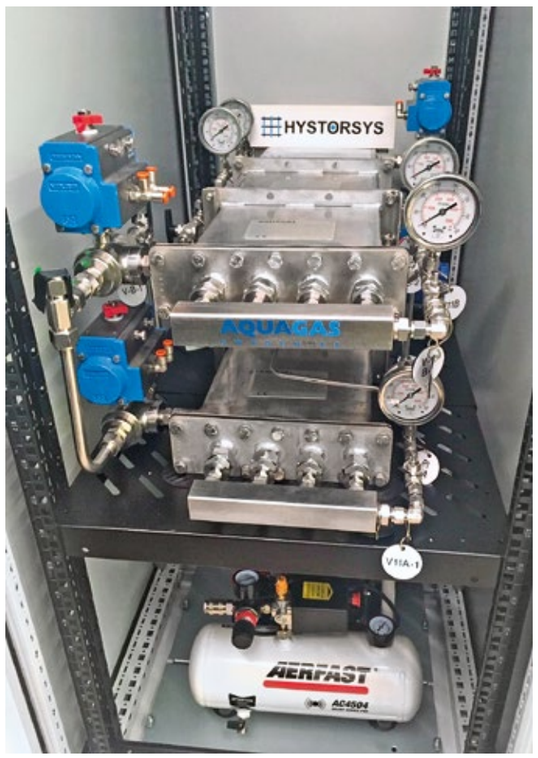

Fig. 6: Compressor

A device monitoring AC power has an online connection to the Luleå University of Technology, where researchers in the engineering department expressed great interest in the performance and quality of off-grid systems such as Nilsson's. The cooperation is mutually beneficial, as the researchers contact him each time there are irregularities, or unusual production or consumption patterns, to ask him if he did anything out of the ordinary, such as charging two cars at once while vacuuming, washing clothes and cleaning dishes, potentially putting a lot of stress on the system. The researchers monitor electric power generation by the PV system, overall consumption, the AC voltage and frequency in hertz, and several other parameters. Beside indicating the impact of fluctuations in production, consumption and AC output, monitoring helps them determine how the system handles the switch between running the house entirely off PV energy on a summer day, off batteries during the night and in cloudy weather, or off hydrogen in wintertime.

4. CLIMATE CONTROL AND WATER SUPPLY Some central heating and thermal storage components of the house. The three 1,000-liter tanks in the background store water at 35 °C for an outdoor snowmelt system underneath the paved driveway and yard. Plastic tubes are used extensively, 4 inches (10 centimeters) below the ground, where hot water circulates to heat the surface and melt ice and snow in winter. The system is not running all the time – it's sufficient to start it and let it run for a bit after snow or ice has accumulated. The elliptical expansion container in front of the three large tanks functions as a pressure relief device, while the two 400-liter tanks in the foreground contain water at 50 °C for household consumption (once a week, the water is heated to 65 °C to eliminate possible legionella bacteria). One of those tanks provides redundancy, for example, if there is a leak or an extraordinary use of hot tap water in the house.

The 13-kilowatt geothermal Viessmann heat pump collects energy from two boreholes that extend 590 feet (180 meters) underground. The pump allows for space heating (underfloor heating) and hot water should the heat produced by the fuel cell not be enough, that is, from November to February. It heats 3,000 liters of water to 35 °C for the driveway and yard snowmelt system as well. As one can probably deduce from their design, the tanks are efficiently insulated to minimize heat loss or, in the case of the tank containing the drinking water (seen partly on the far right), to avoid condensation.

The tank holding the 500 liters of drinking water comes with a water purifier (blue container). Absent municipal supply, the household has water for three days, including water for electrolysis. In summer, each day that the system runs off solar power counts when it comes to producing hydrogen, and a water supply failure could mean the loss of dozens of normal cubic meters of hydrogen.

Nilsson, who used to work at and head a refrigeration supply company for mobile applications, knows the tricks of the plumbing trade. For example, he has installed all tubes, mechanical connections and valves himself. The quality and attention to detail is impressive.

LIVING OFF-GRID The Nilssons' house has gained significant fame in Sweden's energy and construction sectors, as well as around the world. Not only has the housing sector shown interest, but – more significantly – utilities have sought inspiration from the villa in Gothenburg. Besides representatives for several Scandinavian and European countries, Nilsson has hosted delegations coming from places as far away as India and Australia.

Fig. 7: Fuel cell

Still, don't worry if you think going off-grid demands being an engineer with Nilsson's skills. Due to his background in electrical engineering and his experience of owning a refrigeration business, managing a wind power company and, in his current career, providing advice as an energy consultant, he gained the knowledge and know-how it takes to pull off a project like this. Let's also not forget he managed to bring several suppliers and manufacturers, as well as engineers from academia, on board.

As a result, Nilsson Energy, has developed a design standard known as RE8760, which is exactly why you shouldn't give up on going off-grid. Just like only few of us insist on building our homes completely on our own, from foundation to roof, going off-grid has become a turnkey solution – offered by Nilsson Energy.

NILSSON ENERGY
The company specializes in off-grid solar energy solutions for homes and apartment buildings, using compressed hydrogen as long-term and batteries as short-term storage. Electric power and heat are produced from hydrogen via fuel cells.

Tab. 1: Energy data

	SOLAR PV	SOLAR THERMAL
Production	22,000 kWh	6,500 kWh
Direct consumption	7,000 kWh	1,500 kWh

Storage		
A total of 15,000 kilowatt-hours generated by the solar PV system is converted through water electrolysis into 3,000 normal cubic meters of hydrogen	Those living in the house are supplied with 2,200 cubic meters for heating and electricity in winter (November through February, when PV production is negligible).	800 cubic meters of surplus hydrogen could be used for a planned hydrogen fuel cell car.

His company is also implementing a major project to get a public housing development in the Swedish town of Vårgårda completely off the electrical grid and the heating network. Plus, it designed and built a solar-powered hydrogen fueling station for cars and trucks in Mariestad, a highly progressive city in environmental terms. The city's large Electrivillage section has likewise been designated by UNESCO as a showcase for sustainable development. In addition to the fueling station, Nilsson Energy installed combined solar power and hydrogen solutions in some Electrivillage buildings. More on the Vårgårda housing development will follow in a later issue of H2-international.

TAKEAWAY In my opinion, it is most impressive what he and his wife, and the project partners, have achieved. The house in Gothenburg is an astonishing feat of engineering, and it has more than proved that off-grid is an option today, even in a cold climate such as that of Sweden's west coast. ||

The author wishes to thank Hans-Olof Nilsson for his kind invitation and subsequent generous sharing of information, which have made writing this article possible.

All images courtesy of Hans-Olof Nilsson
Written by Michael Jensen

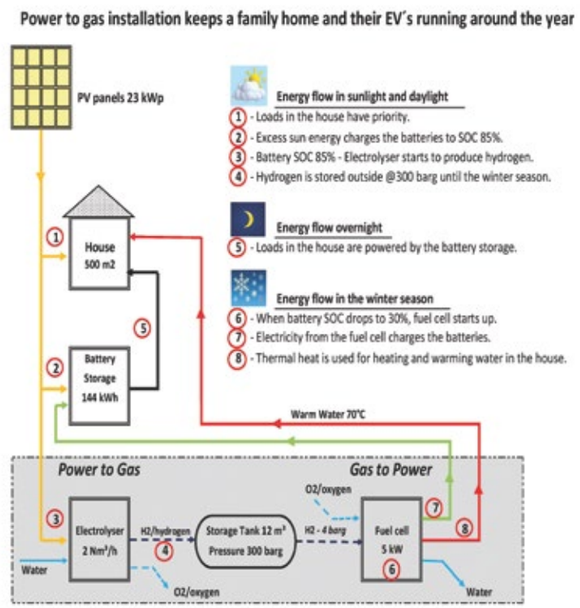

Fig. 8: Illustration of the energy system

Category: Energy Storage | **Authors:** Julia Epp, Anke Schmidt

WHAT EXACTLY IS POWER-TO-X?

Social acceptance and the vital role of communication

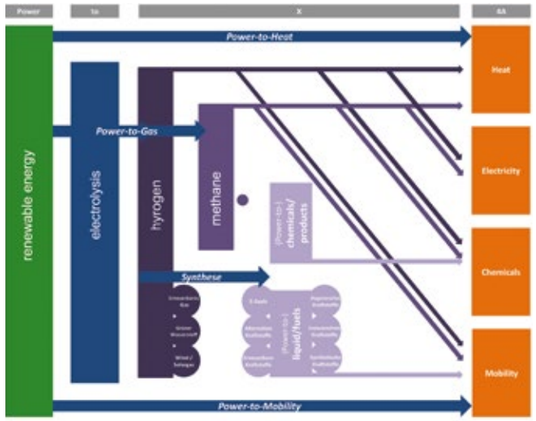

Fig. 1: Illustration of power-to-X processes, products and applications [Source: WZB]

Efforts to transform the energy sector have so far focused on increasing renewable generation capacity to lay the foundation for a future energy system. This has made the use of electricity in the heat and transportation markets all the more important, since electric power is an efficient means of generating and using renewable sources of energy. To offer transformative solutions to address their intermittency, renewed attention has to be given to storage technologies, grid flexibility and demand side management. Power-to-X, or P2X, provides multiple options to meet the challenges ahead.

Michael Sterner [3], a professor at OTH Regensburg University in Regensburg, Germany, defines power-to-X as "the means to convert electricity, understood to be primary energy, into an energy carrier, heat, cold, product, or raw material. It is an umbrella term for different ways of generating energy, namely power-to-gas, power-to-liquid, power-to-fuel, power-to-chemicals and power-to-heat." His definition shows that the X in P2X stands for a variety of products, processes, technologies and applications (see fig. 1).

Some, specifically power-to-heat and power-to-mobility, use electrical energy as a direct power source. Others, namely power-to-gas, power-to-liquid, power-to-fuel and power-to-chemicals, produce substances or materials for certain sectors of the economy. A third group of methods stores electric power in hydrogen and methane to meet demand from the public grid at some future time. Thus, P2X provides the opportunity to create long-term storage options and substitute hydrogen, methane and other synthetic fuels for fossil energy sources in transportation, chemical processing and heat production.

The relatively low efficiency of power-to-X methods producing synthetic fuels limits their employment to areas in which the direct use of renewable sources of energy is either barely possible or simply not possible at all. For example, the high energy density required in the maritime and aviation industries makes electrification difficult to achieve, whereas chemical plants use hydrogen as a base component to manufacture several kinds of goods, such as adhesives and fertilizers.

So far, most P2X technologies have yet to progress beyond the pilot or demonstration stage. Nevertheless, the current increase in renewable generation capacity and the growing political pressure to develop alternatives to fossil fuel-fired processes have elevated their importance. Research into the social aspects of the energy sector transformation, as well as P2X, mainly focuses on the level of acceptance that can be gained from members of society. Those working in the field follow the public debate, look at the age ranges involved and determine the factors influencing the employment and diffusion of certain technologies.

SOCIAL ACCEPTANCE OF P2X Acceptance means that an entity, the subject, accepts or adopts something, the object, within a certain setting, the context [1]. Based on this triangle, popularized by Wüstenhagen [4], acceptance may be grounded in either community, market or socio-political contexts (see fig. 2). Research into community acceptance focuses on the local adoption of technology by analyzing the views of citizens and their responses to an object in the area. The degree of acceptance will depend on the fairness of procedures and practices in planning and decision-making, just outcomes, and the trust of residents in specific technologies. The latter plays a role when aiming to put up new P2X systems or fueling stations.

Market acceptance refers to the attitudes of investors and consumers. It shows the impact of social acceptance on group processes, for example, in what way companies make P2X part of corporate strategy. Indicators are the popularity of a technology or a product, such as the number of hydrogen vehicles sold.

Socio-political acceptance reflects society's view of a technology. It is influenced by the opinions of not only the broader public and politicians but also other groups with an impact on the narrative, journalists and association members among them. It sets the stage for community and market acceptance.

Distinguishing between these three types of acceptance is vital if one intends to link certain statements to each of them. There is a distinct difference between protests against the construction of a new P2X system and surveys that ask consumers about their use of fuel cell vehicles.

UNCLEAR TERMINOLOGY As for socio-political acceptance, scientists at the Berlin Social Science Center, or WZB for short, have identified the following issues that need to be overcome as soon as possible: First, the words and phrases associated with P2X and used when discussing individual P2X technologies have been the source of much confusion. P2X stands for a conglomeration of methods, applications and technologies. One can already infer from figure 1 that there are many diverging views on the topic. Moreover, power-to-fuel has prompted an outpouring of sub-definitions and synonyms, all of which have seemingly been conceived without following a systematic approach.

Fig. 2: Triangle of social acceptance [Source: Adapted from [4], p. 2684]

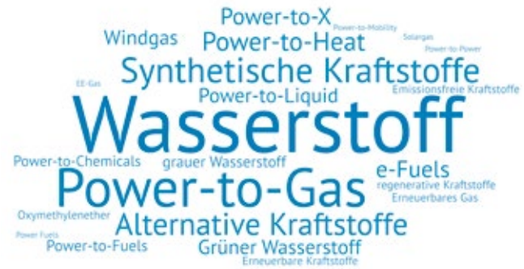

Fig. 3: The word cloud in this image is the result of analyzing a database called LexisNexis and indicates how frequent key phrases associated with P2X appeared in German-language media from 2014 through Feb. 20, 2019. [Source: WZB]

Not exempt from the above, hydrogen is sometimes referred to as windgas, green hydrogen or renewable gas. Explaining P2X has already been difficult because of the complexity of the topic and the low level of awareness among the public. If the aim is to increase the involvement of environmental associations, politicians and citizens, using multiple terms for one and the same thing or for similar processes is far from ideal.

Second, a WZB study looked at how often P2X-related words and phrases appeared in German-language media and in what way their frequency affected public discourse (see fig. 3). Hydrogen and power-to-gas received, by far, the most attention in reports and were often used interchangeably. The study also showed that terms such as synthetic fuels, alternative fuels and e-fuels have become commonplace. They were mentioned at about the same rate, although the authors of the articles in question did not distinguish between them. Other terms used by the media included low-emission, regenerative or renewable fuels, despite describing the same idea.

Third, grasping the concept of P2X is made more difficult by the parallel nature of electrification and synthesis. Power-to-heat is understood to mean the generation of power through the use of electrical energy in the heat market, for example, via heat pumps. The use of P2X materials such as hydrogen and methane in that sector is called power-to-gas for heating or power-to-gas in the heat market. The same applies when describing power-to-mobility, which is the direct use of electricity in vehicles, whereas burning hydrogen in a fuel cell vehicle has been termed power-to-gas for mobility, that is, transportation. Another growing problem is that not everyone understands fuel cell vehicles to mean electric transportation.

Thus, it should be noted that the P2X narrative is relatively complex. A lack of appropriate marketing strategies will have a detrimental impact on public acceptance of these innovative technologies.

THOUGHTS ON CONSISTENT COMMUNICATION The aim of science communication should be to provide clarity of thought. Figure 1 shows how many methods could replace the X in P2X. The degree of acceptance can only be the topic of a study if that acceptance can be delineated by accurately defined parameters. Discussing P2X with laymen makes sense if and when P2X can be properly understood. Thus, it is recommended that any communication strategy includes a clear description of the differences between P2X processes, products and applications.

Confusing power-to-heat, as well as power-to-mobility, with other P2X technologies could pose some difficulty, since all of them involve different processes and degrees of efficiency. Past WZB studies have found that a core requirement for accepting P2X is that the technologies enable the use of renewable energy sources over a long time [2]. Power-to-gas and power-to-fuel are less efficient than power-to-heat and power-to-mobility. The processes and products of the former would require more wind farms and solar fields.

Hydrogen and power-to-gas are increasingly used in the media to refer to the transformation of the energy and transportation markets, as well as an integrated energy system. Compared year on year, the number of articles that link hydrogen to that transformation more than doubled in 2018 alone. Referencing these established concepts and images could contribute a great deal to detailing the future role of P2X.

In addition, there is a need for concrete projects to make P2X accessible to the public. Their objectives could be to showcase P2X technology at events explaining the transformation of the energy and transportation markets, exhibit pilot projects at public gatherings and offer citizens tours of P2X facilities. A more direct, more personal experience of P2X could engender trust in the technologies, marking the first step toward acceptance. ||

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HYDROGEN ISLANDS IN THE NORTH SEA

100 MW power-to-gas system planned

Connecting offshore wind farms to the public grid is still fraught with problems. The main challenge is how to transmit the large amounts of energy generated in the North and Baltic Sea to the coast, since the lines have not yet been adapted to the task. As a result, many stakeholders in the sector are exploring alternative ways to make sensible and efficient use of wind power in their regions.

Transmission network operator TenneT has recently suggested building artificial islands off the North Sea coast. These islands could then be used to put up electrolyzers or methanation systems powered by wind energy. The company said that following the construction of offshore wind farms, it now aimed to promote green hydrogen production to facilitate the creation of long-term storage solutions and renewable industrial and transportation sectors.

In 2018, Wilfried Breuer, COO of TenneT, told energate, "We think that using only electricity to decarburize the energy system will take too much effort and be too expensive." In his view, producing hydrogen, and synthetic methane, and transporting it through the existing gas pipeline system from the north to the south of Germany was the cheaper solution. "We've run the numbers. At EUR 50 for one metric ton of carbon dioxide, renewable hydrogen becomes economically viable," he said. However, Breuer left the company this month.

Constructing the North Sea Wind Power Hub, as Dutch parent company Tennet Holding calls it, is no longer just an idea on the drawing board. As early as 2016, the business gave a presentation on the outlines of the project. In the meantime, TenneT Germany and TenneT Netherlands have set up a partnership with Energinet, Gasunie and Rotterdam's port operator to come up with a plan to build one or several hubs in the North Sea. Industrial corporations, such as Tata Steel, are likewise pushing for hydrogen, for example, as a replacement for the coke they use in steelmaking.

