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H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

→ MAKING HYDROGEN ECONOMICALLY VIABLE IN THE STEEL INDUSTRY

→ BIPOLAR PLATES: KEY COMPONENTS OF STATE-OF-THE-ART FUEL CELL STACKS

CONTENT

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E-JOURNAL ON HYDROGEN AND FUEL CELLS

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WHERE TO GO FROM HERE?

Dear readers,

When discussing current advances in hydrogen and fuel cell technology, people often start by talking about transportation, along with success and failure in the automotive industry (see pp. 26 and 31). In the past several months, however, other applications have begun to move into focus.

No, I'm not referring to stationary systems. Like passenger cars, both residential fuel cells (see p. 14) and fuel cell power plants (see p. 19) have yet to make a mark, not to mention that they continue to rely on natural gas, a fossil fuel, to meet much of the demand.

A better example is the market for electrolyzers, which has experienced notable growth in the past few years. Ever since one industry after another began viewing hydrogen as an effective means to store renewable power, that is, ever since energy systems integration and power-to-gas came to be talked about all over Germany, manufacturers have seen a lot more requests for their products (see report about Hannover Messe on p. 9).

But the ones that have really grabbed the spotlight are railroad and commercial vehicles. Regarding trucks, Nikola is generating all the buzz, and, this time, it has large orders to back up its claims (see p. 51). In early 2019, we will also find out whether Germany's northernmost state, that is, Schleswig-Holstein, has what it takes to pioneer the use of fuel cell trains and make them part of regular runs. It will all depend on which of the bids to operate portions of the state's rail system are going to make the cut before the process ends at the turn of the year. By then, it will have become clear if fuel cells are able to compete with diesel hybrid systems and battery-powered locomotives. We will get to that in the October issue.

Surprisingly, hydrogen is also making a splash in places that are often less willing to leave traditional methods of production behind: the steel and refinery industries. Starting up demonstration systems (see p. 36) may be a small first step to take. But at the same time, politicians, business leaders and association members have come together for intense discussions on the subject. Studies have been conducted (see p. 34) and factories toured (see p. 7) to explore what kind of potential hydrogen has for meeting exceedingly stringent environmental regulations.

All sectors mentioned above could make use of enormous quantities of hydrogen. Producing the gas entirely from renewable sources would mark a significant milestone on the route to transforming the energy system and represent a big leap toward a low-emission industry.

First, however, we need to be clear about what is possible and wanted. We need to make sure that hydrogen isn't used for greenwashing, so that only prestige projects will see the light of day – while, elsewhere, huge amounts of energy will be wasted.

The potential is there. All we need to do now is to unlock it.

Best wishes,

Sven Geitmann
Editor of H2-international

WERNER TILLMETZ RETIRES FROM ZSW

Professor Werner Tillmetz

Professor Werner Tillmetz will step down from his roles as a board member of the German Solar Energy and Hydrogen Research Center, or ZSW for short, and the director of its electrochemical energy division this fall. "I'll turn 63 in September, at which point I'm allowed to retire," he told H2-international. "Considering the projects that have been underway, from NIP 2 to H2 Mobility, I think the hydrogen and fuel cell community has made good progress over the years and gained many young and bright advocates. Likewise, China and Japan will help turn the technology into a global growth market." At the time of writing, the tenure and promotion committee had not yet responded to the question about who would replace him. ||

LINDE ENDS BEEZERO

Quelle: Linde

In mid-2016, industrial gas supplier Linde took the novel approach of creating a free-floating carshare program that offered only fuel cell vehicles. The corporation founded a subsidiary named Linde Hydrogen Concepts to buy 50 Hyundai ix35 Fuel Cell cars, which customers could book via an app and pick up at public parking lots instead of designated rental stations. The goal was to gain insight into fleet performance to advance the development of hydrogen technologies.

After running for exactly two years, the program ended on June 30. There is no word yet on what will happen to the vehicles, although it is said that they will continue racking up miles elsewhere. Both Hyundai and Linde seemed satisfied with the results.

"When we launched our BeeZero project, our aim was to raise the profile of hydrogen vehicles among the public, explore how economically viable it is to manage a whole fleet and see how customers will respond to our offer. We've achieved all our objectives, from raising the visibility of hydrogen technologies in transportation to getting fuel cells back into the debate about cleaner engines to demonstrating that the cars are suitable for everyday use," a spokesperson for Linde said. ||

NICO ROSBERG RECEIVES GREENTEC AWARD

Source: GreenTec Awards

Nico Rosberg, flanked by Bernhard Mattes (left), the president of Germany's automotive industry association, and Andreas Scheuer (right), federal minister for transportation

In mid-May, the GreenTec Awards recognized collaborative efforts that help protect the environment as well as conserve natural resources and promote sustainable choices in everyday life. More than 1,000 guests from the worlds of business, science, politics and entertainment attended the gala, which marked the start of IFAT, the world's premier show dedicated to the water and waste industries.

One of the 11 winners selected by the 75-judge panel was Alstom, which received an award for the design of its hydrogen-powered, zero-carbon train called Coradia iLint. Nico Rosberg, who held the title Formula One World Champion in 2016, was named Entrepreneur of the Year for his tremendous support of a sustainable lifestyle and innovative renewable technologies in his role as an investor and shareholder in Formula E. It was said that Rosberg had been one of a few strong backers of changes to the transportation infrastructure. The organizer of the event proved its commitment to sustainability with the hiring of CleverShuttle to drive around attendees in a Toyota Mirai. ||

NEW MANAGEMENT DUO AT H-TEC

H-Tec Systems, a German GP Joule subsidiary, has come under new management. In May, Heiner Gärtner and Ove Petersen began to transfer responsibility for day-to-operations to Frank Zimmermann, H-Tec's chief financial officer, and Joachim Herrmann, while they retained their lead positions at the parent company (see picture on the right).

The subsidiary has set its sights on expansion. In April, part of its Lübeck-based staff moved to a new location, which has offices and a factory hall, in Braak's Stapelfeld industrial area in the county of Stormarn, northeast of Hamburg. Zimmermann told H2-international that the company was planning to make the new site the center of its stack research and development. ||

ELECTROLYZER FROM JAPAN RUNS AT H2HERTEN

Source: Asahi Kasei

In late April, Asahi Kasei Europe started up one of its alkaline electrolyzers (see image) at the German h2herten Hydrogen Center of Excellence in Herten. The recently established business is part of the Asahi Kasei Group, a Japanese chemical company that employs 30,000 and has intimate knowledge of chloralkaline electrolysis. The electrolyzer in Herten was designed specifically to produce hydrogen from intermittent renewable sources. The initial plan is to have the system put to the test during a one-year demonstration project, co-funded by North Rhine-Westphalia's state economic development program NRW.Invest and NRW Japan K.K. and coordinated by EnergieAgentur.NRW.

"Europe's energy market has been witnessing dramatic changes. There is burgeoning demand for all kinds of renewable production and storage technologies," said Hideki Tsutsumi, the president of Asahi Kasei Europe. Consequently, Asahi Kasei has been participating in other projects, such as the European Union's three-year ALIGN-CCUS. ||


Source: H-Tec Systems

F. Zimmermann and J. Herrmann

FALKENHAGEN RESTARTS POWER-TO-GAS PLANT


Source: Uniper

Heat released during methanation is used in a veneer plant close by.

Store&Go, a European Union research project, entered phase two with a methanation unit being added to the power-to-gas system in Pritzwalk's Falkenhagen suburb, in the German region of Prignitz. Set up right alongside the facility for producing pure hydrogen, the new unit will create renewable methane at a maximum rate of 57 normal cubic meters, or 600 kilowatt-hours, per hour and inject the gas into the national pipeline network. Uniper, which operates the plant, said in a statement that the second phase, during which renewable power would be converted into synthetic methane, would start a new chapter of electricity production in an integrated energy system.

"This pipeline-connected power-to-gas installation is the perfect opportunity to explore the technological and regulatory issues we face when constructing and operating storage facilities. […] Carbon-neutral gas could be essential to meeting the EU's decarbonization and clean energy targets," said Christian Ehler, who represents Brandenburg state in the European Parliament. "To unlock the full potential of power-to-gas and let it become the green battery that will drive market transformation, we need fewer regulations and equal opportunities for the builders and operators of these plants," said Michael Riechel, the president of the gas and water industry association DVGW.

In 2013, the site was among the first to test this kind of hydrogen storage. Three years later, a consortium of 27 organizations launched Store&Go, supported by the EU with EUR 18 million. By contrast, there has been no information about what will happen to a similar system in Hamburg's neighborhood Reitbrook. Uniper, which co-managed that project until its end in 2016, said that the installation had been "shut down for now but is ready to come online again if needed." ||

REGULATORY AGENCY AGAINST POWER-TO-GAS
When the methanation system was put into operation, Axel Wietfeld, chief executive of Uniper's German subsidiary, Uniper Energy Storage, called for changes to the laws that govern these types of systems. But Jochen Homann, head of the agency that regulates the energy market, dismissed the idea, according to the Schweriner Volkszeitung. He reportedly said, "We don't want the gas pipelines to add to challenges in other areas, such as electric power production and telecommunications."

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

DWV – MANAGEMENT STAYS ON

Annual meeting in Salzgitter

The German Hydrogen and Fuel Cell Association has re-elected its board members to serve in their current capacities for another two years. Efforts undertaken in the last two had borne fruit, its chairman, Werner Diwald, said at the annual meeting, held May 30. He added that much had been accomplished in Germany and throughout Europe. The next goal was to professionalize the organization as soon as possible.

He said that hydrogen and fuel cells were mentioned seven times in the coalition agreement signed by the governing parties in Germany and that the European Union was taking note of them, too, both developments he attributed to the lobbying efforts of his organization, also known as DWV. Continuing those with the same vigor would require some restructuring, he explained.

It was for this reason that the board of the association, which has grown to over 100 organizations and around 230 individuals, had been in talks with prospective association partners, such as the BVES for energy storage and the DVGW for gas and water, to establish a shared office.

Its members seem to trust current management to tackle the challenges ahead, as they reelected the entire board at the meeting. This means that changes in personnel will have to wait for at least another two years.

JUNIOR RESEARCHERS GET RECOGNIZED FOR THEIR WORK This year, the award for the best dissertation went to Matthias Breitwieser, who invented a new technique to produce membrane electrode assemblies. Breitwieser, a recent PhD graduate, who works at the University of Freiburg's microsystems engineering department, and Matthias Klingele, one of his colleagues, had received an f-cell award as early as 2015, after developing an ionomer membrane that, in liquid form, can be ink-jet printed or sprayed onto a fuel cell (see H2-international, April 2016). Based on that research, he improved the process, further reducing the platinum loading while increasing stability, to create a new multilayer composite membrane (more on this in the October issue).

Marius Holst was presented with the award for the best master thesis. He explored options to use waste heat from power-to-gas systems, investigating several ideas for pipeline injection to heat homes and design an integrated energy system that combines electricity generation, heat production and transportation (see October issue).

Karsten Maybee received an award for his bachelor thesis about industrial membrane coatings. Professor Birgit Scheppat, the association's vice chairwoman, stressed the fact that the young researcher had taken the exam as a part-time learner, that is, he had studied and worked a regular job.

The event was hosted by Salzgitter Flachstahl, which invited attendees to tour its factory after the end of the agenda. And Alstom Transport Deutschland, also based in Salzgitter, offered a test ride on its new Coradia iLint fuel cell railcar. ||

Fig. 1: Award winners Maybee, Breitwieser and Holst (from left), with Scheppat and Diwald

Category: Book Recommendations | **Author:** Sven Geitmann

CLEAN REVOLUTION

Disrupting energy and transportation

A visionary and outside-the-box thinker, Jeremy Rifkin played a big part in making hydrogen and fuel cells a hot topic at the turn of the new millennium. As the author of "The Hydrogen Economy: The Creation of the Worldwide Energy Web and the Redistribution of Power on Earth," published in 2002, he toured around the world to present his groundbreaking idea of creating a hydrogen economy. While Rifkin keeps a low profile these days, Tony Seba, also an American, has stepped up and has written an impressive book about the times that are changing.

Titled "Clean Disruption of Energy and Transportation," it hit the shelves as early as May 2014. It caused quite a stir at home, as the author didn't mince words and announced the end of conventional energy production and the disappearance of the internal combustion engine. Following his book's release, he travelled to many places around the world, speaking at conferences and appearing on TV shows to share his ideas and discuss the possibility of revamping the energy market.

It took three years, however, before Seba's illustrative publication reached the shores of Europe. In 2017, the MetropolSolar Rhein-Neckar association had the 290-page work translated from English into German. That MetropolSolar's chief executive, Daniel Bannasch, has since been one of its most vocal advertisers should come as no surprise, considering the book truly lives up to its title.

The award-winning author and thought leader describes in simple terms how large energy suppliers have made big bucks with fossil fuels and centralized generation. He also explains why and how the situation could – or, rather, will – change rapidly. In short, the book is about more than just introducing readers to innovative technologies. It is about entirely new business models that will leave legacy companies no chance of surviving the competition unless they instigate radical changes, quickly.

Seba backs up his projections with a wealth of easily understandable facts and infographics. He also makes clear what progress has been made, from solar energy to electric transportation to autonomous driving. He details how interconnected these new technologies are and what benefits that brings. For example, he lists nine reasons why electric vehicles are disruptive, that is, why they will supersede current modes of transportation. Even if a few paragraphs and statements show up more than once in one way or another, the book is a must-have.

Seba, who used to work for Cisco Systems and went on to head several high-tech companies, wrote his book based on 20 years' experience as a consultant for businesses in Silicon Valley. He is also a lecturer at California's Stanford University. ||

"Without a doubt, Tony Seba is one of the world's greatest minds on energy and transportation. The takeaway from his book is that disruptions happen more rapidly than even experts could predict. It will help readers understand the pattern of these changes, which will soon lead to a fully renewable energy system, and prepare them for the transformation of the market. Likewise, it presents a second opportunity for those who underestimated the success of PV, storage technologies and electric transportation."

Professor Eicke Weber, formerly head of Fraunhofer ISE

"Seba describes a fast-paced and inevitable technological and economic advancement, one that is – basically, on the side – also a social and environmental revolution. It's a radical change governments and corporations that have come to depend on nuclear energy and fossil fuels may be able to delay for a while. But they can't put the genie back in the bottle."

Daniel Bannasch, chief executive of MetropolSolar

Seba, T. (2014). *Clean Disruption of Energy and Transportation: How Silicon Valley Will Make Oil, Nuclear, Natural Gas, Coal, Electric Utilities and Conventional Cars Obsolete by 2030.* 290 pages. ISBN-13: 978-0692210536

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

HYDROGEN AND FUEL CELL INDUSTRY EXUDES CONFIDENCE

Hannover Messe 2018

Fig. 1: Olaf Lies, Heinz Jörg Fuhrmann, Gorgo Chatzimarkakis and Werner Diwald at the panel discussion

This year, the mood at the shared space Hydrogen + Fuel Cells + Batteries was as buoyant as it hadn't been in a long time. Nearly all players in the hydrogen and fuel cell market exuded great confidence during Hannover Messe, held April 23 through 27, and spoke passionately about new interesting projects and orders. It was an experience that stood in sharp contrast to the event's overall numbers, which seemed to be trending slightly downward. In 2018, Hannover Messe attracted 210,000 attendees, 10 percent more than two years ago. But 2016 had seen no CeMAT taking place at the same time and boosting the number of exhibitors by about just as much.

Prior to the show, Tobias Renz, the organizer of the Hydrogen + Fuel Cells + Batteries exposition in hall 27, had cheerfully told H2-international that an even greater number of electrolyzer manufacturers would exhibit their products this year. In fact, they arrived in such numbers that the elevator pitches, for years a regular feature of the Technical Forum, took twice as long, so that the session had to be split into two held at different times.

Of note was that companies such as McPhy have begun to offer large-scale systems ranging from 20 megawatts to 100 megawatts. In Hannover, it exhibited a modular and scalable solution called Augmented McLyzer. Power density, too, had reached levels that "no one had ever expected of alkaline electrolyzers," a spokesperson said. Performance now seems to match PEM fuel cells, after the 85-staff business had proudly announced that it had been able to double hydrogen production capacity while keeping efficiency and surface area at previous levels. The breakthrough had been the result of several developments, including a collaboration with De Nora.