This summer, TenneT wants to publish a feasibility study on the project. It also said that the venture would be scheduled for implementation in 2035.

> "At present, the cost per unit is considerably lower if energy is transmitted and stored long term in the form of gas instead of electric power. Combining the strengths of the electrical grid and gas pipeline system could be a notable asset in popularizing hydrogen use if the gas is transported through available offshore pipelines to the coast."
> *TenneT*

ELEMENT ONE PROJECT Another project has seen transmission network operator TenneT TSO, based in Germany, partner with Gasunie and Thyssengas. Together, the three corporations want to construct the first-ever 100-megawatt power-to-gas system in the German state of Lower Saxony, as part of a venture they named Element Eins. When complete, it would be the biggest power-to-gas system in Germany.

The environment and energy minister for Lower Saxony, Olaf Lies, said in reference to Element Eins that "a few industrial businesses have already been spearheading efforts to bring power-to-gas systems to the forefront. It is now imperative we create an environment in which the market can flourish. This is our goal with this project. Solutions to integrate the electrical grid with the gas pipeline system offer especially great potential for growth. Likewise, renewable hydrogen provides myriad opportunities for heating, manufacturing and transportation."

According to current plans, the EUR 150 million system could be commissioned in 2022.

NEW BIDDING PROCESS So far, energy sector regulations have proved to be a great impediment to the implementation of projects like the above. Electrolyzers are still considered final consumers, preventing power-to-gas systems from becoming economically viable. In response, TenneT, Shell and Siemens suggested in mid-December last year that bids on offshore wind capacity include methods to produce hydrogen from the excess energy generated by wind farms.

A study carried out by consulting firm E-Bridge has found that following the above recommendation would link up to 900 megawatts of offshore capacity to hydrogen production between 2026 and 2030, making power-to-gas ready for the market in little time. The plans would involve building on potential areas that have so far not been considered in regular bid requests for offshore electricity. The first such invitation could be made in 2022.

Lex Hartman, the chief executive of TenneT until the end of 2018, said that "if we intend to follow through with the ambitious targets for adding renewable energy generation capacity by 2030, we must not waste the chance to tap into available potential. If we are to add capacity to profitable offshore wind energy projects, there need to be enough power-to-gas systems in operation to make those worthwhile. They provide the flexibility needed to take pressure of the public grid and prevent energy shortages. They would also lead to fewer grid expansions after 2030."

In mid-February, Gasunie and TenneT additionally published a study on the German and Dutch energy systems, with an outlook on infrastructure changes until 2050. Among other things, it states that in 2050, the direct use of electricity will meet up to 30 percent of total energy demand in Germany and electric power produced from hydrogen and methane will meet up to 40 percent. ||

- Nikogosian, V., Özalay, B. (Nov. 2018). Wasserstofferzeugung in Kombination mit Offshore-Windausbau.
- Gasunie, TenneT (Feb. 2019). Infrastructure Outlook 2050.

MAJOR PROJECT IN EMSLAND REGION

Fig. 1: Adapting an existing gas pipeline to transport hydrogen [Source: Amprion]

The race to build the biggest multi-megawatt power-to-gas plant has begun: On February 11, in Berlin, TenneT (see p. 26) and two transmission system operators, namely Amprion and Open Grid Europe, or OGE for short, announced their joint plans to construct a 100-megawatt electrolysis system. As part of Hybridge, they intend to put up a hydrogen production system and adapt an OGE pipeline near Lingen, in Germany's Emsland region, to transport the gas. The project is expected to cost EUR 150 million.

The government has yet to approve the venture. Klaus Kleinekorte, Amprion's chief technology officer, said the goal was to "create an environment that will make multi-gigawatt power-to-gas systems available post-2030 to meet demand across several sectors." Thomas Hüwener, a member of OGE's board of directors, added that the companies aimed to "bring large-scale installations successfully to market. We already have what we need: the technical specifications, a suitable site and opportunities for hydrogen use. We're ready."

Both businesses would like to start right away. However, they were still waiting for "the government to give the go-ahead," said Hüwener. Kleinekorte explained they needed "a regulatory framework to carry out the project. This is where politics comes in. If the government helps set the proper course, the system could be operational as early as 2023." This means as soon as it is announced that Hybridge is getting underway, stakeholders in the energy industry can take it as a sign that public officials and network operators have come to an agreement on the market conditions that will keep risks manageable. ||

Category: Energy Storage | Author: Sven Geitmann

JOINT EFFORT TO TRANSFORM THE ENERGY SECTOR

Growing partnership between Greenpeace Energy, GP Joule and EdN

Fig. 1: Frank Zimmermann, H-Tec; Reinhard Christiansen, EdN; and Sönke Tangermann, Greenpeace Energy (from left) [Source: Greenpeace Energy]

In 2019, Reinhard Christiansen, the chief executive of Energie des Nordens, or EdN, is continuing at the same pace at which he implemented his ideas last year. On January 24, he signed a purchase deal for another PEM electrolyzer, in addition to the 225-kilowatt unit, type ME 100/350 by H-Tec Systems, that was started up in October 2018. He is planning to have the new and larger ME 450/1400 device with a capacity of 1 megawatt installed in the German town of Haurup. Reportedly, this second plant will inject 3.75 million kilowatt-hours of hydrogen, produced from surplus wind power, into Germany's pipeline system.

Christiansen told H2-international the "Windgas Haurup project has to be highly cost-effective. Implementation is only possible because Greenpeace Energy's customers stated their willingness to finance it via a surcharge on their gas bills. Hydrogen production is mightily expensive at this initial stage. We'll go ahead regardless because setting an example will help introduce the technology to the market and ensure that there will be a green heat industry. We couldn't move forward without the money coming in from the new, comparatively high gas price. We're happy Greenpeace chose to join our project, making the venture possible at all."

It will be the second system to produce windgas for Greenpeace Energy, a Hamburg-based cooperative utility. The first, in Haßfurt, came online in October 2016. The business also acquired a 51 percent stake in EdN. As a result, the latter, a joint effort of 70 renewable energy companies, has been co-managed by Christiansen and Sönke Tangermann, one of Greenpeace Energy's chief executives, since October 2018.

Regarding the 1-megawatt electrolyzer, whose construction will be supported with funds from Germany's NEW 4.0 program, Christiansen said it would be "located in an ideal spot, in a part of the power grid where turbines generate a lot of surplus wind power, which we could feed to our electrolyzer to produce renewable hydrogen, that is, windgas. So instead of reducing wind farm output, we'll be using every last kilowatt-hour." Tangermann added that "to guarantee Germany's energy market transformation will be a success and enjoy broad support from the public, it is high time we utilize all the capacity we have and don't curtail production because electric power produced by coal plants is clogging up the grid. This is especially true for wind power here, in the north of the country."

THREE-WAY ALLIANCE Besides acquiring a second electrolyzer, Christiansen inked a deal in September 2018 to have his citizen-funded wind farm in Ellhöft supply electric power to Greenpeace Energy customers. "Our business benefits everyone," said Nils Müller, Greenpeace Energy's other CEO. The power purchase agreement between the two companies is thought to ensure an economically viable operation of the farm when the incentives provided by the German renewable energy law have run out. The overall aim is to keep as many farms connected to the grid as possible. Christiansen, a wind power pioneer, said confidently that "many wind farm operators will follow our example."

Soon after the deal was struck, Greenpeace Energy signed another with the parent company of H-Tec, GP Joule. In late November 2018, the two businesses agreed that GP Joule customers, who had initially been supplied by the company's in-house Connect division, would get renewable electricity from Greenpeace starting on January 1, 2019. GP Joule's founder, Ove Petersen, said that "we can only transform the energy market if we decide to work together to advance the technology. This means involving those consumers who enjoy the advantages of green energy solutions in their daily lives, for example, by using them to power homes and vehicles. It is where our partnership can make an invaluable contribution." ||

FUEL CELL CATHODE AIR BLOWERS

Stationary fuel cells require components that are suited to fulfil special requirements. This is particularly true when it comes to their cathodes, where air flow needs to be controlled, often by using blowers. Christian Radau, product manager at Gebr. Becker, a vacuum pump and compressor manufacturer based in Wuppertal, Germany, said to H2-international that "since electrical output is proportional to the amount of oxygen available, the quantity of inlet air is an important factor when running the device. This, in turn, means you need to be able to match blower output to demand with great precision." To do that, the business uses variable-speed drives in its units.

Fig. 1: Blower, type VASF 2.80, without (optional) silencers [Source: Gebr. Becker]

Considering a fuel cell generates direct current and the blower is mounted directly onto the unit, it seems the most appropriate choice for powering the latter is a DC-excited synchronous motor, as it is highly efficient and consumes little energy. This is why, besides an advanced cooling system, Gebr. Becker employs side channel compressors with improved aerodynamics to supply air to the cathode. The company's latest product line was about 10 percent more efficient than the prior one, Radau said. Its modular design also made it possible to install the frequency inverter in any cool and large enough section of the cell. Additionally, the unit's frictionless operation minimized wear and tear and air pollution while likewise reducing maintenance work and noise emissions. ||

PRESSURE TRANSMITTER FOR FUELING STATIONS

Fig. 1: Compact Eco Hydrogen – a dry-cell, thin-film sensor – can be used for pressure measurements up to 700 bars [Source: Labom]

Expectations are that Germany will have around 100 hydrogen fueling stations by the end of 2019. Their parts must satisfy the most stringent standards regarding safety and reliability. So does the measurement equipment used, for example, to check tank pressure. Labom, based in Hude, began working on pressure sensing solutions for hydrogen tanks in 2010. Keeping the unique chemical properties of the gas in mind, the company's staff has since designed a number of pressure transmitters well-suited to the task.

Risks associated with hydrogen tanks include permeation and embrittlement. Allowing the tiny hydrogen atoms to diffuse into the oil-filled diaphragm of a sensor would eventually produce false measurements or have gas leaking from the instrument. To avoid such a scenario, Labom's Eco Compact products have a membrane made of gold. Its high density makes the sensor much less permeable to hydrogen. The explosion-proof unit has been SIL2-certified and ranges to 1,000 bars. Florian Simpson, the company's global sales manager, said Labom had managed "to turn an ordinary product into a highly specialized, highly reliable solution."

Another method with which to analyze hydrogen tank pressure is the company's dry cell, a thin-film sensor with no fluid-filled components (see fig. 1). The unit transmits pressure to a thin metal film, expanding the material. This, in turn, triggers a change in resistance, which is used to obtain measurements. The business makes dry cells from gold or nickel-base alloys, as these, too, are much less susceptible to hydrogen-induced cracking. ||

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

SHORTAGE OF FUEL CELL BUSES

Huge demand, few options

Fig. 1: Sora, the name of the bus shown in the photo, is an acronym standing for sky, ocean, river and air. [Source: Toyota]

In many communities, electric buses have been the latest innovation to grab the attention of passengers and mayors alike. While passengers are just thrilled about the quiet and smooth ride, mass transit companies are looking for businesses that can deliver these types of vehicles, especially fuel cell ones, as quickly as possible. However, few options are for sale, despite a boost in demand. And although the European Union has offered a great deal of funding to help towns and cities make the switch to sustainable alternatives, financial support alone will not be enough if bus makers fail to deliver.

There is no doubt that the future of mass transit belongs to electric vehicles. For this reason, the Fuel Cells and Hydrogen Joint Undertaking decided to relaunch its project named Joint Initiative for hydrogen Vehicles across Europe, or JIVE, in early 2018. The aim of JIVE 2, headed by Element Energy, is to put an additional 152 fuel cell buses on the streets of 14 towns and cities in Germany, France, Iceland, the Netherlands, Norway, Sweden and the UK. Together with the 139 units deployed during the first project, the number of hydrogen buses in Europe could total almost 300 by 2023. At that point, they will need to be available 90 percent of the time, while their fuel cell stacks will have to last at least 20,000 hours.

ELO MOBILITY

One business that could give fresh impetus to bus manufacturing is Berlin-based startup ELO Mobility. Henning Heppner, its chief executive and likewise the founder of ebee Smart Technologies located at the same address, has partnered with Dutch fuel cell manufacturer HyMove to create a modular bus engine. He said that "thanks to a combination of hydrogen fuel cells and a tried-and-tested yet highly innovative bus design, we can provide our customers with a first-rate electric vehicle experience." The head of business development at ELO Mobility, André Stephan, added there was "huge demand for these kinds of buses worldwide. But all stakeholders would also like to see them being used at home, in the German mass transit system." Several pre-production units are slated for testing between 2021 and 2022.

Then, last fall, the EU announced it would provide EUR 40 million for a second project called H2BusEurope, with the aim of building another 600 fuel cell buses and the related infrastructure. This project is part of Connecting Europe Facility, launched in 2014. The EU Commission allocated EUR 700 million to the program in 2018 to help decarburize Europe's transportation market. So far, it has supported 641 projects with a total of EUR 22 billion.

H2BusEurope is being coordinated by Nel Hydrogen, a fuel cell maker based in Norway. Given the fact that the country is not part of the EU, there were no plans to use it as a destination for buses from the project. But that did little to deter Norwegian businesses from participating in the broad roll-out of fuel cell buses and hydrogen stations in Europe. All throughout Scandinavia, industrial companies set up partnerships to update their fleets. Nearly a third of the fuel cell buses to be tested in JIVE 2 will reportedly run in Denmark, albeit its government sees the electrification of taxi cabs and buses as merely one method among many to turn the country's capital Copenhagen into the world's first zero-carbon city by 2025. Plans are to begin putting them in service in 2020.

NO CAPACITY IN EUROPE Klaus Stolzenburg, one of the owners of engineering firm Planet, has been closely following the market for fuel cell buses for years. He told H2-international that JIVE's project partners began looking for vehicles in 2017 and planned to deploy them in cities such as Cologne and Wuppertal (see p. 34) in 2019. But because of today's limited production capacity, it is difficult to say whether the project can meet expectations.

A case in point is the joint statement issued by five European bus manufacturers, namely EvoBus, MAN, Solaris, Van Hool and APTS-VDL, as early as November 2014. They said they could see between 500 and 1,000 fuel cell buses being used in mass transit between 2017 and 2020. But since then, only one of those five, Van Hool, had begun to offer them for sale, Stolzenburg noted. In short, communities searching for renewable options are at a disadvantage in any negotiation at present. For example, British manufacturer Wrightbus has yet to deliver a unit with right-hand drive.

> "In the end, the question is whether you consider it a great success that following 20 years of development and research, barely more than 500 fuel cell buses are expected to be in service in Europe in 2022."
>
> *Klaus Stolzenburg, Ingenieurbüro Planet*

At least one company, Polish manufacturer Solaris Bus & Coach, has announced it would bring a fuel cell model to market this year. Named Urbino 12 Hydrogen, it would have a length of 39 feet (12 meters), a range of more than 217 miles (350 kilometers) and room for 80 passengers. Likewise, it would feature a 29.2-kilowatt traction battery, in addition to a 60-kilowatt fuel cell. In September 2018, the company was acquired by Construcciones y Auxiliar de Ferrocarriles, or CAF, a Spanish rolling stock manufacturer, which now owns all of the bus maker's stock. Chairman Andrés Arizkorreta said that CAF aimed "to become a leading provider of urban transportation solutions and, especially, electric vehicles."

Stolzenburg went on to say that the "big five, Daimler, Iveco, MAN, Scania and Volvo, will be relying on battery-powered vehicles in the short-term, despite their limited range," adding that "EvoBus' announcement to bring a fuel cell REx bus [i.e., an electric bus equipped with a fuel cell range extender] to market in 2022 is, I believe, more evidence that in spite of expected advances in battery technology, all-electric buses won't be capable of providing the needed range on a single charge."

REACTIVATING CHIC In light of the great difficulties in the bus market, Christian Winzenhöler, who heads bus operator Winzenhöler, went back to tried-and-tested vehicles. After having not much luck with buying new buses in 2017, his business acquired two that had been used to demonstrate the technology during an EU-funded project, Clean Hydrogen in European Cities, in Switzerland before being taken out of service when it ended. He subsequently managed to make them part of a venture supported by Germany's National Innovation Program Hydrogen and Fuel Cells, or NIP 2, in the Höchst industrial area in Frankfurt am Main. Since being put in service in September 2017, they have been used to conduct research at the site while the government has paid their running costs. And despite having clocked in over 14,000 hours prior to the launch of the project, their availability has increased from 81.4 to 93.5 percent. Early this year, Winzenhöler then bought the fuel cell buses no longer needed in Hamburg (see box).

Fig. 2: One of Winzenhöler's hydrogen buses, on display at the f-cell show last year.

"The Höchst industrial area is the ideal environment for the use of these buses," Winzenhöler said and pointed to the local Agip gas station, which has been equipped with a pump to supply hydrogen created as a byproduct in chemical companies not far away. He also told H2-international that "the buses have proved to be extremely reliable, so we bought the entire fleet that was taken out of service in Switzerland. Together with the four from Hamburg, we now have eight fuel cell buses. Six will be or have been used on regular runs, while the other two are standing by, just in case we have some unexpected downtime." He went on to say that "it seems to me as if fuel cell buses could, in the long run, replace those powered by conventional fuel." >>

HAMBURG RETURNS HYDROGEN-FUELED EVOBUS UNITS

The four EvoBus hydrogen buses that had been running for Hamburger Hochbahn for years were dropped from service at the end of 2018. As part of Innovation Line 109, they had transported passengers between Hamburg Central Station and Alsterdorf since 2014. At first, they were thought to mark the beginning of the end for fossil fuel transportation. Ultimately, though, the bus operator stopped the long-term trial because of delivery issues.