BRIGHT OUTLOOK Although there are many stakeholders striving to develop systems for green hydrogen production, competition among them has been anything but fierce. One likely reason for this is that they expect the market will be large enough for sharing. Werner Diwald, the chairman of the German Hydrogen and Fuel Cell Association, said that Germany had the potential to see 2,000 megawatts of electrolyzer capacity being installed provided renewable hydrogen competed on an equal footing with biofuels. He added that the gas would also offer a less expensive way to lower carbon dioxide emissions. On that point, some progress had been achieved in negotiations about the second Renewable Energy Directive in Brussels. At the time of writing, the talks had yet to yield results.

When asked about where to use the hydrogen produced via electrolysis, more and more people are pointing to the steel industry (see pp. 7 and 34) and refineries. During a panel discussion about renewable hydrogen in the steel industry, the secretary general of Hydrogen Europe, Jorgo Chatzimarkakis, said, "We Europeans are world leaders in the electrolyzer market. The [GrInHy] project in Salzgitter gives us a chance to jump-start a hydrogen economy." He also noted that renewable means to produce steel used in automotive manufacturing would add a mere EUR 150 to the price of a car. But it would require unanimous support from the political sphere to prove that "Europe is 100 percent behind these projects and citizens will buy the products coming out of them."

Despite the new techniques, the industry is not about to write off natural gas reforming. Rouge H2 Engineering, an Austrian energy storage company, exhibited a reforming unit that is said to be installed, together with three others, in a 40-foot container in Ternitz, in the state of Lower Austria. This prototype will then be monitored for three months before being field-tested at potential customer sites. Rouge's chief executive, Florian von Hofen, told H2-international that the technology could reduce the cost of hydrogen to EUR 3 per kilogram.

ON TO SUCCESS, STEP BY STEP Even regarding policy changes, the belief among many now seems to be that the German government will act before the next general election to ensure that operating electrolyzers will become economically viable in the near future. Klaus Bonhoff, the chairman of NOW, said that what he had read in the coalition agreement had been very encouraging. Hydrogen and fuel cells, along with concrete steps for support, were mentioned as many as seven times in

the document. Meanwhile, Thomas Bareiß, an undersecretary in the economy ministry, has publicly called for implementing those steps. In light of the government's gradual change in attitude, Jorgo Chatzimarkakis said, "Something is going to get done. Very good news, indeed."

Bareiß confirmed that "China is investing enormous amounts of cash into setting up hydrogen fueling stations. We need to expand our network as well." He added that Germany had made a lot of funds available. As part of the National Innovation Program NIP 2, it had allocated EUR 1.4 billion for hydrogen and fuel cell projects until 2026, with another EUR 2 billion coming from the private sector. "There's more than enough money available. Policymakers and businesses are committed to the technology, plus we have the appropriate planning security. It's the foundation we need. Hydrogen and fuel cells work. We'll be moving forward."

AUTOMOTIVE SUPPLIERS TAP INTO POTENTIAL What was very well received by stakeholders was the message that large automotive suppliers seemed to have recognized the potential of fuel cells. Plastic Omnium's exposition made it unmistakably clear that fuel cells are to play a key role at this globally operating Tier 1 supplier. In the months leading up to the event, it had bought three businesses: Swiss Hydrogen, a fuel cell manufacturer based in Switzerland; Optimum CPV, a Belgian tank manufacturer; and PO-CellTech, an R&D institute headquartered in Israel. The last was established only in late 2016, in partnership with electronics firm Elbit Systems. Plastic Omnium said that the startup had around 130 staff members, who, from tanks to fuel cells, had been modelling the entire process of changing one form of energy into another inside a vehicle, including pressure reduction, valves and energy management.

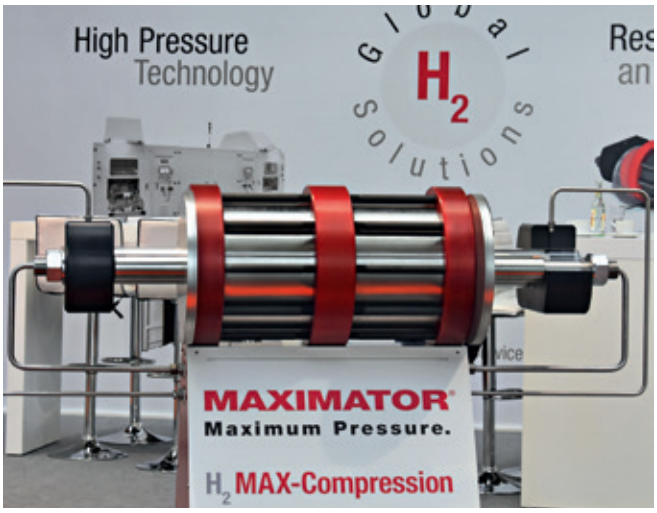

Fig. 2: Maximator's colt-like solution

French auto supplier Faurecia is likewise shifting its focus to new markets. In May 2017, it began to collaborate with Stelia Aerospace Composites, after it had entered into partnership with valve manufacturer Ad-Venta. The executive vice president of Faurecia Clean Mobility, Christophe Schmitt, said that the shared goal was to design a high-pressure hydrogen storage system for a large fleet of light commercial vehicles powered by fuel cells. In September last year, >>

Source: Chiyoda

Fig. 4: Demonstration system in Yokohama

the company had already entered into collaboration with CEA, to design fuel cell systems that, according to Schmitt, would specifically meet the needs of vehicle applications. Ultimately, the aim was to become a leading supplier for this kind of alternative powertrain. Faurecia announced a demonstration vehicle for the end of this year.

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HIGH PRESSURE AT HYDROGEN STATIONS Maximator, on the other hand, had designed a high-pressure hydrogen compressor to improve the situation at hydrogen fueling stations. Its compression rate of 100 kilograms per hour is much higher than what commonly used devices can achieve today. The company, based in Nordhausen, Germany, also equipped the system with a colt-like solution to allow for an easy replacement of high-pressure seals, which are subjected to considerable strain. They have been identified as a weak spot of hydrogen fueling stations and have often been the cause of unplanned downtime. Maximator's new piston compressor, built in just six months, contains a reserve of up to eight seals, which are replaced automatically between fill-ups. "The system has built-in redundancies," is how a staff member put it, adding that it was also less expensive than, for example, an ionic compressor.

JÖRG WEIGL

Fig. 3: Jörg Weigl's LED bar lights up a fuel cell prototype.

Once every few years, Jörg Dieter Weigl shows attendees one of his innovations in the shared space. This time, the invention was a compact energy storage system, typically battery-powered and suitable for both stationary and vehicle applications: EnergyTube by Unicorn Engineering. Weigl had installed metal hydride storage and a fuel cell stack from Singapore inside the space usually taken up by batteries and exhibited a 55-watt prototype, said to be expanded to 100 watts.

Maximator's booth showed merely a mock-up (see fig. 2), but a production-ready system is said to be available soon. To this end, the company formed a team consisting of hydrogen experts, some of whom used to work at Linde in Vienna. Additionally, the family-owned holding, which belongs to the Schmidt Kranz Group, created a joint venture with TesTneT Engineering, with a focus on investigating the bursting behavior of pressure vessels. The new business intends to construct a test facility that allows hydrogen tanks to burst during stress cycles to determine temperature, humidity, fast fill, fast drain and pre-existing damage thresholds, among other things, in real-life conditions. The head of TesTneT, Marius Herr, said that the system was scheduled to come online in mid-2019.

Off the orange carpet that covered the floor of Tobias Renz's exposition, exhibitors in hall 27 had few intriguing products to show. One exception was WätaS Wärmetauscher Sachsen, a midsize company based in the German state of Saxony, which in 2017 was presented with the state's Integration Award for employing 28 refugees on a regular, continuing basis. At Hannover Messe, right at the entrance to the Energy hall, it showcased "the first PEM fuel cell that has been developed and manufactured in Saxony state and provides 1 kilowatt of capacity." The bipolar plates for the unit are produced in-house (see p. 34).

LOOK TO JAPAN AND AUSTRALIA FOR LIQUID HYDROGEN

At the German-Japanese Economic Forum, the question was: "Challenges of a Future Sustainable Energy Supply in Germany and Japan – H2 as a Solution?" Roland Käppner, who is in charge of hydrogen product development at thyssenkrupp, used the event for a presentation of market-ready electrolyzer systems above 100 megawatts. Even more interesting, however, were the reports about Asia, or, more, specifically, two international projects for large-scale hydrogen supply to Japan.

Through a gasification process, Australia intends to produce hydrogen from brown coal in Latrobe Valley and "dispose" of emissions via carbon capture and storage. The Australian government's treasurer, Scott Morrison, explained at the launch of the project in mid-April, "We've got AUD 100 million going to that project over the next few years, we're investing in jobs in the Latrobe Valley." As part of HySTRA, liquid hydrogen is later to be transported on a tanker – which, however, runs on conventional fuel – to Japan to provide sustainable energy supplies, especially during the 2020 Summer Olympics in Tokyo. In May, construction on the import side of the equation started in Kobe, supported by the New Energy and Industrial Technology Development Organization, or NEDO. The on-site tank to store liquid hydrogen tank is said to have a diameter of 19 meters, or 62 feet, so that it can hold 2,500 cubic meters, or 88,000 cubic feet of liquid hydrogen, which is planned to be fed into a nearby 1.1-megawatt gas turbine by Kawasaki Heavy Industries.

By contrast Chiyoda Corp., a Japanese industrial equipment manufacturer, favors another route, namely adding hydrogen to toluene. Mixing both substances will create methylcyclohexane, or MCH, named SPERA Hydrogen® – as in "spes," which is Latin for hope – by the AHEAD consortium. Starting in 2020, it is planned to be shipped in liquid form from Brunei to Japan (see p. 24 and H2-international, October 2017). In 2013, Chiyoda built a first demonstration system in Japan's city of Yokohama. The corporation, which has numerous hydrogen production facilities around the world,

said that tests had shown that the hydrogenation of toluene occurred at 99 percent efficiency and dehydrogenation based on MCH at more than 98 percent. Consequently, and with support from NEDO, it began in 2015 to establish a global hydrogen supply chain, including a hydrogenation plant, from the Sultanate of Brunei, on the Indonesian island of Borneo, to a dehydrogenation system in the Japanese city of Kawasaki. Production and hydrogenation in Brunei is said to start in 2020. The SPERA hydrogen will then be shipped on conventional tankers to Japan.

Cornelius von der Heydt, head of sales at Hydrogenious, said, "Chiyoda relies on toluene due to its lower price. Professor Hansong Cheng, the chief executive of Hynertech, uses a substance that we have no information on, but one that is said to come from the same chemical family as N-ethylcarbazole."

SYNERGIES BETWEEN AUTOMOTIVE AND HYDROGEN PRODUCTION IAV attracted much attention as well. The company, based in Berlin, was a co-located exhibitor in the shared space of Lower Saxony state and showcased a small model of its electrolysis system. The organization typically develops solutions for Audi and Volkswagen but may try its hands on other energy technologies. Currently, IAV's Ralf Wascheck is looking for some overlap between fuel cell and electrolyzer technology. The goal is to determine whether economies of scale can be realized if both technologies are being used simultaneously.

It was the reason for IAV's construction of an alkaline 150-kilowatt electrolyzer in Gifhorn, as part of a project supported by the German economy ministry. What the company hopes to achieve are synergies. "The use of automotive components and production techniques cuts costs to a considerable degree. Virtual engineering reduces the time and effort needed for development. Two examples are tried-and-proven injection molding and mass-produced components, such as exhaust gas recirculation systems, which make the electrolyzer a more competitive product." What is important to note is that the same logic applies in reverse, which means that the automotive sector also benefits from a growing electrolyzer industry. As one IAV employee was pleased to report, the project had garnered much praise at the show. Even the manager of the neighboring Enercon booth had shown interest in it.

The next Hannover Messe will take place April 1 to 5, 2019, with Sweden as the partner country but without a CeMAT running in parallel. ||

NORWAY IN SPOTLIGHT OF F-CELL AWARD

In 2018, the f-cell show will take place Sept. 18 through 19 at what used to be its long-time location, called Haus der Wirtschaft, a building in downtown Stuttgart, Germany. As in past years, there is going to be an f-cell award ceremony, but both the ceremony and the symposium will look a bit different this time. Baden-Württemberg's state environment ministry will award two prizes of EUR 10,000 for "innovative collaborations and ideas, from Baden-Württemberg to Norway." Applicants must show that one of the participating organizations is based in the southern German state and one in the northern European country. The submission deadline is July 27. The award will be presented during the evening event on the first day of the conference.

The show will feature both expert presentations and new networking opportunities, the latter through an f-cell app developed for this purpose. "We're taking a whole new approach to encouraging attendee interaction," said Silke Frank, who works for the show's organizer, Peter Sauber Agentur Messen und Kongresse. There will also be two large rooms for exhibitors interested in an exposition of their products. ||

SOLAR INDUSTRY LOOKING FOR PARTNERS

While hydrogen and fuel cell companies are in search of new markets, a growing number of solar advocates is on the lookout for new energy storage equipment. Intersolar Europe, which will take place June 19 through 22, at the same time as ees Europe, intends to offer them a place to meet. At the time of writing, the efforts to set up a co-exhibitor space featuring hydrogen, power-to-gas and fuel cells in hall B1 had paid off, with 10 organizations, including Aradex, GP Joule, HPS, Hydrogenics, Proton Motor, Siqens and Wystrach, agreeing to participate. ||

EMOVE360° ADDS FUEL CELLS

The eMove360° Europe show, which will be held Oct. 16 through 18, is poised to welcome the fuel cell industry into the fold. The show's organizer, MunichExpo, has partnered with the German DWV – Hydrogen and Fuel Cell Association, among others, to schedule a Fuel Cell Conference for the first day of the event. It is said to be attended by representatives for high-profile companies such as Alstom, Daimler and Toyota.

"Lately, we've seen fuel cells become the best alternative to combustion engines, particularly for long-distance travel. After all, they are a form of electric transportation and, as such, they can be a good addition to battery electric vehicles, instead of competing with them," the organizer said in a statement. ||

Category: Stationary Systems | **Author:** Dr. Sven Rosinger, Siegfried Suchanek

ESI IN NEW HOUSING DEVELOPMENT

Oldenburg turns airbase into energy-efficient neighborhood

Fig. 1: Fliegerhorst – a living lab

The repurposing of the old Fliegerhorst airbase in Oldenburg, Germany, offers the unique chance to develop a smart city concept that can later be applied to similar communities and cities across Germany and Europe. One part of the airbase, altogether 3.9 hectares, or 9.6 acres, has been designated a living laboratory to test new energy and transportation technologies. Soon, it will likewise be home to a future-proof infrastructure. To conduct initial research, construction has begun on a mainly climate-neutral housing development. In this energy-efficient neighborhood, hydrogen will play a key role in advancing energy systems integration, or ESI, also known as sector(al) integration.

ENaQ is the first research project to merge housing development, energy supply and systems integration to provide mostly local energy resources for consumption. Plans are to build around 110 residential units and make electricity, heating and cooling, and gas part of a local multi-energy system. Besides constructing new buildings, the project will renovate houses previously used as officers' quarters to ensure that the findings can also benefit owners of existing building stock. Overall, the neighborhood will house a cluster of energy producers and consumers, the former with the means to convert and store surplus energy or offer it to others immediately.

The housing development that the project aims to create is one of maximized efficiency and minimized energy waste, along with an increased use of nearby resources. It is to result in not only an integrated energy system, but the creation of a secure open-source platform that complies with privacy regulations and allows citizens to automate local energy trading.

In addition to technical matters, researchers will study the social and economic ties between residents. In the end, the long-term success of climate-neutral energy produced and consumed in one district or neighborhood hinges on public acceptance and on business models and public-private partnerships that directly engage the local community. One more aim of the project is to develop and evaluate the services and additional benefits that will be offered to residents and system operators.

HYDROGEN AS A PRIMARY ENERGY CARRIER One important part of the entire approach is the use of hydrogen as a carrier of energy, or, more specifically, the development of a specialized energy system in the form of a power-to-gas installation. This system would use electrolysis to store power in hydrogen and generate electricity from the gas via a fuel cell, a process also known as back-to-power.

The planned high-pressure storage tank will perform an essential function in this scenario, as only a demand-responsive system can provide enough options for energy-efficient neighborhoods. The portable storage unit can be filled with hydrogen at a pressure of up to 700 bars and dispense the gas for a variety of uses, such as the operation of stationary units, including emergency and home power supplies, and fuel cell vehicles, of which ENaQ will probably have bikes, cars, vans and special vehicles, as in riding lawn mowers, street cleaners and the like. Overall, this means that it is not the application that will have to get to the refueling station, but that the station will have to be moved to where it is needed.