Nevertheless, Hochbahn will stick to its goal of having around 1,000 clean buses in service by 2030, albeit most of them are going to be all-electric. In February, it said it would add between 30 and 35 battery-electric ones to its fleet by the end of the year and another 30 by 2020. Likewise, in the next few months, it intended to build a new depot with enough room for 240 electric units.

And yet, Christoph Kreienbaum, a spokesman for Hochbahn, told H2-international that the bus operator wasn't about to give up on hydrogen. It still owned two battery-electric buses equipped with a fuel cell each to extend their range. Additionally, in the past five years, it tested several technologies on the Innovation Line to see how effective they would be in powering public transportation. The company's aim for 2020 is to have a fleet of only zero-emission buses, as required by Hamburg's city government. To accomplish that goal, it needed "buses that were ready for prime time." But considering "the relevant bus makers said they had none ready for production, we had to fall back on battery-electric units," Kreienbaum explained. Still, he added that "while we chose to get all-electric buses this time, we didn't make that decision because we thought hydrogen technology wasn't good enough. We'll be keeping an eye out for new vehicles."

The buses used by Hochbahn have since been purchased by bus operator Winzenhöler, Christian Winzenhöler, the company's chief executive, confirmed to H2-international (see above).

REGIONALVERKEHR KÖLN
In the meantime, HyCologne has been providing the region around Cologne with the resources it needs to test new hydrogen-powered vehicles, although a great many fuel cell buses have already been put in service in the area. To increase their numbers further, plans are to install two new fueling stations, one each in Meckenheim and Wermelskirchen, to refuel mostly hydrogen buses. Reportedly, they will have 350-bar pumps, which could also be used to fill up passenger cars. Additionally, the fueling station in Hürth will receive an upgrade to its on-site storage tanks, so each of them can supply 200 kilograms of the gas. The chief executive of Regionalverkehr Köln, Eugen Puderbach, explained that "the two new fueling stations we are planning to put up in Meckenheim and Wermelskirchen will be vital components of our strategy to turn the Rheinisch-Bergischer Kreis and Rhein-Sieg-Kreis counties into zero-emission mass transit areas."

NEW COMPRESSOR TECHNOLOGY FOR WUPPERTAL

Meanwhile, the city of Wuppertal has been trying to get a large fleet of fuel cell buses up and running. The aim of H2-W – Hydrogen Transportation for Wuppertal is to put 45 of them in service by 2021. Ten are intended for use by WSW mobil, the city's mass transit company. Reportedly, they will come from Belgian bus manufacturer Van Hool, which signed a deal in February 2018 to deliver 30 fuel cell buses to Regionalverkehr Köln (see p. 34). And in October 2018, at a signing ceremony attended by WSW mobil, Maximator concluded an agreement with AWG Wuppertal to construct, ship, assemble and bring online a fueling station.

The president of WSW mobil, Ulrich Jaeger, stated that "all-electric buses don't have the range we need for our mass transit system, so we are looking forward to making use of fuel cells as a clean alternative. Since hydrogen can be produced from renewable energy sources in Wuppertal, we will be providing a one-stop solution."

The fueling station will be the first to be equipped with a MAX Compression unit, which Maximator unveiled at Hannover Messe in 2018 (see H2-international, July 2018). The distinctive feature of this hydrogen compressor is its automated seal replacement function. The 400 kilograms of hydrogen the station will deliver each day will come from a Hydrogenics electrolyzer using excess energy generated by AWG's waste management facility.

FCP NEEDS TIME

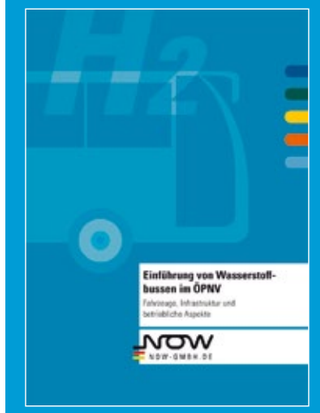
Another two German companies, Chemnitz-based Fuel Cell Powertrain, or FCP for short, and e.GO Mover (see p. 8), are comparatively new entrants to the market. FCP has partnered with Hörmann Vehicle Engineering to manufacture clean buses and logistics vehicles. Unlike other companies in the industry, both are trying to avoid the use of temporary battery storage as much as possible and are thinking about using supercapacitors instead. These are not only more durable but can also be (dis)charged at a faster rate.

FCP's Volkmar Vogel said his company had already been contacted by several prospects who were interested in its fuel cell buses, albeit the vehicles would remain prototypes for years to come. Hörmann Vehicle Engineering is part of the Hörmann Group, a family-owned business based in Kirchseeon, near Munich. The group continues the work of Leadec Engineering, a now-defunct Chemnitz-based company that had around 110 staff and a road and rail department focusing on the design and construction of motorbikes and trains.

AUSTRIA

Germany's Alpine neighbor is likewise contemplating the deployment of fuel cell buses. For three weeks in late 2018, Austria's public railroad operator, Österreichische Bundesbahnen, had a hydrogen bus running on one of its Vienna Airport Lines, between Vienna-Schwechat Airport and the inner city. Since then, it has thought about whether to turn this kind of bus into a permanent feature of its transit system. It said that both the drivers and passengers of the test vehicle had taken a liking to it. The bus, which was delivered by ebe Europa on a low-bed trailer from as far away as the Netherlands, was manufactured by Autosan, based in Sanok, Poland. Its range is 186.5 miles (300 kilometers).

Silvia Kaupa-Götzl, the chief executive of Postbus, told heute.at that "as Austria's largest bus operator, we think that we, too, have a responsibility to protect the climate. Our long-term goal is to see all our buses powered by alternative engine fuels." Several weeks earlier, in October 2018, the country's transportation minister, Norbert Hofer, had said that "of course, we need more hydrogen fueling stations. We have already begun to implement our plan to expand the infrastructure." This year, Gerald Zaczek-Pichler, spokesman for Holding Graz, then said to H2-international that "on Jan. 21, we submitted the funding application for our move2zero research project. Our aim is to have only fuel cell buses running on Line 66 in the future. This requires seven units in total." If the government approves, the company could install the fueling infrastructure in 2020 and 2021 and put the buses in service in 2022.



In December 2018, the German National Organization Hydrogen and Fuel Cell Technology, or NOW, published a 48-page book offering bus operators guidance on hydrogen-powered mass transit. Its authors not only describe essential aspects of operating fuel cell buses in the public system but also explain the contribution of hydrogen-fueled vehicles to protecting the climate and reducing local pollution levels. The PDF file is available in German only.

→ www.hzwei.info/sdm_downloads/now-bus-leitfaden

UNITED KINGDOM

The UK, too, has been pushing fuel cell buses for years. In 2016, at the ZEB event in London, Wrightbus showed its StreetDeck FCEV model (see H2-international, March 2017), which it announced as the world's first fuel cell double-decker bus. Developed for use in projects such as JIVE, it has 64 seats, an FCveloCity fuel cell by Ballard, a Siemens drive unit and a 48-kilowatt battery. According to Mark Nodder, up until recently the chief executive of the Wrights Group, the vehicle could easily replace its diesel counterparts in mass transit. Reportedly, some of these units will soon arrive in cities such as London, Birmingham and Aberdeen.

SOUTH KOREA AND CHINA

On the Asian continent, the fuel cell industry has undergone a much more rapid development than in Germany or Europe. For example, Hyundai announced it was planning to deliver 30 hydrogen-powered buses to Seoul, as well as another five cities in South Korea, as early as this year. Meanwhile, 13 companies based in Asia signed a letter of intent to put up hydrogen fueling stations. Together, they plan on investing more than EUR 100 million in a company called HyNet, also known as Hydrogen Energy Network.

China, too, is leading by example: In December 2018, bus manufacturer Yutong handed the keys to 20 fuel cell buses to Zhengzhou Public Transportation Corp. Their stated range is 310.5 miles (500 kilometers). Another 25 similar buses were delivered to Zhangjiakou and would run during the 2022 Winter Olympics in Beijing.

A month later, in January 2019, the Ronn Motor Group based in Arizona signed an agreement to manufacture hydrogen-powered buses in a joint venture with Durabl Motors and offer them for sale primarily in Asia. Ronn Ford, the group's founder, said they "are expected to be 30 percent lighter using our new nanocomposite and fuel cell technologies, which will both extend driving range. Although built inside China for China, we fully expect to export these buses to developing hydrogen economies such as California and London."

COST-CUTTING
Just a few years ago, bus operators paid between EUR 200,000 and EUR 250,000 for a typical Euro VI diesel bus but more than EUR 1 million for a fuel cell one. Following the success of CHIC, prices dropped by 60 percent by 2018, making hydrogen buses between two and two-and-a-half times as expensive as traditional diesel models. Today, the cost of buying fuel cell buses in bulk, or, more specifically, over 100 at once, is EUR 400,000 for each unit. The threshold to bid on FCH JU projects was EUR 650,000 in JIVE and is EUR 625,000 in JIVE 2.
According to Ballard, the running costs per kilometer or mile were the same as for diesel and natural gas buses. Nel even went as far as saying they were a bit below those of comparable diesel and battery-electric models.

JAPAN

Meanwhile, Toyota has been improving its Sora fuel cell bus, first unveiled in the fall of 2017 during the Tokyo Motor Show. In the spring of 2018, the bus with a seating capacity of 22, and room for 56 standing riders, went on to become street-legal and commercially available. It is equipped with two 113-kilowatt electric motors and two fuel cell systems also used in the Mirai. Toyota intends to deliver over 100 of them until the Olympics take place in Tokyo from July 24 through Aug. 9, 2020. Their reported range is 124 miles (200 kilometers), based on 24 kilograms of hydrogen.

Toyota will bring its devices to European markets by shipping fuel cell stacks and hydrogen tanks to Caetano-Bus based in Portugal starting this fall. José Ramos, the bus operator's president, said that "we are very proud to be the first in Europe to benefit from Toyota's leading fuel cell technology." The automaker is likewise preparing a phased introduction of other fuel cell vehicles, including commercial trucks and SUVs, which are slated to arrive in 2025, according to the Reuters news agency. ||

Fig. 1: Aberdeen is participating in High V.LO-City with four buses manufactured by Van Hool. [Source: Aberdeen City Council, HyER]

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

FUEL CELL BUS PLEDGE

European Zero Emission Bus Conference in Cologne

More than 370 people came to the city of Cologne to attend the European Zero Emission Bus Conference, or ZEB for short. The event, which took place from Nov. 27 through Nov. 28, 2018, was a follow-up to the initial conference in London in 2016 and gave attendees the opportunity to keep up with advancements in fuel cell bus technology and tout upcoming projects. But the main question, like elsewhere, was where the buses will come from **(see p. 30).**

That Cologne was hosting the second ZEB was little surprising given the fact that electric vehicles have become a common sight along the Rhine river. At present, the city's transportation company, Kölner Verkehrs-Betriebe, owns one of Germany's largest fleet of electric buses and is planning to increase their numbers further. Its 2020 aim is to have 150 electric wheel loaders, forklift trucks and small and large street sweepers, as well as 50 or so buses, in operation. To do that, it will reportedly invest more than EUR 40 million.

What's more, the transit company serving the region around Cologne, Regionalverkehr Köln, signed a deal with Van Hool last year to purchase 30 fuel cell buses. The agreement was hailed as the largest order for these kinds of vehicles in Europe, since transit and utility corporation Wuppertaler Stadtwerke had gotten involved as well, ordering another 10 buses. The A330 units, equipped with Ballard stacks, are slated for delivery this spring.

More evidence of how committed the city is to hydrogen was provided by Cologne's mayor, Henriette Reker, at the start of the ZEB, when she signed a letter of intent to support using buses powered by alternative fuels. She then handed it to Maja Bakran Marcich, deputy director of the European Commission's transportation division.

> "The acquisition of an additional 30 fuel cell hybrid buses is a show of our unwavering commitment, and that of our partners, to zero-emission mass transit in our service area."
>
> *Eugen Puderbach, chief executive of Regionalverkehr Köln*

	Van Hool A330
Length	39 ft (12 m) with 2 axles
Fuel cell	Ballard FCveloCity-HD85 module
Engine	PEM electric motor made by Siemens
Output power	210 kW
Tank capacity	38.2 kg of GH_2
Range	217.5 mi (350 km)
Passenger capacity	29 seats, with room for 46 standing riders

Bakran said that she "welcomes Cologne's decision to join the Clean Bus Deployment Initiative launched by the European Commission last year. Personally, I am delighted the city has chosen to replace its conventional buses with zero-emission models, be they hydrogen-powered or electric, by 2030. This course of action will be vital to decarburizing the transportation sector." The Clean Bus Deployment Initiative was established on July 13, 2017, in Brussels and has since been joined by nearly 40 cities and regions, as well as 11 bus operators. The aim of the project is to increase the speed at which clean buses are brought to market.

The fuel cell vehicles will come from Van Hool's main factory in Koningshooikt, Belgium, where the business has been manufacturing buses for the American market since 2005 and the European one since 2007. By the end of 2018, it had delivered 53 fuel cell units to customers. "We are thrilled that Regionalverkehr Köln, which has had two of our hydrogen buses in service since May 2014, shares with us its data and

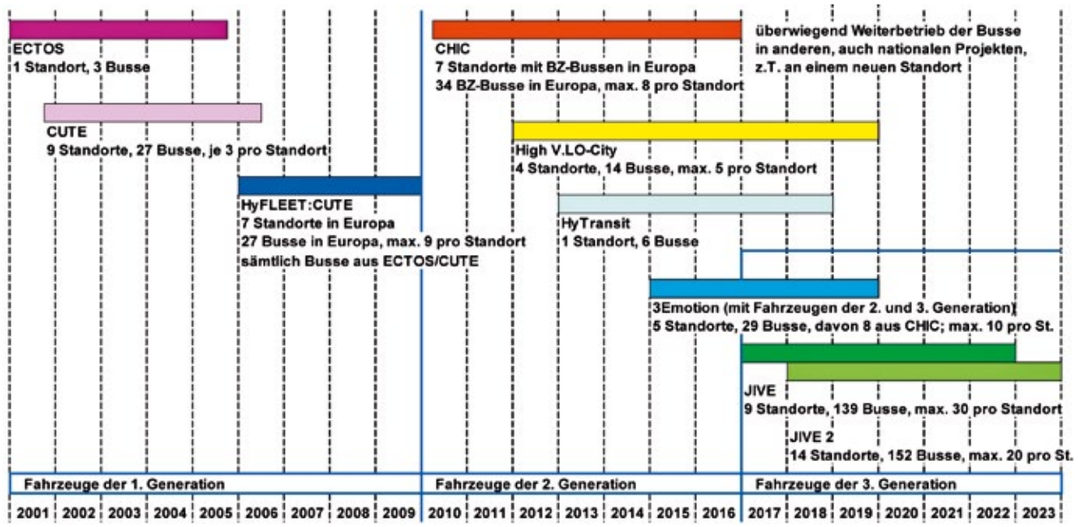


Fig. 2: List of past and current bus projects partly or wholly funded by the EU [Source: Klaus Stolzenburg – Ingenieurbüro Planet GbR]

experience of using them on a daily basis. Its insights will help us design an even better vehicle," said Van Hool's chief executive, Filip van Hool. Eugen Puderbach, the chief executive of Regionalverkehr Köln, added that "hydrogen-powered buses are among the cleanest vehicles used in mass transit."

HYDROGEN BUSES CRUCIAL TO FUTURE MASS TRANSIT

The conference, organized by the Hydrogen Europe association, provided attendees with an overview of all fuel cell bus projects running at the time (see fig. 2). One was High V.LO-City, which is still in operation and is testing 14 buses in different locations until the end of this year (see fig. 1). Bart Biebuyck, the executive director of the Fuel Cells and Hydrogen Joint Undertaking, stated that one of his organization's longtime goals was to "support every aspect of development, from establishing a business model to proving the economic feasibility of fuel cell buses. High V.LO-City is a crucial step forward, since it has allowed us to test small bus fleets in cities and towns throughout the UK, the Netherlands, Belgium and, now, Italy. It proves that these vehicles can provide as much flexibility as their diesel counterparts and offer the same level of mass transit capacity while avoiding the noise, emissions and particulate matter produced by current solutions. All things considered, hydrogen buses are the key to efforts of cities and towns, such as Sanremo, to improve quality of life." ||

FCH JU BUS STUDY

In 2018, the Fuel Cells and Hydrogen Joint Undertaking published a comprehensive study about how to create demand for fuel cell buses. Drawing on a wealth of experience gained from past EU demonstration projects, it describes on 127 pages suitable strategies for jointly purchasing fuel cell vehicles and keeping them in service beyond the incentive stage.

→ https://www.fch.europa.eu/publications/study-strategies-joint-procurement-fuel-cell-buses

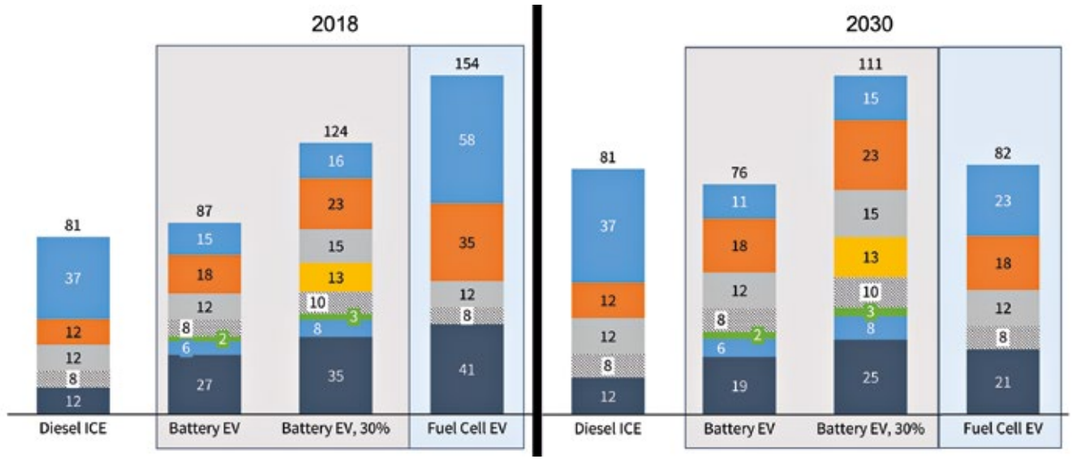


Fig. 3: Yearly running costs of a 12-meter (39-foot) bus in 2019 and 2030 (in thousands of euros), [Source: Element Energy]

Fig. 1: 7-Eleven truck equipped with Toyota fuel cell system [Source: Toyota]

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

NEW FOCUS ON COMMERCIAL VEHICLES

Electric trucks and buses to the rescue

Now that electrification has gained a foothold in the passenger car market, it is starting to have an impact on commercial vehicles as well. While electric trucks and buses have, for a long time, been studied and tested as part of research and demonstration projects around the globe, more and more politicians and environmental associations have begun to explore the potential that this, not so small, sector has for curbing emissions. Not unlike the market for passenger cars, the one for commercial vehicles may soon find itself on the brink of a revolution.

Some seemed caught off guard when discovering in mid-February that the heavy-duty truck industry had been unscathed by the past months, despite one debate about climate change, pollution or diesel fuel following the next. And this although a recent report stated that trucks produced around 5 percent of carbon dioxide and 27 percent of all other emissions from vehicles in Germany. True, it may not sound like much. But semitrucks use around 30 liters of diesel to go as little as 62 miles (100 kilometers).

So far, no EU-wide rules have forced automakers to lower carbon dioxide emissions from trucks and buses. This situation is about to change, however, following the European Parliament's November 2018 vote in Strasbourg to set an emissions reduction target of 35 percent. They did so despite a letter penned by automakers, most of them German ones, such as Daimler and MAN, warning the commission that pursuing the 35 percent aim could have a severe impact on the continent's commercial vehicle industry. They were willing to agree to a maximum of 7 percent by 2025 and 16 percent by 2030. Bernhard Mattes, the president of auto industry association VDA, said at the time that "the threat of an excessive fine, EUR 5,000 for one gram above the limit, could even drive a few manufacturers out of business."

As per the EU Commission's plans, new vehicles sold in 2025 or later must emit 15 percent less carbon dioxide than they do today. In 2030, the percentage is to climb to 30 percent. Overall, GHG emissions must drop by 40 percent or more by 2030, according to Margaritis Schinas, the commission's chief spokesman. Businesses that exceed the limits will incur hefty fines of up to EUR 4,000 a gram starting in 2025 and EUR 6,800 in 2030.

Bas Eickhout, a member of the European Parliament, told German broadcasting corporation ARD that the vote had marked "the first time we have established these kinds of requirements throughout Europe. In light of the heavy opposition that we faced from the auto industry and countries such as Germany, I think we have drawn up an ambitious plan."

Some members of parliament have also been calling for 2 percent of all new vehicles to produce zero emissions starting in 2025, lower than the 5 percent they had originally been aiming for. Whether these requirements will come into effect is another matter, as the EU's member countries and its parliament will first have to agree to a consensus view.

A VARIETY OF APPROACHES Automakers are working on several distinctly different solutions that could fulfil the above targets: While Iveco, Scania and Volvo are concentrating their efforts on LPG, the chief executive of Daimler's Trucks division, Martin Daum, believes the winning strategy will be electric vehicles, including FCEVs, and autonomous driving. The aim of the truck maker is to invest around EUR 500 million in these technologies in the next years. But he cautioned against too high expectations, noting in an interview with Stuttgart's daily newspaper, Stuttgarter Zeitung, that fuel cell trucks "cost around four times as much as battery-powered models, even though the latter are already much more expensive than those with internal combustion engines." But despite those drawbacks, he said, fuel cell trucks were "a welcome addition to our battery-electric portfolio."

One company, Faun, uses both batteries and fuel cells in garbage trucks, whether they are used to clean streets in cities, roads in the countryside or autobahns. It favors hydrogen for longer routes and has added fuel cells to its modular vehicles as range extenders. Bernd Althusmann, the minister for economy and transportation in the German state of Lower Saxony, remarked during a visit to Faun's headquarters in Osterholz-Scharmbeck in mid-February that "we need to explore all kinds of zero-carbon and low-carbon technologies if we are serious about lowering GHG emissions and meeting climate goals."

By contrast, Swedish truck manufacturer Scania, a VW subsidiary, designs vehicles that run off fuel cells only. In collaboration with waste management company Renova, it has been designing its own engine, and a prototype unit could be available in 2020. In the meantime, the automaker is building four fuel cell trucks for Asko.

Efforts to design new motors are also being made by automakers in Asia and North America, Hyundai (see H2-international, January 2019) and Nikola Motors among them. The latter, a startup business based in the United States, said in late 2018 it would unveil its truck adapted for the European market in Phoenix in April 2019. The vehicle named Nikola Tre, which means three in Norwegian, could be built in Europe following a trial period between 2020 and 2023.

Trevor Milton, the founder and chief executive of Nikola Motors, said the truck would be "the first European zero-emission commercial truck to be delivered with redundant braking, redundant steering, redundant 800-volt DC batteries and a redundant 120 kW hydrogen fuel cell, all necessary for true level 5 autonomy. Expect our production to begin around the same time as our USA version in 2022-2023."

Scottish-based HV Systems is trying to attract investors with a concept similar to that of Nikola's. However, so far, the company's website has offered little beyond rough sketches of its HV Truck™ and H2Van™.

Toyota has made much more progress to date. In the summer of last year, the Japanese automaker announced that, together with convenience store chain 7-Eleven, it would test fuel cell trucks for their suitability to deliver goods to supermarkets and cut emissions that way. The first two (see fig. 1), which will feature the same stacks as the Mirai, are expected to start driving this spring in Tokyo, as agreed to by both companies in 2017 (see H2-international, January 2018). Equipped with three tanks that hold 7 kilograms in total, they will reportedly keep the food refrigerated and the vehicles going for 124 miles (200 kilometers).

Loop Energy has taken a different approach, adding fuel cell range extenders to hybrid trucks. The business was joined by Andreas Truckenbrodt, who used to be the chief executive of Daimler and Ford's former joint venture Automotive Fuel Cell Corp. and is still the president of the Canadian Hydrogen and Fuel Cell Association. Having added fuel cells to two Peterbilt 579 vehicles, it has scheduled tests this spring in California.

British-based ULEMCo, on the other hand, wants to do away with fuel cells altogether and use hydrogen only. It is currently coordinating a project called "Hydrogen Truck Implementation for Maximum Emission reductions," or HyTIME for short, whose aim is to replace diesel fuel with hydrogen. The two-year venture will make use of a technology called H2 Dual Fuel H2ICED®, which is to be tested in different vehicles and cities, such as Aberdeen. ||

Category: Research & Development | **Authors:** Momoko Kristuf, Marcel Corneille

MEASURING UP TO STANDARDS

How to Increase public acceptance through clean fuel

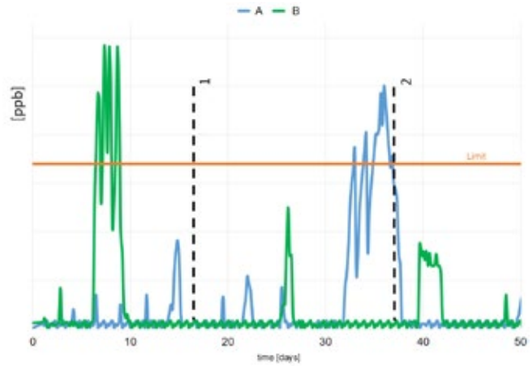


Fig. 1: Constant monitoring will record all impurities. While sample measurements may record them as well (substance A), they might also be overlooked (substance B). This is especially problematic if these impurities exceed threshold values set out in the relevant standards.

Measuring the quality of hydrogen is often, unjustifiably, viewed as time-consuming and expensive. Rather, it helps to better understand and improve technical processes. The path to regular quality measurements of hydrogen is being intensely debated as we speak. Fuel cell manufacturers demand from hydrogen producers that the gas meets very high purity requirements to prevent damage to their fuel cells. In turn, producers of hydrogen are calling for more robust fuel cell systems to be able to decrease purity and cut costs.

Current discourse often ignores the reason why quality assurance is important to the entire industry. It serves to engender trust in the technology as an increasing number of hydrogen systems are becoming available for sale. Thus, measurements should first and foremost benefit the users of these systems.

WHY MEASURE? More and more fuel cell vehicles are being brought to market these days. A failure of these first consumer fuel cell vehicles could severely tarnish the reputation of an emerging hydrogen economy. This alone should be reason enough to implement measures to ensure that the hydrogen is of high quality.

Low-quality gas could damage not only fuel cells but also other components in the process chain. For example, frozen impurities could put seals and valve heads at risk. Storage systems, such as metal hydride tanks, could suffer as well.

To prevent damage, it is important to conduct regular quality inspections along the supply chain. This is equally true for traditional fuels: Even today, they are still tested in regular intervals. Leading oil corporations have said that they test their fuels for harmful substances at least 6,000 times a year. These inspections cover everything from production, transport and distribution to refueling at gas stations and ensure that the technical processes involved in supply chain management are highly efficient and cost-effective.

WHAT SHOULD BE MEASURED? Besides measuring hydrogen quality, current debate focuses on what kinds of hydrogen impurities these tests need to consider. In transportation, the key standards are DIN EN 17124, ISO 14687 and SAE J2719. They list a variety of impurities, such as

· Sulphur compounds
· Hydrocarbons
· Inert gases
· Oils and fats

Regular testing for all impurities listed in the standards would be both time-consuming and expensive, which is why a suggestion has been made regarding DIN EN 17124 to compartmentalize quality inspections. This means that the inspection would focus only on hydrogen impurities that could be found in harmful concentrations and are thus likely to occur.

The likelihood of impurities needs to be determined individually for each process chain. A consequence of this could be that halogens should be ignored when testing systems using PEM electrolysis, where they are not present, and instead concentrate on the proportion of oxygen and water contained in the gas.

WHICH METHOD TO USE? In principle, two methods could be used to measure impurities. One is a sample inspection in the laboratory and the other is constant monitoring on site. Both have their benefits and drawbacks.

Sampling hydrogen quantities means removing an amount of gas from the production system and analyzing it in the laboratory. This

\+ is inexpensive (if few samples are taken)
\- could mean that temporary impurities are overlooked
\- hampers process optimization because of the time between sample-taking and analysis
\- may cause some impurities to be no longer visible because of condensation

Constant monitoring means measuring the hydrogen on-site throughout a set period, such as two weeks. This
\+ improves understanding of the process
\+ allows for the observation of impurities over time
\+ makes it possible to assess the impact of process improvements immediately
\- is more expensive than sample-taking

Constant monitoring allows for a better understanding of the process. For this reason, it is recommended that the hydrogen system be analyzed initially by taking repeated measurements. As soon as the process has been thoroughly investigated and the hydrogen has been found to be of high quality over a longer period will it be possible to increase measurement intervals. Afterward, even sample-taking methods will guarantee sufficient quality assurance.

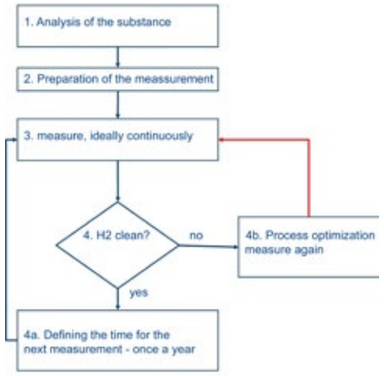


Fig. 2: Series of measurements

WHAT DOES A SYSTEMATIC SERIES OF MEASUREMENTS LOOK LIKE? One suggestion for how to conduct a series of measurements is shown in figure 2.

1. First, determine which impurities could be found in the gas in damaging concentrations (as explained above).
2. Then, prepare the measurement, for example, by installing measuring points.
3. When preparations are complete, conduct measurements.
4. a) If the hydrogen is sufficiently pure, set a date for the next inspection or b) if impurities are detected, track down their sources and make relevant improvements.

Some options for making the system fit for purpose could be to

· Substitute materials
· Replace process fluids
· Clean components
· Change process parameters such as pressure, temperature, etc.
· Integrate filtration units
· Adjust maintenance intervals

When the system has been optimized, the hydrogen quality is to be inspected a second time to verify that the measures were implemented correctly. When using constant monitoring, most measures can be evaluated for their effectiveness in a short time.

REAL-WORLD EXAMPLES A manufacturer of electrolyzers intends to determine the purity of the hydrogen delivered, with the suspicion that despite the usual filtration methods, the gas contains traces of ammonia. For this reason, it conducts the following systematic set of measurements.

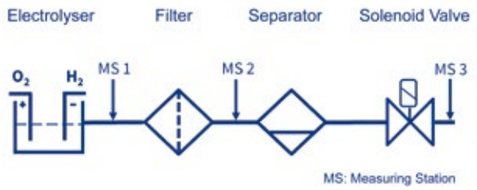


Fig. 3: Schematic diagram of electrolysis

1. First, it identifies the components that could come in contact with hydrogen and analyzes the impact that impurities could have on them. It determines that besides ammonia, the gas might also contain complex hydrocarbons. Based on these findings, the manufacturer sets meaningful measurement points. A simplified diagram of all electrolyzer components and relevant measurement points is shown in figure 3.
2. Based on the selection of possible impurities, a device is chosen to test for both ammonia and complex carbohydrates. This device is integrated into a portable outdoor cabinet and is controlled remotely (see fig. 4) to allow measurements of hydrogen quality at different points along the electrolyzer.
3. Subsequently, hydrogen quality is measured after the gas has passed through the relevant electrolyzer components. The findings are as follows:

· Measurement point 1: The hydrogen contains notable traces of ammonia.
· Point 2: Despite the filtration system, the gas still contains traces of ammonia. However, they are not found in the same concentration along the entire gas flow.
· Point 3: The hydrogen contains traces of lubricants. They can be traced back to a magnetic valve.

4. Depending on the findings, different measures can be used to raise hydrogen quality:

· Installing an improved filter can prevent the occurrence of ammonia.
· Grease can be used to lubricate the magnetic valve: Thoroughly cleaning the valve can prevent traces of grease (that is, complex carbohydrates) from entering the gas stream.

CONCLUSION Systematic measurements at different points along the process chain make it possible to identify all sources of impurities. From these measurements, technical improvements can be derived and tested.

For example, the electrolyzer manufacturer mentioned above needs to conduct regular quality inspections to validate the measures that it implemented and ensure that the hydrogen retains its quality in the long term. From these inspections, it gains a great deal of expertise about the technical processes involved. Consequently, it can optimize components and service and inspection intervals to lower operating and maintenance costs. ||

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

HOW TO RESHAPE THE ENERGY SECTOR

EUR 6.4 billion for 7th Energy Research Program

Fig. 1: Svenja Schulze [Source: BMU]

In the fall of 2018, the German government announced it would provide about EUR 6.4 billion between 2018 and 2022 under its 7th Energy Research Program. This is around 45 percent more than what it allocated to the prior program from 2013 through 2017. The new budget reportedly includes funds for living laboratories and projects involving fuel cells, energy storage, hydrogen technologies and energy systems integration.

The seventh program of its kind was passed by the German parliament last September, and the related funding announcement was published in the federal gazette on Oct. 18 the same year. Documents that outline relevant projects can be submitted to Projektträger Jülich.

It may look like a great start to a new era, with the economy, education and agriculture ministries pouring vast amounts of funding into energy research. But that image is a mirage. The mood in the energy sector is far from euphoric. Uncertainty has pervaded the industry: Companies have no idea whether to invest – and where. And the government seems to lack direction, since it still has no clear objective, which also means it has yet to draft a road map to the transformation of the market.

One question that still needs to be answered is who in the coalition is actually in charge of energy policy. If you go by department name, the economy and energy ministry should be taking over the reins. But as most energy efficiency measures will probably not be very conducive to growth, it is merely limping along. If decisions were made by the environment ministry instead, things would most likely be different: Environment minister Svenja Schulze took a much assertive approach than her colleague in the economy department, Peter Altmaier, when discussing EU limits on carbon dioxide emissions from new vehicles or debating policy at the climate summit in Katowice, Poland. This shouldn't be a surprise, considering the economy minister needs to take the interests of German businesses into account and cannot be seen as the one who cost people their jobs.

FOR OR AGAINST SYNTHETIC FUELS? The ministries also disagree on how to approach e-fuels, that is, synthetic fuels produced from electricity. Staff at the environment ministry, skeptical of their environmental and economic benefits, has been rather cautious about funding them, criticizing that "the sustainability of synthetic fuels sourced from electric power hinges on the availability of efficient production processes and renewable raw materials. Even if created using renewable electricity, these fuels could undermine efforts to protect the climate should they cause a gap in power supply, for example, in households and industry, and bridging this gap would require the use of fossil fuels to generate electric power."

One expected drawback was their "continued high cost compared to other technologies," the ministry said. As for using excess energy to produce them, it stated that "the requirement for curtailing the output of renewable power plants, now and in the coming years, to ensure grid reliability means, in the opinion of this government, that power-to-gas and power-to-liquid systems cannot become economically viable at this time." The decision on whether e-fuels could be offset against carbon dioxide emissions from passenger cars and light commercial vehicles has therefore been postponed to 2023. Likewise, the government has declined to make them exempt from energy taxes.