A PV system has already been installed at the former airbase. It could serve as the electric power source to produce the hydrogen, which would then not be stored temporarily but for the long term. In comparison, batteries

Category: Stationary Systems | **Author:** Sven Geitmann

BEDBURG GOES FUEL CELL

Massive support for residential systems

A planned eco-friendly residential development in Bedburg near Cologne will see the installation of fuel cells to meet residents' heating needs. In a collaborative project between the city, energy corporation RWE Power and manufacturer Viessmann, eight homes in Bedburg's Königshoven district will be equipped with state-of-the-art heating units. According to KlimaExpo.NRW, a North Rhine-Westphalian state initiative, the single-family neighborhood near the open-pit mine Garzweiler would be "Germany's first-ever residential development that uses only the latest residential fuel cell technology to provide heat and power."

Not only can the owners of the eight new buildings choose a fuel cell system to their liking, but they will benefit from more than one program to cover part of the cost. Through its energy efficiency measure, the government-owned KfW bank will offer grants to buy the unit, whereas RWE Power will provide energy and grant consulting services, along with added financial support. Viessmann, too, will open its coffers and bring the funding total up to a maximum of EUR 14,250.

The user-friendly fuel cell heaters can be controlled via smartphone or tablet. They can also feed excess energy into the grid, from which power will be drawn if they cannot meet demand.

"We like the idea of having a particularly efficient home heating system that generates power, basically, on the side," explained Michael Schiffer, who bought one of the homes last November. In a way, the fuel cell heater is his personal contribution to transforming the energy sector. Its round-trip efficiency saves his family both heat and electricity costs compared to conventional units.

It also reduces carbon dioxide emissions by five tons each year. Schiffer professed that this was "of course, only a small amount" right now, but added that "to protect the climate, it is vital that the market for this innovative technology keeps growing." If a battery were added, the carbon footprint of heat and power generation could be another 50 percent lower. ||

"This project is a prime example of what kind of potential future-proof heating technologies have. Thanks to government funding, they can provide long-lasting environmental and economic benefits."

Heinrich Dornbusch, chief executive of KlimaExpo.NRW

ENAQ

ENaQ – Energy-Efficient Neighborhood Fliegerhorst Oldenburg is being funded by the German education and economy ministries as part of the 6th Energy Research Program, under the auspices of the support initiative Solar Buildings/ Energy-Efficient Cities. The grant, ID 03SBE111, amounts to about EUR 18 million. Another around EUR 8 million will come from partners in the industrial sector. The project is managed by a group that is made up of organizations working in the relevant industries and research fields, as well as the public sector. It includes an energy provider, a grid operator, ICT companies, R&D institutions, universities, component and equipment manufacturers, renewable energy suppliers, a residential construction company and an innovation network. It was launched early this year and will run until the end of 2022.
www.enaq-fliegerhorst.de

could only be a short-term storage solution, as they discharge over time.

The pilot systems that will be used to provide energy for the neighborhood need to be part of the field test, a great challenge considering the red tape involved in obtaining certification, approval and operating permits. It is the reason why the development of a simplified public approval procedure has taken high priority.

ENaQ also offers the perfect digital environment to connect hydrogen-based systems. One goal during the planned trial will be to analyze user profiles to broaden and simplify fuel cell application. This analysis should make it possible to replicate the unit and neighborhood design and expand the range of uses. ENaQ will therefore be an important building block of a future hydrogen economy. ||

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Category: Stationary Systems | **Author:** Sven Geitmann

OFF-GRID HOMES

Umwelt Arena shows the way to a future energy system

A completely energy-independent home: a vision that some customers feel has so far not been easy to implement. What could change their opinion is the world's first-ever off-grid multifamily property in Brütten, near Zurich in Switzerland. Since 2016, it has provided tenants with on-site gas and electricity, for both apartments and vehicles. This kind of energy-independent lifestyle has been made possible by combining a PV system, a heat pump and an electrolyzer, which uses a fuel cell to store electric power. As early as this year, Umwelt Arena Spreitenbach, the organization that owns the off-grid building, announced a follow-on project to "show that everyone can replicate our success."

The aim of Umwelt Arena's chairman, housing developer Walter Schmid, co-owner of W. Schmid, was to design and erect a multi-unit property that could be independent of public electricity and gas services (see fig. 1).

Schmid mainly used PV technology to achieve his goal. He built a large rooftop solar installation, made up of monocrystalline cells, and added thin-film modules to the facade. Considering Switzerland has hardly enough sunshine in winter but a relatively long heating season, the system needed efficient and cross-linked energy storage units.

In the beginning, this meant putting a large heat storage tank in the ground and installing a heat pump in the basement. The pump extracts energy from the outside air, two ground probes and a fuel cell unit, through a Diamond Lite PEM electrolyzer, to power radiant heating systems inside the building.

Electricity is either consumed immediately or stored via the electrolyzer. When required, that is, when the sun does not come out, a fuel cell unit by Proton Motor will produce electric power from the hydrogen, and the waste heat from power conversion will be used for heating or directed to thermal storage. Because of the fluctuating voltage at the outlet of the fuel cell unit, the developer installed an Aradex DC-DC converter to raise it from between 50 and 100 volts to 700 volts to guarantee trouble-free operation. This adapter is also connected to an accumulator, which offers short-term power supplies that last two to three days. Overall, the system shows an effective combination of short- and long-term storage options. Besides household appliances, it feeds electricity into a charging station for electric cars.

"Indeed, since we've been living here, we've kept a closer watch on how much energy we consume. But this does not mean we've had to limit ourselves in what we can do at home."

"The elevator recovers energy, so don't hesitate to use it for the way down. You'll put a bit more power into the system."

"When you take a look around the building, you'll see only top-notch, highly efficient devices."

"We can't tilt the windows. To let air in, you can only open them all the way. Doing this several times throughout the day is much more efficient than keeping them ajar for hours."

What tenants say

CUT OFF FROM THE ELECTRICAL GRID The link to the power grid was cut June 6, 2016, during the inauguration ceremony attended by Doris Leuthard, a member of Switzerland's federal council. When the first winter had passed, Umwelt Arena announced that the tenants, who had been selected in a casting, had had light and electricity available for the entire time. They had never had to freeze either, despite January having been the harshest month in 30 years and summer the least accommodating in 20. Each of the apartments had consumed 2,200 kilowatt-hours per year, half as much as the Swiss average. Umwelt Arena, however, had to note that the fuel cell hadn't lived up to expectations at the

Fig. 2: Per hour, the H2m electrolyzer produces 2 normal cubic meters at 30 bars.

Fig. 4: Lots of state-of-the-art technology in one building

start of the cold season. Still, some adjustments and a software update later, that issue had been resolved.

The building's architect, René Schmid, the developer's son, said there was little demand for the long-term storage consisting of two several-meter-long hydrogen pressure vessels underneath the house. The reserves had been tapped on only 25 days a year. The heat pump and the accumulator were enough to provide energy on any given day.

There is a tablet hanging on a wall in each apartment to keep occupants apprised of the energy they consume at any given time.

That's not all, though. Walter Schmid, who is also the landlord, offers tenants two vehicles, an electric and a CNG car. The former is charged by the rooftop solar installation and the energy converted in the fuel cell, whereas the latter needs to be filled up at a conventional CNG fueling station. To not lose sight of what the project intends to accomplish, garden and kitchen waste from the house is regularly taken to a biogas plant to produce fuel for 10,000 kilometers, or 6,214 miles, per year.

Schmid said the building cost around 10 percent more to construct. But since tenants did not pay for electricity and gas, the rent for the nine apartments wasn't higher than in other places. Monika Sigg, who works for Umwelt Arena, added that it had not been possible to write off the expenditure for the long-term storage equipment, that is, electrolyzer, hydrogen storage and fuel cell, as the equipment was part of research and development. She also said that long-term storage had not yet been a financially attractive option for single-family homes.