DIRECT OR INDIRECT HYDROGEN USE?
One recurring and major problem is that e-fuels are often mentioned in the same breath as hydrogen, although both don't necessarily go hand in hand and, in some areas, represent entirely opposite development pathways. For example, you can create e-fuels from hydrogen produced in electrolyzers from renewable electricity and fill up conventional ICE cars with them. While it is true that these fuels release less carbon dioxide than gasoline or diesel, they aren't exactly clean either. By contrast, feeding renewably sourced hydrogen directly into fuel cells, as is done in FCEVs, would lay the foundation for an electric but zero-carbon future ending the reign of internal combustion engines.

The thinking behind this may be that incentives for e-fuels would prevent a swift exit from internal combustion engines, which would be well received by automakers but slow down the transformation of the vehicle market.

The economy ministry seems a bit more open-minded toward these new energy carriers, exactly because they would benefit automakers. Nevertheless, there is still an intense debate about what measures are required to support their introduction to the market.

STAFF SHAKEUP AT THE ECONOMY MINISTRY
In 2018, Rainer Baake asked to be relieved of his position at the economy ministry, reportedly because he was dissatisfied with the objectives set out in the government's coalition agreement. For a long time thereafter, it was unknown who would replace him as second-in-charge of the department. On Feb. 1, Andreas Feicht took on the position. His responsibilities include energy policy and IT. Prior to being the vice president of municipal company association VKU for six years, he was the chairman of WSW Energie & Wasser, the chief executive of WSW Wuppertaler Stadtwerke and the head of WSW mobil.

When asked by H2-international, the economy ministry replied, "Multiple energy scenarios have indicated that synthetic fuels created from electricity will be crucial to transforming the energy sector if ambitious targets are to be met or when the energy system has mostly been decarburized. Since biomass resources will be limited in the future, some application areas could, to our knowledge, not become zero-carbon markets in any other way. This concerns energy generation in aviation and shipping, partly in heavy-duty trucking and in several industrial subsectors. As a result, synthetic fuels, as well as hydrogen, will need to be tested and improved to ensure that supply can meet demand in the long run."

In this context, the department's media relations office pointed to a variety of measures, such as the SINTEG – Smart Energy Showcases project, that would help with researching, developing and demonstrating technology to transform the energy sector. Likewise, the 7th Energy Research Program would lead to the creation of living laboratories focused, among other things, on "synthetic fuels and innovative hydrogen technologies." Thomas Bareiß, who works at the economy ministry, described these labs as "islands free from regulatory compliance." The latitude they offered, together with the financial support they would receive, would create an environment similar to that for startups getting public funding. Thus, they could, in a few places and for a certain amount of time, become testing grounds for innovative solutions and new legislation on blockchains, artificial intelligence, autonomous driving and logistics solutions.

There are differing opinions on whether living labs are the right idea at this time. While some have been calling for more research and testing to be done before these new technologies are brought to market, others believe gathering some practical experience is long overdue. The deadline for submitting proposals for living labs in the first funding round was April 5, 2019.

CARBON EMISSIONS TRADING By contrast, there are more and more calls for pricing carbon dioxide emissions, in a way similar to what the UK did by introducing a minimum carbon price. It is true that since the beginning of 2018, carbon allowances in the European Union have tripled in price to around EUR 20 per metric ton of carbon dioxide. However, they are still relatively cheap. Nevertheless, they are expected to become more expensive in the foreseeable future: Starting this year, the EU will take 24 percent of all excess allowances off the market, with the aim of having its cap-and-trade system contribute to climate protection by around 2020.

In addition to environment minister Schulze, the German equivalent of the Government Accountability Office is also advocating for raising the cost of emitting carbon dioxide. Pricing these emissions, it said, would be simpler and more transparent than the current system of research and demonstration funding. Its comptroller general, Kay Scheller, spoke of "a subsidy jungle," which had led to a thick underbrush of complicated and unnecessary funding opportunities that were "everything but comprehensible." He criticized that the situation had resulted in many programs not exhausting their budgets. One example was the support given to electric vehicles, about which the auditors said that "in 2017, EUR 600 million were allocated to programs that did not require funding" and that "eight out of 16 programs saw less than 50 percent of their budget being spent."

ECONOMY MINISTRY VERSUS ACCOUNTABILITY OFFICE A press release by the office read that "despite making considerable personnel and funding resources available, Germany is not on route to meet most of its aims regarding the transformation of the energy market. […] In the view of the economy ministry, there are no actions to take at present, since it believes that it has been efficient and effective in coordinating the transformation between stakeholders and across organizational levels. We do not share the ministry's view considering its obvious, and sometimes drastic, failure to meet objectives, while it has demanded much from businesses, the public sector and consumers. The minister and his staff display a lack of decisiveness and an unwillingness to do what needs to be done to transform the market in a sustainable and economically prudent manner. This shows a crucial lapse in judgment on the part of the ministry. Rectifying the situation would require an organizational structure that covers all associated responsibilities while providing as much latitude for decision-making as possible."

In response, the economy ministry told H2-international that "the accountability office has leveled that kind of criticism at us before. We, however, disagree with its findings, both in regard to the merits of its argument and the methods by which it arrives at its conclusions. We are precisely where we want to be when it comes to the percentage of renewable electricity among all electric power consumed. We have made grid expansions much more cost-effective by changing to requests for proposals to grant funding. And we have succeeded in keeping surcharges on renewable sources of energy at prior levels. The price of carbon dioxide has finally risen as well, so that allowances can start contributing to climate protection. Plus, Minister Altmaier has travelled across the country to determine where to increase energy generation capacity and successfully negotiated with each state about making a concerted effort to accelerate the process. He has also unveiled an action plan for the national grid. After years of standstill, he has now set us on a path to lower costs for stabilizing our energy system. All of these are incredible milestones that underline the success of Germany's energy market transformation." ||

"It is the view of this office that the methods for coordinating and guiding the energy sector transformation will require notable improvement. The government must act. Else, it could leave a lasting impression nationally and internationally that Germany is incapable of successfully drafting and implementing measures that ensure all of society will be have long-term, reliable access to energy."

Germany's government accountability office

Category: Policy | Author: Sven Geitmann

BROAD SUPPORT FOR EFFICIENCY FIRST

Parties' views on fuel cells, hydrogen and power-to-gas

The idea of using hydrogen as energy storage entered the political mainstream a long time ago. The coalition agreement between the Christian and the Social Democrats in Germany includes several direct references to hydrogen and fuel cells, while a few other parties have made the technologies part of their platforms as well. Still, how a party approaches both is a matter of where it falls on the political spectrum. H2-international has spoken to a number of German politicians about their views of the two energy carriers and summed up their answers below. It should be noted, however, that this article can provide only a snapshot of today's political landscape, as not everyone responded in time.

You might think that establishing a hydrogen economy would be an aim rigorously pushed by the Greens, since hydrogen and fuel cells are often associated with eco-friendly solutions, one of the party's core objectives. But there is little to indicate that this is actually true. So far, members of the Green Party have mostly ignored both technologies and put out too few statements for anyone to hazard a guess what their opinion might be.

BÜNDNIS 90/DIE GRÜNEN (THE GREENS)

In an interview published in the October 2018 issue of H2-international, the co-chairman of the Greens, Robert Habeck, shed some light on where his party stands regarding hydrogen and fuel cells. His fellow party member Hans-Josef Fell, who co-sponsored the Renewable Energy Sources Act, told H2-international that hydrogen was "definitely an important option, in addition to a few others." He noted that besides passenger cars, there were "many markets, such as those for buses, railroad vehicles, airplanes and basic chemicals, where solar hydrogen will play a crucial role." However, he also remarked that putting up the fueling stations required for it would be "a difficult hurdle to overcome."

FDP (FREE DEMOCRATS)

By contrast, the Free Democratic Party has stated much more clearly what it thinks of the technology, as those living in German towns and cities can often be heard saying that the FDP's pragmatic approach to transforming the energy sector is what helped move along local hydrogen and fuel cell projects. Its spokesperson for energy and chair of the agriculture and environment committee in the state of Schleswig-Holstein, Oliver Kumbartzky, said that "one of our state party's long-term objectives is to establish a hydrogen showcase region on the west coast of Schleswig-Holstein. We want to support projects that demonstrate or research the technology or help coordinate development. We believe hydrogen is a good way forward. Unlike today's resources, it produces no harmful emissions and will create much economic prosperity and wealth for the citizens of our great state."

At the federal level, the party advocates allowing synthetic fuels produced from electricity to be offset against carbon dioxide emissions from passenger cars and light commercial vehicles. Recently, Lukas Köhler, a member of the FDP in the German Bundestag, was quoted by the Handelsblatt magazine as saying that "spending every ounce of political capital on pushing one single mode of transportation, that is, electric, is entirely absurd. If we really want to lower the impact of vehicles on the climate, we need to put all options on the table." He went on to say that "if the federal government wants effective climate protection, it needs to argue in favor of including synthetic fuels in emissions calculations during its joint talks with the EU council, commission and parliament. I would think that the CDU in particular would support this goal. During the meeting of the states' transportation ministers, the party voted to advance a petition by the FDP-led ministry in Schleswig-Holstein to have synthetic fuels offset emissions. Of course, the most sensible solution would be to make the transportation sector part of the EU's cap-and-trade program, which would render these kinds of discussions irrelevant."

> "When the Greens, the Social Democrats and the Free Democrats held talks about forming a coalition, a fellow party member of mine in the German parliament, Wolfgang Kubicki from Schleswig Holstein, needed to explain to Anton Hofreiter of the Greens that hydrogen cars do exist alongside battery-electric vehicles."
>
> *Berthold Brodersen, chairman of the local FDP in Northern Friesland*

CDU (CHRISTIAN DEMOCRATS)

Local members of the Christian Democratic Party have been saying for some time that "energy is one of the key issues for SMEs." As for storing that energy, Uwe Feiler, who represents Oberhavel County in parliament, thinks hydrogen could be a sensible way forward. According to him, Germany's economy minister, Peter Altmaier, has a fairly positive view of the technology. Heribert Hennemann, who worked at the CDU's national office but who sadly passed away in August 2018, told H2-international in July of the same year that his party aimed to

- Support the transition from researching and developing hydrogen systems to constructing pilot plants and bringing the technology to market. It also intended to expand the living laboratories, for example, on power-to-gas and power-to-liquid, so they could become another pillar of energy research.
- Continue the National Innovation Program Hydrogen and Fuel Cell Technology, or NIP for short.
- Ensure that the transportation and fuel strategy, also known as MKS, covers every technology relevant to the energy market transformation and increase the budget for its implementation.
- Promote energy systems integration and implement new regulations that will make it possible to turn renewable hydrogen and hydrogen produced by industrial processes into fuel or a base for traditional fuels, such as natural gas.
- Increase the deployment of electric means of transportation, including battery, hydrogen and fuel cell vehicles, across Germany and extend and add funding opportunities, where required, beyond 2020.

As for the cost of power-to-X, he said that "we are going to take a closer look at what changes need to be made to surcharges and fees in the foreseeable future, so we can develop the market and further our aim of bringing together a wide range of energy carriers." It was important to him that electricity remained affordable to both businesses and consumers in the long run. He added that state-of-the-art energy storage devices would be vital to the success of the market transformation and added that his party supported "the switch to new modes of transportation. We will keep an open mind regarding new fuel and drive options, such as electric and fuel cell devices. Likewise, we will continue to support the establishment of a wide-ranging network of charging points and filling stations to bring electric and hydrogen-powered transportation to every part of the country."<<

DIE LINKE (THE LEFT)

The Left has been supportive of NIP as well. However, regarding the large-sale introduction of hydrogen to the passenger car, heavy-duty truck and rail markets, Christina Kaindl, who leads the strategy and policy division at the party's national office, sounded cautious, instead calling on the government to take NIP in a new direction. She was just as skeptical of power-to-gas, remarking that power-to-X systems were rarely fueled by sustainable sources of energy alone. She said, "We regard the broad adoption of power-to-X not only as superfluous at this time but as detrimental to the transformation of the energy sector." If at all, the government should introduce experimental provisions to change surcharges and fees, she added.

The Left believes that bringing together different energy systems will be required only when over 70 percent of all energy is generated from renewable sources, that is, after 2035. Still, it intends to see power-to-gas capacity grow by what it regards as economically prudent, which would mean 50 megawatts of electrolyzers a year from 2020 to 2025. Its aim is to have around 40 gigawatts put up in Germany by 2040 at the latest. Kaindl said it was the reason why "we are against a large-scale roll-out at present. Still, we support limited funding as long as we believe it will allow us to move forward responsibly."

She added that "directly using each kilowatt-hour produced from renewable electricity is a much more efficient way to displace coal or nuclear and transform the energy sector than using this valuable commodity to produce gas and fuel, or heat, while wasting energy. Regarding the fuel issue, it would be more effective to sell cars that run on clean electricity and build enough charging points than to keep ICE vehicles on life support by promoting a grotesquely inefficient supply chain that revolves around synthetic fuel created from electric power. Likewise, it would be more reasonable to push coal power plants, not gas systems, out of the heat market. This would lower carbon dioxide emissions per kilowatt-hour by an additional two-thirds."

The Left favors battery-electric vehicles over fuel cell cars. Their efficiency is around 70 percent compared to 26 percent for FCEVs, since much energy is lost when generating electric power in fuel cells. "This may not only be questionable economically but also limit public acceptance," Kaindl said. She expects all-electric vehicles to play the key role in the auto market, at least regarding passenger cars, and said that charging points could therefore be funded by the government. However, she was strictly against incentivizing electric cars, which is in line with her party's view of not using public funds to support privately owned vehicles. As a result, she also rejected the idea of putting up hydrogen stations for fuel cell vehicles, since they would put a big dent in the public budget. Likewise, she was not at all in favor of synthetic fuels, noting that they would, again, be used in inefficient ICEs.

She added that her party "agrees with the government's Efficiency First slogan. If taken seriously, this approach would afford neither fuel cells nor electricity-sourced fuels the room that some interest groups think they have and demand they should." The Left sees opportunities for fuel cell use in the maritime, aviation and heavy-duty truck industries, in emergency and forestry vehicles, and in heaters. "As for all other application areas, fuel cells and power-to-X have long since lost to direct drive and battery-electric motors," she said. "One explanation for it is their extremely low efficiency, which is governed by the laws of physics, no less. We don't believe it is very reasonable to try to make up for that difference in efficiency by providing direct or indirect subsidies. What this means is that we no longer regard some technologies as competitive, and we aren't going to change our minds about it anytime soon."

SPD (SOCIAL DEMOCRATS)

Andreas Rimkus, the deputy spokesperson for the Social Democratic Party in the Bundestag, has been the most vocal proponent of a hydrogen economy among the party's members, often portraying himself as belonging to parliament's "secret hydrogen society." Last fall, he published a position paper to argue his case for integrating the electricity, heat and transportation markets and promoting power-to-gas. ||

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

AN ENERGY INDUSTRY ROAD MAP

Coal Commission to push for hydrogen and power-to-gas

A few months ago, Germany's Commission on Growth, Industry Restructuring and Employment published its final report, suggesting that the country phase out coal power production by 2038. The document, presented to the public on January 26, recommends replacing most of today's generation capacity with gas-fired power plants. Additionally, its authors call for assisting regions affected by the changes.

One Coal Commission proposal is to stop approving the construction of new coal power plants, while another is to lower current generation capacity. At present, power plants burning brown coal have a combined capacity of 19 gigawatts and those fired by black coal provide a total of 22 gigawatts. The commission recommends cutting those numbers across Germany to 9 gigawatts of brown and 8 gigawatts of black coal by 2030 and reducing the capacity of both to zero by 2038.

It seems that the commission regards hydrogen storage and power-to-gas systems as solutions that show great promise and could become a crucial part of a future energy

Fig. 1: Plans are to stop using the huge bucket-wheel excavators for mining brown coal in the foreseeable future, [Source: obs/Kabel1]

> "Germany needs a consensus view that has the support of a majority of the public and ensures a balanced and just transition to a new energy system guaranteeing supply over the coming decades. Reaching such consensus among all stakeholders in the sector is the only way certain to provide a predictable and reliable framework for the sector and give impetus to transforming the German energy system over the long term."
>
> *Commission on Growth, Industry Restructuring and Employment*

system. Moreover, the associated technologies are available in Germany's coal mining regions today and could provide them with excellent opportunities for job creation and economic development.

The commission's 336-page report mentions hydrogen more than 50 times. Power-to-gas and power-to-X show up 15 and 18 times, respectively. Some concrete suggestions are:

- Research storage technologies and power-to-X processes.
- Use power-to-gas to support middle Germany's natural gas pipeline system.
- Establish a Fraunhofer research institute on energy infrastructure (at BTU Cottbus-Senftenberg or Zittau/Görlitz University) and build a reference plant for hydrogen production.
- Expand the applied research center at BTU or Zittau/Görlitz University to provide more opportunities for studying hydrogen technology.

Living labs or showcase regions to demonstrate zero-carbon energy generation could be built in the Lausitz, the Helmstedt or the Rhein Ruhr area. Organizations to help implement those projects are named in the document. They include HZwo, Hypos and Energy Saxony.

Among the concrete plans are proposals to build a power-to-x system at Fraunhofer IMWS in Leuna and a pilot installation at TU Bergakademie Freiberg. The government could also support large-scale hydrogen production in the Lausitz Energy Cluster, or LCE for short. And Cottbus intends to offer zero-carbon mass transit under the motto "hydrogen keeps you going." Additionally, hydrogen trains might run between Borsdorf and Grimma, or even the entire way between Leipzig and Zeitz, at some point in the future.

Funding support for restructuring is seen as a potent means to help coal regions develop a modern, sustainable energy industry. In all, EUR 40 billion have been allocated for assisting those areas – most of all, Lausitz but also Rhineland – until 2040.

The Coal Commission's final report, however, makes only recommendations about how to forge ahead with the transformation of entire regions. In short, the document is not binding. As a next step, a package of bills will be presented to parliament for approval.