Fig. 3: Two large pressure vessels to store hydrogen

FOLLOW-ON PROJECT IN ZURICH Meanwhile, Umwelt Arena has completed the construction of its "multifamily development showing the future of energy." The main differences between this building (see p. 3) and the one in Brütten are a link to the nearby natural gas grid and the use of biogas as an energy source. In January, the company presented the 11-apartment house in Zurich's Leimbach quarter as the "follow-on to our Brütten showcase project," >>

UMWELT ARENA

Umwelt Arena is both the name of a Swiss building and organization. The Arena in Spreitenbach is an example of spectacular building design, created by Walter Schmid. It was inaugurated in August 2012 and houses the headquarters of the namesake company, concert and event spaces and an exposition of sustainable living and related products, renewable energies and state-of-the-art transportation. The stock-listed company operates under the auspices of Aargau, known as "Switzerland's energy canton," which is committed to bringing security of supply and sustainable energy production to the forefront of the market transformation debate. Schmid, who has been and continues to be the driving force behind the organization, explained that it was crucial to aid in the understanding of mostly highly complex and abstract issues such as sustainability and energy efficiency. "Each of us should, on balance, recognize the advantage for themselves," he said.

Source: WeberHaus, www.umweltarena.ch

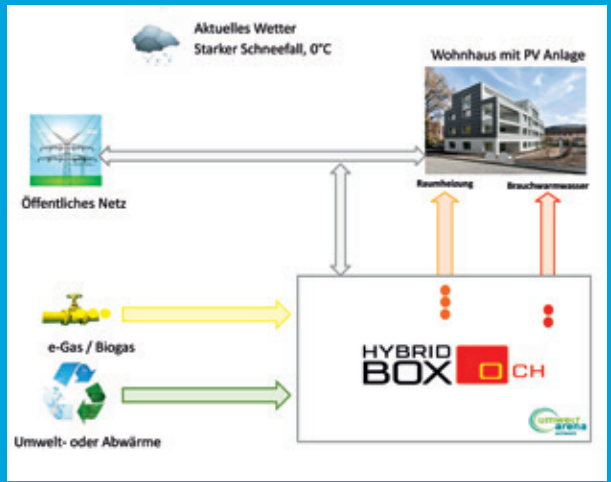
Fig. 6: Picea system installed on the outside of the WeberHaus building

which uses both power-to-gas and methanization. The excess energy generated in summer is said to be converted into so-called e-gas and injected into Switzerland's natural gas pipelines. A revolutionary Hybrid Box allowed the use of stored gas in winter, as a carbon-neutral means to heat the house. Sigg said, "The system can even feed power into the grid in winter, something previously unimaginable for a PV-based building. It leaves no questions as to what needs to be written off." Additionally, the company has stated that the project was not only forward-thinking, but that it had great potential for replication elsewhere.

HPS PARTNERS WITH WEBERHAUS Home Power Solutions, also known as HPS, has recently announced that it would start collaborating more closely with WeberHaus, a prefab home builder based in Rheinau's Linx district, in the German state of Baden-Württemberg. In mid-March, WeberHaus announced a joint pilot project in Germany's Sauerland region, where a first HPS Picea system had been installed in a newly constructed building. Zeyad Abul-Ella, chief executive of HPS, said the company guaranteed customers "that all the energy they need will come from their own systems, to meet the entire demand for clean power in single-family homes." Since February, a limited number of Picea devices has been up for sale, at a price of EUR 54,000. ||

HYBRID BOX

The Hybrid Box is a compact and patented station to meet a building's energy needs as part of one, unified system. It adjusts output to electricity supply and demand, although the focus is on providing sufficient heat inside the house.



VIESSMANN OFFERS FUEL CELL RETROFIT

Vitovalor PT2 at Hannover Messe

In April, Viessmann, a family-owned business based in Allendorf, Germany, started selling two new and improved generations of Vitovalor systems.

PT2 is a whole-home solution for single-family and duplex houses. The space-saving unit has two components, a gas condensing boiler, integrated with a fuel cell, and a 220-liter tank, both with a matching height of 1.8 meters, or 5.9 feet. The boiler capacity ranges from 11.4 to 30.8 kilowatts. The unit has a minimum service life of 80,000 hours and requires maintenance only every five years. It is the first product that can rightfully be called an integrated fuel cell unit. In the previous generation, branded 300-P, the boiler system had, basically, been "slapped" onto Panasonic fuel cell equipment. This time, the devices work in concert, as part of a system specifically designed to meet the needs of the German market.

By contrast, PA2 is used to retrofit state-of-the art gas condensing boilers. It consists of a fuel cell, a gas purifier and the controls and is 1.6 meters, or 5.2 feet, high. Rene Eickhoff, product manager at Viessmann, explained that the unit presented a good opportunity for owners of residential and commercial real estate to reduce energy costs and carbon dioxide emissions. The manufacturer's ads zero in on its 10-year warranty and the government's fuel cell incentive of up to EUR 11,100. ||

POWER PLANT TO SUBSTITUTE H_2 FOR CH_4

In the Netherlands, a power plant running on natural gas is said to be converted into a hydrogen facility. In mid-March, Mitsubishi Hitachi Power Systems announced it would adapt one of Nuon Magnum's three 440-megawatt combined-cycle units in Eemshaven, in the Groningen region, for hydrogen by 2023. The change in fuel would be part of the ongoing Carbon-Free Gas Power project.

The plant's operators, Nuon/Vattenfall, Statoil and Gasunie, had commissioned MHPS to conduct a feasibility study about the use of hydrogen to produce power at the plant. MHPS, based in Yokohama, was formed in 2014 as a joint venture between Mitsubishi Heavy Industries and Hitachi. Alexander van Ofwegen, Vattenfall Netherlands, said that to fulfil the Paris agreement, the Dutch electricity industry's carbon dioxide emissions had to be between 55 percent and 75 percent lower in 2030, compared to 1990 levels. Replacing natural gas with hydrogen could make an important contribution to meeting that target.

Magnum-Kraftwerk in Eemshaven

By contrast, the power plant burning hard coal in Lünen, Germany, will be reducing production and is said to be completely shut down next March. In 2015, Mitsubishi Hitachi Power Systems had installed a power-to-gas system at the plant, as part of an EU program that covered 80 percent of the cost, or EUR 11 million. The system created methanol from hydrogen produced through electrolysis and from carbon dioxide released during flue gas desulfurization. ||

BUILDING CONTINUES IN GRENZACH-WYHLEN

Construction continues on a new power-to-gas system in Grenzach-Wyhlen, despite considerable opposition. A citizens' initiative had tried to remove the site from consideration, but Freiburg's regional authority approved it in mid-March, as the hydrogen-producing facility met federal pollution standards (see H2-international, March 2017). Nevertheless, there have been calls to verify that, once started up, the system would comply with the noise limits set by law.

"We believe hydrogen will be invaluable to the country's energy transformation and, particularly, this project in Wyhlen. It is the sole reason why we applied for a building permit, although typically not needed for a plant of this size," Irene Knauber, head of service and production at Energiedienst Deutschland, said. She added, "Nearly every day, we receive requests from private citizens interested in fuel cell vehicles. This goes on to show that people are increasingly aware of the opportunities that hydrogen can offer. […] Our plan is to bring the system online in the fourth quarter." ||

Fig. 1: Constructing the power-to-gas system

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

CHINA IS MORE OPEN TO ADOPT HYDROGEN

Interview with Stéphane Aver, chairman of Aaqius

Source: Aaqius

Fig. 1: Stéphane Aver

Using cartridges to store hydrogen may not be a new idea, but it is one that has never been successfully implemented – until now. Aaqius, a technology supplier based in Switzerland, has developed a unit called *Stor-H,* which is well on its way to becoming a viable option in several countries. The handy cartridge is intended to power vehicles in not only France, Morocco and the United Arab Emirates but also China. *H2-international* spoke with the chairman of Aaqius' board of directors, Stéphane Aver, about the *Stor-H* technology, the planned cartridge vending machines and ambitious production targets.

H2-international: Mr. Aver, would you mind sketching out what your basic idea is?

Aver: Stor-H is the world's first energy standard for the connected, digital, 21st century sustainable economy. The 20th century ended eighteen years ago. So much has changed in our lives since then but we have still not innovated in the way we produce, distribute and consume energy. Look at how Google, Amazon, Alibaba, Uber, AirBnB have changed the way we consume information, shop for goods, consume mobility, and travel. And in the world of "hardware" look at how Tesla has revolutionized mindsets in the automotive industry. In green energy, the current 700 bar hydrogen storage standard, requiring multi-million Euro infrastructure investments for each filling station reflects a 20th century approach to the problem. *Stor-H*, through its solid storage of green hydrogen in safe, easy-to-use connected cartridges distributed in state-of-the art vending machines, accessible through a smartphone APP, radically changes all of this.

How did you approach this concept?