Timm Kehler, chairman of the Zukunft Erdgas advocacy group, said the time was right to flesh out the details of the legislative proposal by including a specific target for green gas generation capacity. All in all, he believes it is a good sign the commission suggested advancing the integration of the electrical and gas grids through putting up power-to-gas systems. However, Hans-Josef Fell, the co-sponsor of the German Renewable Energy Sources Act, stated that the commission had failed to come up with appropriate policy solutions to protect the climate, adding that the authors of the report barely took note of climate-induced factors. Additionally, the chairman of Eurosolar, Axel Berg, lamented that the targets set out in the Paris climate accords would be fulfilled neither in 2020 nor in 2030 should the government adopt the commission's suggestions as they were. Rather, he added, they amounted to a rejection of the COP21 goals, since they would again slow down the transformation of the energy sector. ||

> "The commission's final report provides us with the first road map for transforming our region. We now intend to take an active role in the process. As noted in the report, hydrogen and fuel cells offer the economic viability and usefulness we desire. We see it as an opportunity to turn the Lausitz into a national showcase region. Such a project would be a key component of our strategy to deal with the impact of Germany's exit from coal power production. What we need now are regulations to be able to implement all those ideas."
>
> *Ralf Thalmann, chief executive of Cottbusverkehr*

Category: Rules & Regulations | **Authors:** Gerd Harms, Dennitsa Nozharova

HyLaw IDENTIFIES BARRIERS TO GROWTH

Rules and regulations in Europe

Abb. 1: An HyLaw beteiligte Länder

The aim of the EU-funded HyLaw project is to promote the launch of hydrogen and fuel cell technologies by giving stakeholders a detailed overview of current regulations and showing political decision makers where the sector is faced with legal barriers to growth. Coordinated by Hydrogen Europe, it is the EU's first project that focuses on regulatory issues concerning hydrogen production and sale.

In all, 23 partner organizations are working on the HyLaw project, funded by the Fuel Cells and Hydrogen Joint Undertaking (see fig. 1), with the representatives for Germany coming from hydrogen and fuel cell association DWV. In early 2017, the participating researchers began identifying rules and regulations relevant to hydrogen and fuel cells and the legal barriers to market these technologies. This first project stage focused on hydrogen production, storage, transport and supply, as well as fueling stations, vehicles, pipeline injection, electrolyzers and stationary fuel cells. Other topics, including hydrogen trains, river watercraft, the national pipeline system and underground storage will be addressed at a later stage.

In contrast to other EU member countries, Germany has already had an apt and detailed regulatory framework in place, including numerous laws, regulations, standards and worksheets on relevant rules. Usually, they serve their purpose and are clear enough to be understood. Nevertheless, the wording of some of them is imprecise, or leaves room for misinterpretation, which leads to risky investments or much effort and too many resources being spent on regulatory procedures. The following paragraphs will be used to provide some examples.

HYDROGEN AS FUEL Since January 2018, organizations have been able to offset hydrogen or synthetic natural gas, or SNG for short, against GHG amounts released into the atmosphere. The rules for crediting those amounts are found in Sec. 3 (2) of the 37th BimSchV federal pollution regulation. However, their narrow and impractical definition does not provide an impetus for the hydrogen market. As a consequence, the ambitious aims for transportation, set out in the new EU-wide Renewable Energy Directive II, would, in all likelihood, not be met.

In addition, there is no EU-wide country of origin certificate for renewable hydrogen, making it more difficult or even impossible to guarantee adherence to rules on emission allowances and trading. This is why the European Commission has been asked to develop such a system of origin, which would be applied especially to hydrogen that is produced through water electrolysis by drawing electricity from the public grid.

Purity requirements for hydrogen as fuel in vehicles are laid down in international standards SAE J2719_201511 and ISO 14687-2. The regulation governing the expansion of alternative fuel infrastructure, also known as AFID, references the ISO standard, binding all EU countries. At present, however, few independent laboratories in the world can inspect materials at the level of purity required by the standard. Should the current situation prompt several EU countries to set differing requirements, separate markets will emerge, which could severely limit the commercial use of hydrogen in the vehicle market. The European Industrial Gases Association, or EIGA, and the ISO/TC 197 committee have already begun preparing a revision of the pollution limits specified in the standard. Their efforts need to lead to practical results as soon as possible.

OFFICIAL CALIBRATION OF FUELING STATIONS The official calibration of throughflow meters has faced issues related to the special properties of hydrogen as an energy carrier. Flow quantities, which are measured in kilograms, vary by temperature and the number of subsequent refills. Together with the calibration agency, stakeholders will need to devise a practical method for standardizing measurements in a way that meets the needs of fueling station operators and respects the rights of consumers.

APPROVING ELECTROLYZERS EU Directive 2010/75/EU on emissions from industrial facilities was transposed into German law via the Federal Pollution Prevention Act and a namesake regulation. The former is known as the BImSchG and governs systems that require approval, while the latter, called 4. BlmSchV, specifies those systems. Attachment I, or Anhang I, of the 4. BImSchV classes systems for hydrogen production under section 4.1.12, Production of Gases at Industrial Scale.

The construction of systems at an industrial scale is subject to a time-consuming, public approval process based on Sec. 10 of the BImSchG. What "industrial scale" is, however, has not been defined yet. The failure to address this issue could lead each German state to define different requirements and procedures for approval, creating an impediment to sensible standardization.

Some electrolyzers were built for the sole purpose of researching, developing or testing new substances, fuels, products or procedures in the laboratory or pilot stage according to Sec. 1 Para. 6 of the 4. BImSchV, without a formal approval procedure based on the BImSchG. However, because of sufficient technology readiness and a growing number of fueling stations, these kinds of exceptions will soon barely be possible when constructing new electrolyzers. Thus, it would be necessary to provide a threshold value for production at industrial scale. The closest equivalent may be to tie electrolysis capacity to real-life storage quantities. Exceeding 3 metric tons of storage would, in any case, require a special BImschG-based approval process, which means that a limit of between 1 megawatt and 1.5 megawatts of capacity would be appropriate for creating simplified procedures.

POWER-TO-GAS Two primary power-to-gas processes are the production of hydrogen through electrolysis and that of synthetic methane. Produced from renewable electricity, both could be used in vehicles, industrial facilities, heating and electric power generation. The sector-crossing aspect of power-to-gas links the technology to the electrical grid and the gas network, as well as their respective markets. The rules about unbundling, that is, the separation of energy production from transmission management, included in the EU electricity directive 2009/72/EG and the EU natural gas directive 2009/73/EG, apply to power-to-gas systems. Both directives have been transposed into national law in Germany and are part of the country's energy legislation.

However, because power-to-gas is not only a means to convert energy to create a gaseous energy carrier, but also a method for storing store that energy, it needs to be determined if it is subject to the newly proposed EU electricity directive, which contains new rules on unbundling to separate storage from transmission.

To create a set of rules on the use of certified green electricity from the public grid in power-to-gas systems, it will not only need a single definition of power-to-gas, but EU legislation will also have to contain definitions to specify property-related unbundling rules that cover the electricity and gas markets. The European Commission regulations on national environmental and energy subsidies beyond 2020 need to be adjusted as well, so that they include the production of hydrogen via electrolysis for use as fuel and industrial base material in the list of markets that require a great amount of electricity. Additionally, Anhang 4 of the Renewable Energy Sources Act should be changed to allow multi-year permits to reduce the surcharges that the law places on electricity taken from the public grid. >>

FINAL RESULTS OF THE EU WORKSHOP

1. Hydrogen fueling stations: In many European countries, approval for hydrogen fueling stations takes a long time and incurs a great deal of cost. Additionally, project developers are not certain of the rules. Harmonizing regulations in Europe is urgently needed. Denmark, Germany and the Netherlands were used as examples of how to advance standardization and create a reliable setting for investment. It was emphasized that political considerations would decide whether a member country supports a hydrogen economy.

2. Gas pipelines: In the future, energy supply will undoubtedly be linked to the gas industry and the conversion of the gas grid for increased hydrogen usage. The legal issues surrounding hydrogen use have to be addressed now. Key points mentioned were proof of origin, a sole definition of power-to-gas from a legal perspective, the basics for an integrated energy system and the possibility of injecting hydrogen into the pipelines. At the EU level, differing regulations on grid injection in the member countries represent a great impediment to energy transmission across national borders and the integration of a future European pipeline system.

3. Maritime industry: There are currently no discernible rules on maritime operations. The ongoing revision of IMO regulations does not involve hydrogen. The International Maritime Organization restricts itself to rules on liquified natural gas. This means that sea or transport ships powered by fuel cells can only be approved via the Alternative Design process, which is a time-consuming and expensive procedure. Thus, an important pathway to decarburizing the shipping industry is currently unavailable. The IMO codes should be revised further. This, however, would require answering numerous technical questions, which are everything but trivial. The same is true for rules on refueling and loading hydrogen ships and the requirements for maintenance and inspections.

LIVING SOURCE OF INFORMATION HyLaw has been the first project to provide an overview of the legislative framework in 17 European countries. The related workshop held on Dec. 6, 2018, illustrated the differences between these countries with regard to national laws and the transposing of EU legislation. The researchers working on HyLaw have compiled 55,000 data records to reflect current trends and allow for comparisons between all partner countries. The aim now is to determine whether specific barriers and limitations are bound to arise from justified claims (e.g., safety and consumer protection) or whether they place undue restrictions on further advancement.

The data records and their interpretations have been made available to give everyone the chance to contribute suggestions for improving them. They mark a starting point, a living source of information, that allows users to comment and propose additions or changes. These comments from individual countries will later become part of the National Policy Papers of the 17 partner countries. An EU Policy Paper will be published soon as well. ||

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Both for Deutschen Wasserstoff- und Brennstoffzellen-Verband e. V.

Category: International | **Authors:** Franz Lehner, David Hart

FUEL CELL INDUSTRY MOVES AT RAPID SPEED

Fuel Cell Industry Review by E4tech

January saw the publication of the Fuel Cell Industry Review 2018, including market figures and analyses. The review was created by the team of E4tech, which has contacted fuel cell companies once a year since 2014 to provide an independent overview of the fuel cell market based on aggregated shipment numbers. Below are some excerpts from its report.

In 2018, fuel cell system sales continued to grow. In all, companies shipped 74,000 systems, around 4,000 more than in 2017. The same kind of trend could be observed with regard to generation capacity, which grew by 145 megawatts to around 800 megawatts. All figures include estimates for the last three months of the year, which means they may still be revised before the actual totals are published in the 2019 review.

Shipments have increased steadily year after year, especially in the vehicle sector. In light of the attention that hydrogen and fuel cells have received, one may wonder why the market has not (yet) experienced exponential growth. In this context, it should be noted that a large part of current production was prompted by two crucial factors: For one, strategic considerations had pioneers such as Toyota, Honda and Hyundai fund fuel cell RD&D themselves. For another, the regulations on stationary systems, as well as public funding in South Korea, Japan, North America and now Germany, have contributed to making the technology competitive.

Despite growth in past years, fuel cells remain a niche product compared to traditional solutions in the markets for vehicles and stationary power generation. Still, the rate at which partnerships, investments and projects are and have been announced should be seen as a positive sign: Even if it hasn't yet resulted in higher sales, it does show that businesses are laying the foundation for future growth.

In all, the authors of the E4Tech report contacted more than 100 companies for their yearly industry survey and compared responses with publicly available data to fill in information where necessary. The count in the vehicle sector, however, stands for the number of vehicles manufactured not for the fuel cell modules sold.

AUTO SUPPLIERS SEE SIGNS OF THE TIME Policies for protecting the climate and improving air quality are important, long-term drivers of the markets for fuel cells and renewable hydrogen. In the short term, some automakers are apparently still "distracted" by the objective of catching up with the market leaders in battery-electric vehicles. But what is especially encouraging is the commitment of many auto suppliers. The past years, and 2018 in particular, show they have moved into key strategic positions in the fuel cell sector, even though fuel cells are not their core business. A few examples among many are traditional suppliers such as ElringKlinger, Plastic Omnium, Faurecia, Freudenberg and Bosch. Their dedication helped set up reliable supply chains and attract more investment to strengthen the viability of the industry. The most important link missing in the chain today is that between market players such as Ballard, which sell fuel cells only, and OEMs like Toyota.

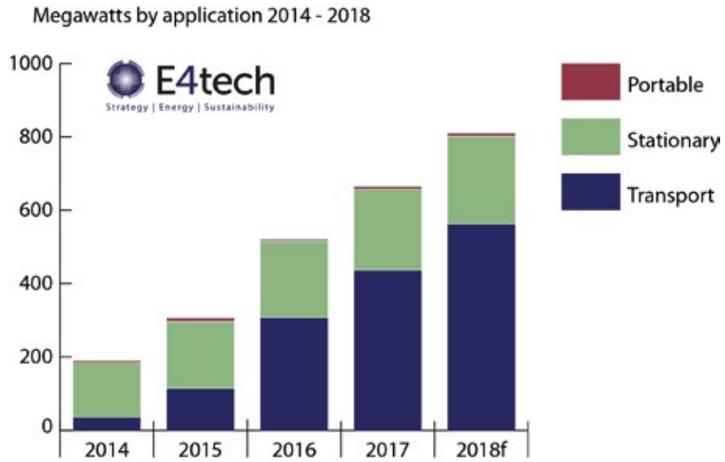

Fig. 1: Yearly fuel cell capacity, broken down by application, shipped between 2014 and 2018 (in megawatts)

f: 2018 includes forecast for fourth quarter

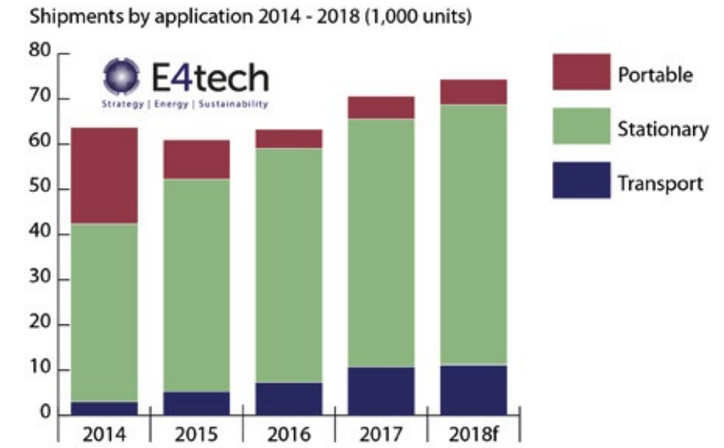

Fig. 2: Yearly number of fuel cell units, broken down by application, shipped between 2014 and 2018 (in 1,000s)

f: 2018 includes forecast for fourth quarter

Looking at the individual figures indicates that, like in past years, capacity mainly grew in the vehicle market, by nearly 30 percent in comparison to 2017. This sector contributed 560 megawatts to the 2018 total, with around 475 megawatts, or 4,500 systems, installed in passenger vehicles. A fuel cell capacity of about 100 kilowatts per car can add up quickly. Vehicle sales continued to grow in China at a rate of over 1,000 per year, although many stacks sold in the country have only 30 kilowatts of output, as fuel cells are mainly used to increase the range of buses and small trucks.

The 11,500 fuel cell vehicles shipped in 2018 also include 5,000 fuel cell forklift trucks. This submarket grew last year as well. And although Plug Power dominated the competition in this area, there are other companies, such as Nuvera, Daimler and Fronius, just to name a few, that make stacks for forklifts. Likewise, fuel cells were used increasingly in other means of transportation, for example, railroad vehicles, drones and watercraft. So far, however, none of those have had more than a negligible impact on the total.

LITTLE GROWTH IN STATIONARY SECTOR By contrast, stationary systems continue to make up the majority of units shipped worldwide. For several years now, the statistic has shown a steady annual addition of fewer than 50,000 micro-CHP systems in Japan, where SOFC devices took an even bigger chunk of the market in 2018. Like in 2017, businesses such as Kyocera, Miura and Hitachi Zosen were reported to have offered customers commercial multi-kilowatt units.

The total number of units was also influenced by sales of uninterruptible power supplies in several parts of the world, although the South Korean and US markets were the only important ones for selling large, decentralized units with more than 100 kilowatts of capacity for baseload purposes. And PAFC technology by Doosan became even more popular in 2018, mostly at home in South Korea, where the Renewable Portfolio Standard has made fuel cells an attractive investment option for energy companies.

Following some rough times, FuelCell Energy is looking to the future with renewed optimism, not least because the US government reintroduced its investment tax credits in 2018. Additionally, Bloom Energy had a successful IPO last year after putting in much effort and even though it still does most of its business in the US, it managed to ship its first multi-megawatt system to a company in South Korea. Overall, the market for stationary systems continued to grow in 2018 – albeit at a slow pace, making up 5 percent of all units, as well as 8 percent of total capacity. On top of this, it still relies on a very specific kind of regulatory environment to succeed.

While measuring portable fuel cells in megawatts makes little sense, these small 100-watt systems, which often include direct methanol fuel cells, generated notable sales last year. Additionally, myFC, which has become the only company still selling multi-watt fuel cell USB chargers, shipped out devices in 2018, too.