Aver: Aaqius specializes in the development, industrialization and market deployment of innovative and disruptive "low-carbon" technology standards for the energy and mobility sector worldwide. Our focus on technology standards, and on integrated local ecosystems, is our way of de-risking our investments and ensuring broad market penetration. With our *Stor-H* cartridges, vending machines, IT platform and smartphone APP, what we are really doing is transforming traditional energy consumption into a connected, digital service that is particularly suited for light urban mobility. Protected by over 150 patents, the *Stor-H* technology enables the solid storage of hydrogen, at very low pressures, in safe easy-to-use cartridges that can be distributed in vending machines, thus eliminating the need for expensive and intrusive infrastructure.

Since when are you working on this concept?

Aver: Since 2006, Aaqius has to-date successfully created three "low-CO_2" technology solutions in the area of engine emissions controls (local pollutants, particulates, NO_x after-treatment). Each solution has already become a global standard in the automotive industry. In 2009 we launched our internal development of a disruptive means of storing hydrogen safely and easily in order to accelerate the deployment of "zero-CO_2" mobility. And once again, our focus is on creating a technology standard on a worldwide scale.

In November 2017, during the Dubai Airshow, Michael Levy, your vice president of research and innovation, and Dubai Aviation City Corp. signed a memorandum of understanding to conduct a feasibility study. What is the objective of this study?

Aver: Dubai wants to create a logistics hub for the 21st century: sustainable, ecological, zero-CO_2, and using the latest innovations our century has to offer. This is why they chose *Stor-H* for deployment in Dubai South. This is an emerging 145 sq. km master-planned smart-city that is the Emirate's flagship urban project. It is projected to sustain a population of a million, and is designed to support every conceivable kind of business and industry. It is home to the world's largest airport in the making – the Al Maktoum International Airport – and is host to landmark events such as *World Expo 2020* and the *Dubai Airshow*. Furthermore, Dubai South is to be a sustainable city with a minimal carbon footprint.

Experience has taught us to carefully evaluate the technical and economic feasibility before rolling out our innovations in any given market. The study is intended to identify how the *Stor-H* solution needs to be adapted to the specific usage and environmental needs that are unique to Dubai South.

Shortly before the show, Aaqius had entered into partnership with the city of Marrakesh, its local university and the Research Institute for Solar Energy and New Energies, also known as IRESEN. It was reported that 50,000 two-wheeled, three-wheeled and four-wheeled vehicles would receive a hydrogen upgrade by 2021. The number of motorbike upgrades alone was said to be adding up to 20,000 units. How do you intend to achieve these targets?

Aver: In Morocco, as in each of the geographical areas where we are deploying *Stor-H*, we always go through the same

steps that have helped us succeed in the past: performing a technical and economic feasibility study of the local ecosystem, and putting in place the required relationships with industrial partners and national/regional/local authorities. Aaqius' growth has been built on a unique "R & B" (Research and Business) model that combines strong technical expertise, disruptive innovations, and the ability to successfully develop these innovations into profitable businesses through the creation of technology standards. The deployment of these solutions requires that Aaqius organize and structure long-term partnerships with all of the key players in the value-chain, universities, private/public research organizations, industrial companies, investors, and political stakeholders.

In April 2018 we created an affiliate, *Stor-H* Morocco, to manage our partnerships with Maghreb Oxygène (Akwa Group) for the production of green hydrogen, PEPS/Imperium Holdings and Menara Holdings for the production of our 2/3-wheel hydrogen motorbikes. And by the way, we will not be upgrading or retrofitting motorbikes that are currently on the road; we will be locally producing new hydrogen vehicles.

What about Censtar Science & Technology Corp. in China? How successful has the cooperation been? It was said that until the end of 2018, you wanted to develop your technology to a point at which around 100,000 electric vehicles, including bikes, heavy-duty trikes, scooters, golf carts and forklifts, used in Jiangbei, a new economic development area in Nanjing, could be equipped with Stor-H cartridges in two years' time. Afterward, you would start offering products on the national market. Is this project on schedule?

Aver: The deployment of *Stor-H* in China is on schedule; our focus now is on seeing how we can accelerate our progress to move ahead of schedule. The market opportunity in China is huge and we have to move fast. The Chinese government is focused on revolutionizing the way they produce, distribute and consume energy. They see *Stor-H* as an accelerator for change in this sector. With over 40.000 points-of-sale (service stations) for electricity, gasoline, diesel and natural gas, Censtar is a key player in energy distribution in China. Their distribution network is obviously a big asset for us in the deployment of *Stor-H*.

We are in the process of qualifying industrial partners for the production of our cartridges and of our hydrogen 2/3/4 wheel vehicles. And we expect to create a local affiliate, *Stor-H* China, before the end of 2Q 2018 to manage these business relationships.

At ICC 2017 in Beijing, China's economy minister presented you with the Cleantech Award for Stor-H. Is the People's Republic more open than its European counterparts to adopting hydrogen technologies?

Aver: It is absolutely clear that the People's Republic of China is more open than Europe to adopt hydrogen technologies, and in particular *Stor-H*. They have already understood that hydrogen is an essential part of the energy mix for tomorrow's mobility, for example. Last November in China, with the help of French former-Prime Minister Mr. Jean-Pierre Raffarin, we met with Mr. Nur Bekri, Minister of NEA (National Energy Administration) and Vice Director of NDRC (National Development and Reform commission). Mr. Bekri understands the importance for China to implement the *Stor-H* standard of energy and has expressed his support for its deployment. He reiterated his support to us at the most recent BOAO Conference in April.

"The air quality in Marrakesh is about to take a dramatic turn for the worse. We need the transportation sector to change. Together with Aaqius, we're taking on today's biggest challenge, which is to make motorcycling a cleaner form of transportation."

Ahmed Akhchichine, council president of the Marrakesh-Safi region

Fig. 2: Khalifa Suhail Al Zaffin, Dubai Aviation City Corp., talks with Jean-Pierre Potel and Adil Gaoui (both Aaqius) and Ismail Al Marzouqi (also Dubai Aviation; left to right)

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Subsequently Aaqius signed agreements with two agencies of NDRC, the Investment Association of China (IAC) and the Energy Research Institute (ERI) to organize and accelerate the deployment of the STOR-H in China. This highly visible support at the national level is instrumental in helping us to quickly identify the required R&D and industrial partners and to put in place effective cooperation agreements.

On Jan. 15, Aaqius unveiled a vending machine for hydrogen cartridges during the World Future Energy Summit in Abu Dhabi, where you shared exhibition space with other organizations from Switzerland. How does the device work?

Aver: With *Stor-H*, we are leveraging on cutting-edge innovations in logistics, point-of-sale distribution, and cloud-based e-commerce, to make energy consumption and mobility easier for our users. The *Stor-H* vending machine is an integral part of the connected digital ecosystem that allows users to exchange their empty cartridges for full ones. It is based on a standard vending machine design that has been upgraded to allow it to be geolocalised by our *Stor-H* users through the *Stor-H* APP. Contactless payment technologies (NFC) have been integrated to make it easy for users to quickly access full cartridges.

Our IT platform keeps track of users and cartridges (each cartridge is connected to the Cloud and has a unique identification number). This allows users to quickly and easily drop off their empty cartridges and pick up full ones. The *Stor-H* vending machine is connected to a supply chain database that allows our logistic ("milk-run") partner to track real-time the number of full and empty cartridges in each vending machine in order to optimize the scheduling of delivery vehicles (which will also run on >>

Fig. 3: The vending machine distributes 300 hydrogen cartridges per day

Stor-H cartridges). The empty cartridges are then transported to dedicated sites for refilling.

How and where are the cartridges filled? Has there already been a service to pick up empty units, refill them and take them back to a dealer?

Aver: We have several options for the refilling of our cartridges. In areas where hydrogen service stations are already in place (350 bar, 700 bar) we can integrate on-site filling units to leverage on this existing infrastructure. This also shows that our new energy standard, low-pressure *Stor-H* cartridges, is in fact complementary with the high-pressure standard that is used for vehicles (> 1,5 t; ex, the Toyota *Mirai*). In parts of the world where the 700 bar infrastructure is not yet in place we are partnering with industrial companies (such as Censtar in China) to build dedicated centralized facilities. The logistic services are needed to take the cartridges from the filling sites to the vending machines (and back again) are already in place. Once again, whenever possible, we integrate our specific *Stor-H* ecosystem requirements into existing services and infrastructure. This is what we need to do to accelerate our deployment and optimize costs.