ASIA TAKES THE LEAD, AGAIN The global makeup of the market changed little in 2018: Asia still tops the list of most units delivered, primarily because of the ene. farm program in Japan. Going by capacity, North America ranked first, also thanks to 2,800 vehicles that were made on the Asian continent and many of which were shipped to California, whereas fewer than half, or, more specifically, 1,300 new cars, were sold in South Korea and Japan during the same period. >>

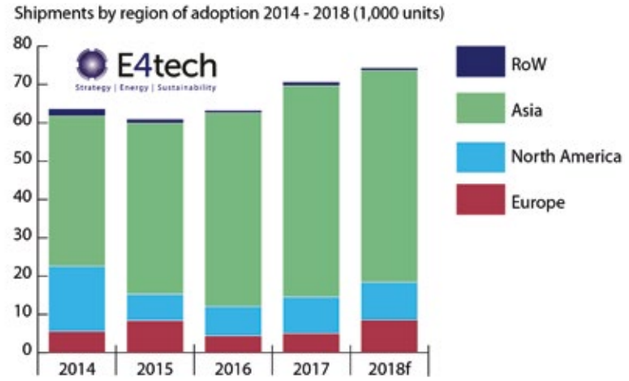

Fig. 3: Yearly number of shipments, broken down by market region, from 2014 to 2018 (in 1,000s)

f: 2018 includes forecast for fourth quarter

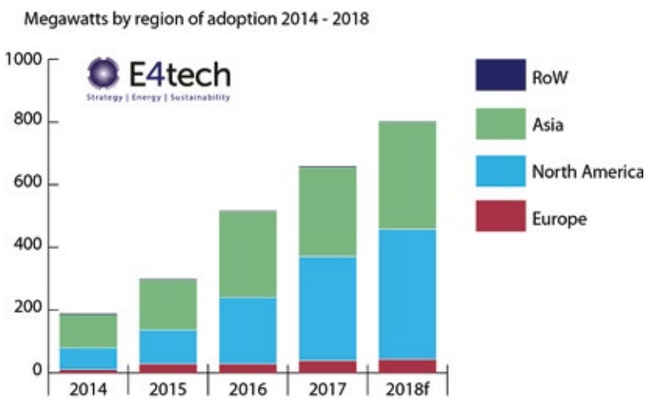

Fig. 4: Yearly capacity, broken down by market region, from 2014 to 2018 (in megawatts)

f: 2018 includes forecast for fourth quarter

The entire report including shipment numbers, data tables, analyses and notes on individual companies can be downloaded at no cost by visiting www.FuelCellIndustryReview.com

Forklift trucks by Plug Power were one of the main products sold in North America last year, besides USPs. The market in Europe grew, too, albeit from a comparatively low baseline. A crucial factor contributing to the total was the purchase of small CHP units, supported by the German KfW433 program. Megawatt capacity in Europe originated, as in the prior year, primarily with 300 fuel cell vehicles imported from Asia to Europe. The markets in the rest of the world contributed no more than negligible amounts to the total; the principal products sold in other countries were USP systems. Still, one high point was the commissioning of the first fuel cell bus in India.

EUPHORIA MAKES WAY FOR REALISM 2018 provided a much rosier outlook for the vehicle market than the year before. Hyundai demonstrated it is at least as ambitious as Toyota, announcing an expansion of production capacity, so it will be able to manufacture 40,000 fuel cell vehicles by 2022. The heavy-duty truck market is growing, too. Besides Nikola's announcement that it signed an agreement with Anheuser Busch to build 800 trucks, Hyundai and H2Energy stated they would begin to deploy a fleet of 1,000 trucks in Switzerland this year. Meanwhile, Alstom's fuel cell railcars have made regular runs in Germany, and it seems as if current backlog is going to keep the company busy for several years to come. Other countries, such as the UK, have expressed great interest in hydrogen trains as well.

The Chinese market, which made headlines in 2017, continues to provide a favorable market environment. But compared to the euphoria sweeping the sector two years ago, 2018 brought the realization that not everything can be accomplished overnight. Putting up hydrogen fueling stations and dealing with a complex type approval process for hydrogen vehicles has taken more time than many market players hoped it would. This has delayed projects for which buses and trucks had been built but had yet to be put in service. Nevertheless, the first fleets have been deployed in multiple cities and have already made a mark. Meanwhile, China continues to pour large amounts of money in the market, attracting industry professionals from all around the world – former staff of the Vancouver-based AFCC joint venture, which became defunct in 2018, among them. This is just one example of how fuel expertise doesn't get lost but lives on in other parts of the world, even if the name and location of the company changes.

Compared to the vehicle sector, the prospects for stationary applications are difficult to predict: Conditions in Japan, South Korea and the United States remain favorable, although key players such as Doosan, Bloom, FCE, Panasonic and Aisin, as well as ambitious new entrants, including Ceres Power and SOLIDPower, will still need to demonstrate that they can compete in a mass market environment that offers no support for fuel cells. ||

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FUEL CELL MARKET: MORE DYNAMISM, MORE MOMENTUM

Sven Jösting's stock market analysis

For me, the new year started off with a bang: While hydrogen and fuel cells had rarely been discussed at the many energy conferences held in past years, power-to-gas, electrolyzers and fuel cells are quickly seizing the spotlight these days. It's very good news for technology suppliers listed on the stock exchange, especially for those mentioned below. The market has finally built enough momentum, and the public is taking note. Also, Tesla's position as the leader of the field took a bit of a hit in 2018: Competition grew fiercer, with more and more businesses offering electric or hybrid models. Take Hyundai and its Nexo. Power-to-X has become a hot topic as well. Two companies that stand to gain a lot from recent developments are Ballard and Hydrogenics. Their fuel cells are being used to power buses, trucks and railway vehicles, and their electrolyzers and fueling stations provide the required infrastructure.

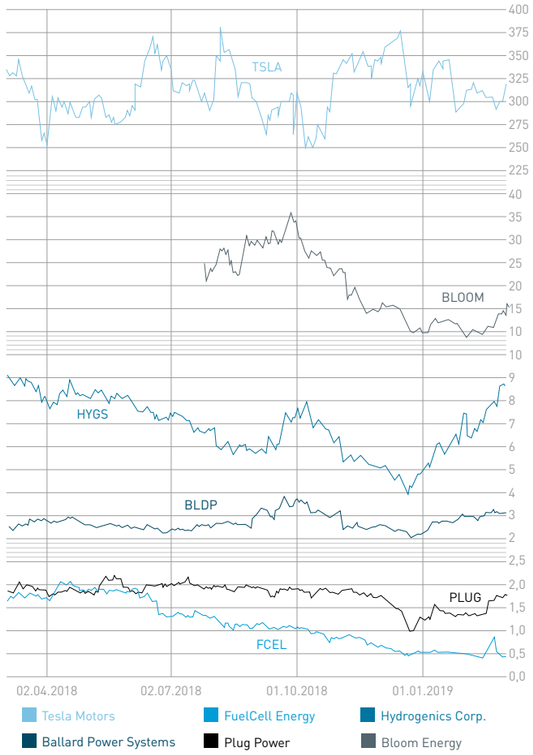

Fig. 1: Historical prices of the six companies covered in this issue. [Source: wallstreet-online.de] Retrieved March 7, 2019

BALLARD – LEAVING THE PAST BEHIND

Following a short-term dip, the stock of Canadian fuel cell manufacturer Ballard Power (Nasdaq: BLDP) went on to rebound in a big way, shooting up daily. A good sign. While the company didn't ink any major deals, it signed several framework agreements and received multiple letters of intent. It also tried to branch out, getting in on projects such as H2Ports. As a global leader, Ballard will remain in the spotlight, in multiple markets, thanks to its highly advanced technology.

Considering the many, successful series of fuel cell bus tests the company has conducted over the years, I think major contract awards will follow soon. Whenever London, or any other big city, decides to implement its road map, a single order could easily translate into stacks for 1,000 buses or more. Then, Ballard could offer the city its new LCS devices, made in China, at a low price and enjoy an advantage its competitors may not have.

2018, THE YEAR OF TRANSITION A sober analysis is needed to evaluate the recently published figures for fiscal year 2018. Losing the large order Chinese business partner Guangdong Synergy had placed with the company was met with disappointment and cut into revenues. However, the situation could change at any time. China remains fully committed to fuel cells, recognizing the great potential the technology has. On to the numbers: Annual revenue amounted to USD 96.6 million, with the fourth quarter raking in USD 28.5 million. The net loss per share was USD 0.15, while cash and cash reserves amounted to USD 192.2 million on Dec. 31, 2018, and provided the manufacturer with a healthy financial cushion. Many of the business's R&D projects are expected to lead to large bookings this year, as well as in 2020. The partnership with Weichai is also thought to make more of an impact soon, which means Ballard should be seen as the market's current number one. Plus, temporary price drops are always an opportunity to buy stock, as long as investments are made with a focus on long-term gains. >>

Fig. 2: Air Liquide is about to expand its hydrogen service portfolio, for example, by building four new hydrogen stations in South Korea and two in Paris. [Source: Air Liquide]

HYDROGENICS – AIR LIQUIDE JOINS IN

Happy news for those who bought stock of Hydrogenics (Nasdaq: HYGS) in late 2018: The price has gone up by more than 70 percent since the last issue of H2-international was published. One reason for the boost has been Air Liquide's acquisition of Hydrogenics shares in the amount of USD 20.5 million, netting the former a stake of around 20 percent in the latter. I expect the acquisition will result in synergies, considering Air Liquide, a French gas supplier, is certainly interested in Hydrogenics' electrolyzer and fueling station technology. This partnership is very similar to the collaboration between Ballard and rolling stock manufacturer Alstom, which is planning to use fuel cells to power its latest generation of trains.

Another reason, besides the one mentioned above, is that Air Liquide awarded Hydrogenics a contract to build a 20-megawatt electrolyzer. This system is seen as the first step in constructing the world's largest electrolyzer farm. It seems likely that this customer's initial order won't be its last but rather the first of many to come.

FUELCELL ENERGY – SOMETHING BIG COMING UP?

After a sharp decline, with high volumes being traded at prices as low as USD 0.40, the tide suddenly turned for FuelCell Energy (Nasdaq: FCEL). While trade volume increased even more, to 17.5 million shares, the price shot to USD 0.90 within a few days. Then, the tide turned again, and the shares fell to a new low. It's almost as if the stock is part of a high-stakes gambling game. Who is in the know?

FuelCell Energy has offered no explanation for the wild swings. So, what is happening? The company has issued different series of preferred stock, which can be turned into common stock. The caveat: There is no conversion price, just a ratio. This might suggest that the large trading volume of between one and over five million shares is part of strategy by those owning the series to short-sell stock post-conversion and benefit from a falling price to buy a greater number of shares for less.

If that is the case, though I can't be sure it is, shareholders who have benefitted from the falling prices could, at some point, switch sides and go long. Clearly, somebody must have snatched up the stock. Considering positive news all around, such as bookings totaling USD 2 billion, it is the only reason I can think of to explain the drastic slump. It has been reported that the series C shares are owned by just one investor, which agreed with FuelCell Energy to receive more in light of what's happened. Is that game also being played regarding Series D preferred stock?

Still, I'm hopeful the price will recover quickly, as soon as partners such as Exxon place orders with FuelCell for their carbon capture system. Else, the oil corporation's media campaign, which specifically named the fuel cell manufacturer, would be a clear attempt at greenwashing. And last but not least, whoever is behind the recent turmoil might also be aiming for a large parcel of shares that could be sold, at a big profit, to a strategic investor, for example, an industrial equipment manufacturer. We'll see.

FIRST-QUARTER RESULTS Revenue in the first quarter, ended January 31, 2019, fell from around USD 38 million to USD 18 million year on year. These kinds of ups and downs each quarter are normal for businesses focusing on large projects. Loss was at USD 0.33 per share, including USD 0.15 for non-cash items. Bookings totaled USD 1.3 billion and could rise by another USD 0.6 billion, provided the company is successful in turning its current bids into contract awards. Cash and cash reserves amounted to USD 68 million, and loan facilities are still available, too.

GENERATE CAPITAL PROVIDES CASH INFUSION Big, positive news came from cleantech fund Generate Capital, which signed a deal with FuelCell Energy about a USD 100 million construction loan facility. The total could even increase to USD 300 million. Generate Capital is thought to have an impeccable reputation when it comes to funding projects. Obviously, the collateral is the project itself. Nevertheless, the facility provides the manufacturer with enough money to implement ideas that it couldn't have otherwise – a win-win for everyone.

Of course, these kinds of ventures are not for conservative investors but shareholders believing in the medium-term and long-term prospects of clean technology. Among those who have so far analyzed the company and its stock, five recommend buying shares while expecting the price to be USD 2 and USD 3 in the long run. Only one sees the stock ending up at USD 0.55.

While the price was down, US-based investment management corporation BlackRock bought nearly 6 million of the company's shares. I agree with the assessments made by BlackRock and the five analysts mentioned above. Plus, FuelCell Energy's latest book value per share was USD 0.86. Even if, in the meantime, the total number of shares has increased considerably because multiple shareholders converted preferred into common stock, that value squares with current

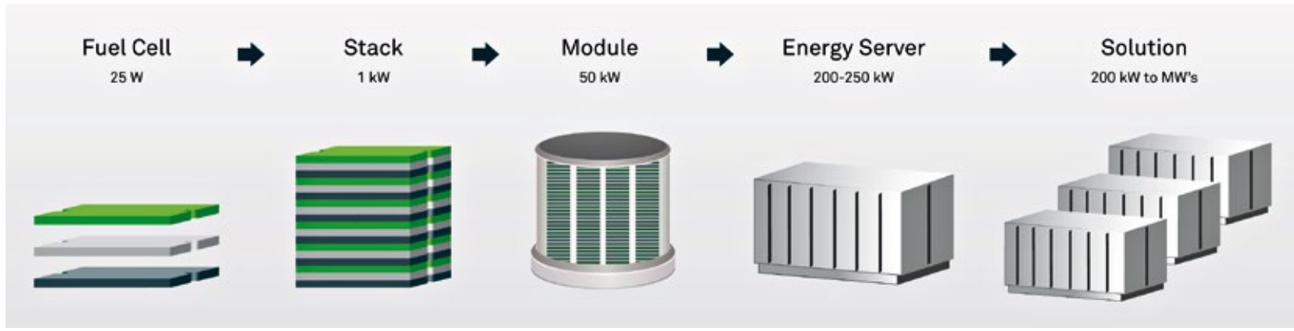

Fig. 3: Bloom combines individual cells and stacks into large hybrid multi-megawatt solutions. [Source: Bloom Energy]

market capitalization and can be used to estimate net worth. I have trust in FuelCell Energy's technology, business model and opportunities for growth.

PLUG POWER – BIG OPENING IN ROCHESTER

On February 22, Plug Power (Nasdaq: PLUG) celebrated the Grand Opening of a new factory in Rochester in the United States. Reportedly, the site will create more than 180 jobs and produce as many as 400,000 membrane electrode assemblies, compared to a company-wide production of 10,000 in 2018. The big increase in capacity is thought to be achieved by using a technology that the manufacturer obtained by buying American Fuel Cell. Additionally, tests of courier vans have created high expectations. For example, one FedEx vehicle has clocked in over 14,000 on-road miles (over 25,000 kilometers) so far and its range has been extended to 160 miles (257 kilometers), which, according to the company, is 166 percent greater than an all-electric solution. It would be a big deal for Plug if a test like this resulted in FedEx placing a large order with the company. Competitors such as Ballard and Hydrogenics are also exploring the market for fuel cell vans, for example, in partnership with UPS.

Plug has gone through several funding rounds and the reasons for some were a bit opaque. And yet, if I look at what fueling stations the company is building these days, business could grow at rates resembling those of Nel. Plug converts electric forklift trucks, that is, replaces their batteries with stacks developed in-house. It also puts up the fueling infrastructure. However, the company trades in hydrogen; it doesn't produce the gas. And while a number of businesses have already begun to manufacture fueling stations, Plug can rely on ample experience with daily hydrogen use.

BLOOM – CURRENT MARKET VALUE A GOOD OPPORTUNITY

Bloom Energy (Nasdaq: BE), a manufacturer of fuel cell systems, is a new one for me to discuss on these pages. The company went public in July 2018, and after issuing shares at a price of USD 25 each, it went on to reach a market cap of above USD 3 billion, though it is valued at less than half of its IPO price today. It posted revenues of USD 742 million for 2018 and expects a steady 20 percent growth per year in the near-term future. The core business of Bloom is to supply companies, and especially large corporations, such as IKEA, with fuel cell power plants, so that they can power equipment independent of utility contracts. Its business model is similar to that of FuelCell Energy, although the latter will sometimes connect systems to those of large utilities. Bloom, on the other hand, specializes in entirely energy independent fuel cell installations.

TESLA – EXECUTIVE EXODUS CONTINUES

The bloodletting among the executive ranks at Tesla (Nasdaq: TSLA) continues. The carmaker's general counsel stepped down only two months after taking the position and its chief financial officer, who had already been in this role once before, years ago, resigned as well, this time after two years. This doesn't bode well. Tesla's CEO, Elon Musk, at least managed to bring his billionaire friend and Oracle founder Larry Ellison on board. Ellison has bought Tesla shares worth over USD 1 billion, making him the automaker's second-largest private shareholder, after Musk.

However, the fourth quarter of 2018 produced relatively underwhelming results. And Musk himself doesn't see the first three months this financial year as a time to fulfil high expectations. More specifically, while revenue in Q4 grew at a considerable rate, to more than USD 7.3 billion, Tesla posted profits of as little as USD 139 million, or USD 0.81 per share, based on GAAP accounting. One good piece of news was that cash flow was positive and stood at USD 910 million. Cash reserves increased as well, to USD 3.7 billion. However, some of that money, or, more specifically, USD 793 million, came from deposits and USD 920 million needed to be paid back for a convertible bond in early March.

MAXWELL TECHNOLOGIES – STRATEGIC ACQUISITION Tesla's announcement to buy battery developer Maxwell Technologies for USD 222 million in shares, since the company is also listed on the stock exchange, was well received by analysts. But what the automaker needs to show is how Maxwell's equipment could be integrated into its vehicles and >>

Fig. 4: The vision of countless homeowners and car aficionados. [Source: Tesla]

which improvements that will bring. The battery developer seems to possess highly advanced technology and, of course, Tesla intends to make use of it. At present, though, the ball is in Maxwell's court, since some of its shareholders filed a class-action suit to try to block the acquisition – which they certainly could if they won in court.

CHINA Gone are the days of full-throated promises to have production up and running in China at the end of 2019. No more announcements have followed the groundbreaking ceremony at Tesla's Shanghai site, acquired through a leasing arrangement. What is less than clear at this point is who will make the money available to build another Gigafactory. To produce in China, companies first need to be approved for vehicle trading in China. As reported elsewhere, the corporation may not even have gotten that far yet. However, everything else hinges on it.

MAJOR SHAREHOLDERS CUT BACK INVESTMENTS T. Rowe Price is one, but not the only, example of a major shareholder that used the fourth quarter of 2018 to reduce its Tesla stock on a massive scale. More specifically, in one quarter alone, it nearly cut down its stake in half, keeping just 9 million of its 17.4 million shares. Goldman Sachs analysts and others stick to their previous recommendations, telling shareholders to sell while setting a price target of around USD 225. I concur. I really don't see how Tesla can turn things around, and the competition is growing stronger every day. Even demand for Model 3 in Asia and Europe doesn't convince me otherwise. Drastically lower delivery times as of late leave me to conclude that the number of orders may be lower than I had assumed.

As for Model 3 leasing offers, one needs to consider the comparatively high price of the car. It will probably be above EUR 55,000 in Europe. Although a USD 50 billion market cap is USD 10 billion below where it was the last time that I wrote about Tesla for H2-international, it is still way too high, despite the prospects for autonomous driving and other technologies. In many countries, including the United States, electric car incentives are being phased out. The lack of these incentives is putting pressure on the market. Can sales in China and Europe make up for a drop in the US by providing new growth opportunities?

MUSK BEING MUSK OR HOW TO KEEP EVERYONE GUESSING On February 28, Musk announced that Tesla would move to online-only sales, that is, customers would have to buy their vehicles on the internet. Plans are to shut down all local showrooms, so say goodbye to a cross-selling strategy that involves in-person sales of Powerwall battery storage units and PV modules. Tesla said it would, at last, be able to offer Model 3 for USD 35,000 sometime in 2019. But the federal government's tax breaks are all but gone. Additionally, the company cut the prices for its Model S and Model X but made the software program for autonomous driving more expensive: It is now at USD 7,000. Good news? No, not at all. Extraordinary losses because of write-offs and stores closing was how this year's first quarter wound up with a loss, not a profit. Will the company's recently announced SUV, Model Y, turn out to be Tesla's secret weapon? ||

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 ones, i.e., they may experience high stock volatility. This article is not to be taken as a recommendation of what shares to buy or sell – it comes without any explicit or implicit guarantee or warranty. All information is based on publicly available sources and the content of this article reflects the author's opinion only. This article focuses on mid-term and long-term prospects and not short-term profit. The author may own shares in any of the companies mentioned in it.

Category: Global | **Authors:** Jennifer Hack, Oscar Williams, Lara Rasha

CLEAN ENERGY TECHNOLOGY OUTREACH

Public engagement group for electrochemical technologies

Fig. 1: Setting up the PV system for use at a UCell event

With the recent IPCC report outlining the measures required to keep warming to below 1.5 °C, implementing low-cost, low-carbon energy alternatives is more important than ever. With this momentum comes the need for experts to carry out strong, impactful programs to demonstrate new electrochemical technologies to the public. The rewards of outreach for researchers and industry professionals alike do not lie just in the greater exposure of their work but also in the diverse audiences they can reach by way of public engagement. Many associate hydrogen with explosions or batteries with phone fires. One central aim of outreach is to dispel the myths about safety issues and ensure that people of all ages are fully informed of the benefits, and faults, of these technologies as they start to enter our daily lives. Engineering a low-carbon future is the responsibility of both current and future generations, which means outreach plays a key role in inspiring the next wave of scientists, engineers and policy makers.

With these aims in mind, UCell has been committed to public engagement throughout the United Kingdom for the past eight years. Based in the EIL, the Electrochemical Innovation Lab at University College London, it is in a central location, ideally situated for reaching a diverse audience and a wide range of ages. The idea for UCell was borne out of a conversation in the pub between EIL researchers and the then-curator of Einstein's Garden, a section devoted to science and engineering at the Green Man Festival in South Wales. The idea was to power the electronics of a small tent in Einstein's Garden by using green energy and, following a UCL summer project, to build a small fuel cell system. This system successfully supplied energy to a garden shed completely off grid, fueled only by hydrogen. One year later, the team was invited back and, in addition to powering the shed with the stack, was asked to carry out public engagement at the Energy Hub. From these foundations, a team of EIL PhD students, post-doctorates and professors developed a fully operational 3-kilowatt stack system in 2013, in time for their third attendance at the festival, to power an entire stage. The stack resembles traditional off grid diesel generators found at festivals but has the advantage of being emission free and almost completely silent. As well as leading to a lasting collaboration with Green Man, the continued attendance at the festival gave the impetus for officially founding UCell in 2013. Since then, it has grown into a thriving outreach group and a central part of EIL activities.

UCELL
An outreach group for electrochemical energy based at University College London. Educates and engages the public on innovative clean energy generation and demonstrates energy conversion and storage research and concepts.

At its conception, UCell's calendar focused solely on the single event at Green Man Festival and reached about 500 festival attendees. In 2018, over 3,000 were directly engaged, with more opportunities still to come. UCell has carried out over 40 events, ranging from music festivals and science fairs to open days, lectures and school visits. UCell members now number in the double digits, with as many women as men participating, and include Masters students, PhDs and professors, as well as external collaborators. They come not just from the chemical engineering department, where the EIL is based, but also from the chemistry and physics departments, as well as the Slade School of Fine Art, highlighting the truly interdisciplinary nature of electrochemical energy research.

Since the team comprises researchers from across the spectrum of electrochemical energy, from electrolyzers to supercapacitors and fuel cells to batteries, the discussions had at each event have often been diverse, with some interesting and often challenging questions being raised. One of those asked by an inquisitive eight-year-old was, "If there are more fuel cell cars, will there be more rain?" More technical questions have included, "What is the risk of storing compressed hydrogen on board a vehicle?" and "How easily can these technologies be integrated into our current infrastructures?" As the energy industry has vowed to decarburize, these questions will become increasingly important, so that carrying out demonstrations and providing educational information accessible to the public is a central role of UCell's work.

UCell members host a booth at these events and use a range of resources, including small demonstration kits, to engage with people of all demographics on the latest clean energy technology. Alongside this, the fuel cell stack has been used to power everything from comedy stages to a thermal imaging camera and equipment at nearby food stands. Given that the device is portable, UCell made the journey from London to Manchester last year to run an event at the prestigious Manchester Science Festival for the first time. Over the weekend, up to 4,000 visitors passed through the doors of the Museum of Science and Industry – a scale of exposure that was as exciting as it was daunting.

Of course, the success of these events rests on the engineering of the demonstration stack. Multiple iterations have led >>

Fig. 2: Trailer including FC demonstration system

to the current generation, a 3-kilowatt stack combined with a battery bank of six 12-volt, 41-ampere-hour batteries. Electrical output varies between 50 volts and 70 volts, depending on the load and variations in operating conditions. This fluctuating output is brought down to a steady 24 volts by using a DC/DC converter, the voltage requirement for the rest of the system. Fuel cell power can then flow through two paths, either to recharge the battery bank if the state of charge is low or directly to the load. Alternatively, if the batteries are fully charged, the stack automatically switches to float mode, which saves on hydrogen fuel, and the batteries discharge to the load. Considering most loads at events require AC voltage, the system's power output passes through an AC/DC inverter, which raises the voltage from 24 V DC to 230 V AC. The entire system is managed and monitored by control equipment programmed through Arduino microcontrollers and powered along with accessories through a 12-volt power supply. The system is in an open-cathode configuration, common for low-power uses, where fans supply air straight to the cathode without requiring energy-intensive compressors. It runs as a stand-alone "green generator," put in a clear acrylic display case on top of a cart, so the components of the system are on full display. The UCell powertrain resembles the setup found in stationary and automotive fuel cell systems but at a lower power output. By comparison, the Toyota Mirai uses a 114-kilowatt stack, while an average kettle uses around 1.5 kilowatts of power and an incandescent lightbulb only 60 watts.

Fuel supply is particularly important for publicly demonstrating the system efficiency and cost-effectiveness of these systems compared to common diesel generators. Typically, the unit operates on a 2-kilowatt average fuel cell output over 10 hours a day at Green Man Festival by using 7.21 m^3 of high-purity hydrogen in the form of a single metal cylinder at 175 bars. Gas supply companies deliver gases directly to sites, even to remote locations where backup power is desirable in the UK (and, of course, pick up cylinders as well).

Given the operating, maintenance and travel costs involved in running an outreach group of this nature, UCell could not survive without support from a range of sources. Over the years, funds have come from the EIL itself, UCL's Department of Chemical Engineering and Faculty of Engineering and from grants externally awarded by the Royal Academy of Engineering and the Science and Technology Facilities Council. Access to funding like this allows groups such as UCell to not only to continue their outreach work in the local area but bring the program to further parts of the country. Available to both established groups and researchers who are just at the start of their outreach journey, public engagement grants form a central pillar of the continued efforts of UK scientists and engineers to educate the public on innovations.

With clean electrochemical energy technologies starting to take off, UCell aims to match the range of outreach on offer to the growing needs of research. A significant milestone for 2018 was to expand outreach activities to encompass demonstrations of not only fuel cells but also batteries, electrolyzers and solar. This likewise served to demonstrate a circular economy, where energy from intermittent renewable sources is stored in batteries or as hydrogen and then converted back to electric power via fuel cells. Other activities involved the purchase of a Toyota Mirai fuel cell car to be displayed at events. With impactful research taking place across the UK, Europe and the globe, public engagement groups such as UCell are key outlets for disseminating scientists' findings, as well as demonstrating technologies in practical, real-world applications. Considering the shifting attitudes and the drive towards low carbon technologies, UCell hopes to become part of a changing environment by reaching as wide an audience as possible, by encouraging debate, discussion and engagement and by inviting the public to be inquisitive and ask questions. ||

Fig. 3: UCell team [Source: UCell]

Written by
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ROBERT ROSE: AN OBITUARY

It is with great sadness that we report the death of Robert Rose, a pioneering force and a strong proponent of a future hydrogen economy. He passed away peacefully in the morning hours of October 17, 2018, at his home in Woodbridge, Virginia, after battling a long illness. He was a highly sought-after expert in hydrogen and fuel cells and a frequent speaker at events not just in the United States but also Europe and Asia.

Born Nov. 6, 1946, in Newport, Rhode Island, Robert "Bob" Rose was a working journalist for the United Press International in New England before moving to Washington, D.C., in 1972, to work as press secretary for then-Senator Edmund S. Muskie of Maine. During a career spanning more than 35 years, he served as an adviser on hydrogen and fuel cells to United States government agencies, nonprofit organizations and the private sector. He also founded Breakthrough Technologies Institute, an independent nonprofit promoting technologies that carry environmental benefits. He launched the institute's Fuel Cells 2000 education program in 1993.

Bob received widespread acclaim for his book titled "Fuel Cells and Hydrogen: The Path Forward." He founded the U.S. Fuel Cell Council, a fuel cell trade association, in 1998, and served as its executive director for 10 years. He later helped merge the council with the National Hydrogen Association to form the Fuel Cell and Hydrogen Energy Association. His tireless efforts on behalf of the industry earned him the Fuel Cell Seminar Award and a Lifetime Achievement Award from the National Hydrogen Association.

A renowned expert in the global hydrogen and fuel cell community, Bob started writing for Hydrogeit Verlag in the summer of 2015. He regularly provided our readers with reports about the United States and Asia. Despite his ailing health, Bob was, up until his final days, committed to introducing hydrogen technology to the market. He last contributed to the German HZwei and the English H2-international magazines in July 2018.

Fortunately, he was still among us to see the American Councils for International Education create the Fuel Cell Rose Education Award in his honor in 2018. The award will be given to doctoral or master's students, or recent graduates, to help them build leadership skills and advance global partnerships and community building in this promising field. Lorne Craner, the president of American Councils, said that "fuel cells 'rose' through Bob Rose and, given his contributions, it's an honor to be able to launch this award in his name." At the time, Bob said it was "gratifying to see all the progress in fuel cell and hydrogen technologies," adding that he was "happy to have been a part of the community behind that progress."

We will miss him dearly. ||

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

Plansee SE, Bipolar Plates, Interconnects and Metal Supported Cells, 6600 Reutte, Austria, Phone +43-(0)5672-600-2422, *www.plansee.com*

ORGANIZATIONS

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

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

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

ORGANIZERS (EVENTS)

Hannover, Germany April 1-5, 2019

Salt Lake City, UT, USA September 23-26, 2019

Shanghai, PR China October 23-26, 2019

Hydrogen + Fuel Cells NORTH AMERICA, Solarpower 2019, September 23–26
Group Exhibit Hydrogen + Fuel Cells + Batteries, Hannover Messe 2019, April 01-05
Tobias Renz FAIR, *tobias@h2fc-fair.com, www.h2fc-fair.com*

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

Peter Sauber Agentur Messen und Kongresse GmbH, f-cell, September 10 to 11, 2019, Haus der Wirtschaft, Willi-Bleicher-Str. 19, 70174 Stuttgart, Germany, Phone +49-(0)711-656960-55, Fax -9055, *www.f-cell.de*

REFORMERS

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

RESEARCH & DEVELOPMENT

DBI Gas- und Umwelttechnik GmbH, Karl-Heine-Str. 109/111, 04229 Leipzig, Germany, Phone +49-341-2457-113, *www.dbi-gut.de*

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

Fraunhofer ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany, Phone +49-(0)761- 4588-5208, Fax -9202, *www.h2-ise.de*

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

Wenger Engineering GmbH, Research and Development Center for Thermodynamics, CFD Simulation & H2-Technology, Einsteinstr. 55, 89077 Ulm, Germany, Phone +49-(0)731-15937-500, Fax -501, *mail@wenger-engineering.com, www.wenger-engineering.com*

STORAGE

GKN Powder Metallurgy, GKN Sinter Metals, PO Box 55, Ipsley House, Redditch B98 0TL, Worcestershire, United Kingdom, *www.gkn.com/sintermetals*

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

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

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

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

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

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

SUPPLIERS

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

Borit NV, Bipolar plates and interconnects, Lammerdries 18e, 2440 Geel, Belgium, Phone +32-(0)14-25090-0, Fax -9, *contact@borit.be, www.borit.be*

ElringKlinger AG, Max-Eyth-Str. 2, 72581 Dettingen/Erms, Germany, Phone +49-(0)7123-724-0, Fax -9006, *info@elringklinger.com, www.elringklinger.com*

HIAT gGmbH, Schwerin, Germany, CCMs / MEAs / GDEs for PEFC, DMFC & PEM-Electrolysis, *www.hiat.de*

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

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

Sandvik High Precision Tube, ZN der SMT D GmbH, 33824 Werther, Germany, Phone +49-5203-91090, *info.hpt@sandvik.com,* H2 Stainless Steel Tube Applications / Coil Container Service – On Site Tubing Solution

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

TESTING

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

Maximator GmbH, High Pressure Hydrogen Technology, Testing Equipment, Customer Testing Services, Lange Strasse 6, 99734 Nordhausen, Germany, Phone +49-(0)3631-9533-5107, *H2Team@maximator.de, www.maximator.de*

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

SMART Testsolutions GmbH, Rötestrasse 17, 70197 Stuttgart, Germeny, Phone +49-(0)711-25521-10, Fax -12, *sales@smart-ts.de, www.smart-testsolutions.de*

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

TEST STANDS

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

EVENTS

May 6th to 8th, 2019
China International Hydrogen and Fuel Cell Exhibition (CHFCE) China International Exhibition Center organized by China Machinery Industry Federation in Beijing, China, *http://en.chfce.com*

May 7 to 9, 2019
The Battery Show Europe in Stuttgart, Germany
www.thebatteryshow.eu

May 7 to 9, 2019
Electric & Hybrid Vehicle Technology
Expo Europe in Stuttgart, Germany, *www.evtechexpo.eu*

Conference: May 14 to 15, 2019, in Munich
Fair: May 15 to 17, 2019, in Munich
together with Intersolar Europe ees Europe & Power2Drive Europe Europe's largest exhibition for batteries and energy storage systems
The exhibition for charging infrastructure and e-mobility
www.ees-europe.com, www.powertodrive.de

May 19 to 22, 2019
EVS 32 Electric Vehicle Symposium & Exhibition in Lyon, France, *www.evs32.org*

May 22 to 23, 2019
f-cell + HFC in Vancouver, Canada, *www.hyfcell.com*

July 2 to 7, 2019
European Low-Temperature Fuel Cells / Electrolysers & H2 Processing FORUM EFCF-Conference with Exhibition in Lucerne, Switzerland, *www.efcf.com*

August 16th to 18th, 2019
4th Asia (Guangzhou) Battery Sourcing Fair (GBF ASIA 2019) Guangzhou Pazhou, China Import & Export Fair Complex in Guangzhou, China
www.battery-expo.com

September 10 to 11, 2019
f-cell in Stuttgart, Germany
www.f-cell.de

September 23 to 26, 2019
Hydrogen + Fuel Cells NORTH AMERICA
Part of SOLARPOWER International (SPI) Salt Lake City, USA, *www.h2fc-fair.com/usa*

October 14 to 15, 2019
6th Residential Energy Storage Forum
organized by Dufresne in Rome, Italy
www.energystorageforum.com

October 15 to 17, 2019
eMove360° Europe International Trade Fair for Mobility 4.0 in Munich, Germany, *www.emove360.com*

October 16 to 18, 2019
Energy Storage World Forum
organized by Dufresne in Rome, Italy
www.energystorageforum.com

November 26 to 28
gat + wat
DVGW Congress in Cologne, Germany
www.gat-wat.de