Is it true that to operate these units, you need nothing more than the Stor-H App on your smartphone?

Aver: Absolutely! With the *Stor-H* cartridges, vending machines and App, energy becomes a digital connected service that can be easily accessed and consumed in a broad catalog of applications. Our proprietary IT platform and its smartphone app allows both businesses (BTB) and consumers (BTC) access to the *Stor-H* ecosystem, where they can manage their mobility and/or their energy needs. The IT platform and app allow the *Stor-H* business model to be easily replicated and scaled up during the rollout of the *Stor-H* ecosystem worldwide. Furthermore, state-of-the art IT technologies are implemented to enable optimal user experience for both BTB and BTC consumers.

Your company has stated that the cartridges work at very low pressures. What is the basis for your storage design? So far, the only thing you've said was that inert hydrogen is stored in a complex, multi-material and ultra-absorbent medium. Metal hydrides or sodium borohydrides come to mind. Is either of these storage methods out of the question?

Aver: First of all it is important to note that we developed, validated and industrialized our cartridge know-how with an earlier application, the solid storage of ammonia for automotive emissions controls. This intellectual property was licensed in 2013 to a major automotive Tier1 supplier. Our fundamental know-how is thus applicable to many different type of storage materials and applications. It is based on innovative ways to integrate storage materials into easy-to-use digitally connected cartridges and in fact we are agnostic as to the specific storage material used in our cartridges.

For the *Stor-H* hydrogen cartridges what we can confirm is that, yes, inert hydrogen is stored in a complex, multi-material and ultra-absorbent medium. And as part of our technology development roadmap we have R&D programs in place with several R&D partners (in France, the UK, Germany) for different types of storage materials. And since we are a private company that funds all of its R&D, our key criteria is, as always, time-to-market and time-to-cash.

Could you tell us the size and weight of your cartridges?

Aver: The *Stor-H* energy standard has two basic cartridge sizes for our BTC applications (2/3/4 wheel vehicles, low power stationary applications) and a cartridge pack configuration for our BTB applications (ground support equipment, material handling equipment, high power stationary applications).

I've read that you equipped as many as 100 scooters with the technology in Paris and Asia. Tests were said to have been successful. Does this mean that Aaqius has production lines up and running for both the storage units and the scooters? Where are those production facilities and what is their capacity? How many cartridges or vehicles can you manufacture per year?

Aver: In the past we have relied on prototyping partners with limited scale-up possibilities. Now that we need to ramp-up in Morocco, Dubai, China we have had to find partners with industrial capabilities. For each of the key physical items in the *Stor-H* ecosystem (cartridges, fuel cells, vending machines, vehicles, IT servers) we have made local/global sourcing decisions in order to optimize investments and operating expenses.

Where do you get your hydrogen from?

Aver: Stor-H is focused on green hydrogen. It just doesn't make sense to continue to promote hydrogen whose production has a significant hydrogen footprint. In each of the three regions where we are currently deploying we have put in place partnerships to source hydrogen that is produced by electrolysis using renewable electricity (solar, wind). In Morocco, Dubai, China the national authorities have strong commitments to the deployment of renewable energy. This is one of the criteria we use to prioritize our investment decisions.

Am I right in assuming that, overall, you support a move away from private transportation to increased vehicle sharing?

Aver: Frankly, this is not a key issue for us. There will always be private transportation, public transportation and vehicle sharing. And today it is not clear that the vehicle sharing models are economically sustainable. This is why we decided early on not to base our *Stor-H* business model on any specific transportation mode. We follow customer usage, and for this reason *Stor-H* is multi-modal.

Recently, you mentioned that you don't want to be dependent on batteries in the same way people have relied on oil for all this time. What advantages does hydrogen have over batteries?

Aver: I think your readers are already familiar with the many advantages that hydrogen has over batteries and particularly over lithium batteries. And so I won't dwell on the technical advantages, such as quick recharge without lifetime degradation, and the higher energy storage densities of our *Stor-H* cartridges. What is interesting for us is that each of our hydrogen vehicle partners already has a lithium battery product line. They have come to us to help them solve issues that were new to us. For example, many airports prohibit the use of lithium batteries in ground service equipment for safety reasons. Another example, the current constraints on the shipping of lithium batteries generates logistic headaches for vehicle producers. Once again, usage is driving them to hydrogen and in particular to our *Stor-H* cartridges.

Your approach comes with an entirely new business model for the energy sector. Your company once said that this kind of model will revolutionize the access to and the consumption of energy. Do you think that Stor-H is a disruptive product that has the potential to make other technologies obsolete?

Aver: The *Stor-H* energy standard is a disruptive product that enables an innovative distribution ecosystem able to provide energy and mobility as a connected, digital service. This is what the 21st century is all about. That much is certain. Will *Stor-H* make other technologies obsolete? We don't know and, in fact, that is not our primary focus. We are using cutting edge innovations (including ours) to change the way people consume energy and mobility. Our "obsession" is on scaling up *Stor-H* as quickly as possible in selected geographical areas in order to benefit from economies of scale and initiate the virtuous cycle that is essential for massive market penetration.

One more question, if I may. You've also been the president of Aalps Capital, a Paris-based investment firm, for the past year and have been the chairman of Tech Value, a Geneva-based IT service provider, since 2002. Do these two companies have any relation to Aaqius?

Aver: 21st century technology innovations require 21st century financing solutions. This is the message we were given by top-tier investors in Europe, Asia, and the US. Aalps Capital was specifically created to address the need for financing adapted to *Stor-H*. The deployment of the digital, connected *Stor-H* energy and mobility ecosystem requires regular and sustained capital investments in a wide variety of equity structures (new companies, special purpose vehicles, start-ups). To accelerate the worldwide roll-out of the *Stor-H* green energy mobility standard Aalps Capital was created in 2017 to offer investors high-return investment opportunities in the low carbon economy. It is an Asset Management Company authorized by the French Financial Markets Regulator N° GP 17000012 (under AIFM European Directive CS 101957) as one of the first innovative green asset management companies in France. Aalps Capital takes active part in the energy transition to zero carbon, thus addressing the requirement of the "Paris Climate Agreement". Thanks to its unique relationship with Aaqius, Aalps Capital grants access to privileged deals to its community of public, corporate and institutional investors, engaged in reducing carbon footprints and willing to participate in deploying tomorrow's standards. ||

Category: Energy Storage | **Author:** Sven Geitmann

ERLANGEN, WHERE LOHCS REIGN SUPREME

Dibenzyltoluene: The future of hydrogen storage

Over the past years, Erlangen, in the German state of Bavaria, has become known as the world's epicenter of LOHC research. It was here that Wolfgang Arlt, a professor at the Friedrich-Alexander University of Erlangen-Nürnberg, conducted his initial experiments on carbazole and other LOHCs, short for liquid organic hydrogen carriers, in 2011. The city is also home to companies such as Hydrogenious and Framatome, which are intent on bringing LOHC technologies to market. Unsurprisingly, a new research facility is being constructed in Erlangen, to help establish a carbon-neutral and sustainable energy supply chain at reasonable cost – a task in which LOHC is to play a key role.

Construction on the main office of the Helmholtz Institute Erlangen-Nürnberg, also known as HI ERN, began in July 2017, on the premises of the *Friedrich-Alexander University of Erlangen-Nürnberg, or FAU for short*. The 3,200-square-meter, or around 34,400-square-foot, building is scheduled for completion in December 2019, at which point it is said to be used, in partnership with FAU and Helmholtz-Zentrum Berlin, as a satellite site of German research institute Jülich Forschungszentrum. By pooling their expertise, the three organizations aim to conduct research into hydrogen-related materials and processes at the site. More specifically, about 110 staff members will investigate opportunities to create more efficient electrocatalysts and LOHCs.

At the groundbreaking ceremony, Ilse Aigner, who was the state's economy minister at that time and is now its minister for housing, building and transportation, said that Bavaria had allocated EUR 32 million to finance the project. She added that while the region got a brand-new Helmholtz research facility, the investment would also help widen Bavaria's lead in scientific fields such as hydrogen storage.

Professor Peter Wasserscheid, HI ERN's co-founder and president, said, "Working alongside experts in various disciplines, in the midst of a first-class innovation hub such as Erlangen-Nürnberg, provides the fertile ground needed to design new and sustainable technologies." Professor Otmar Wiestler, the president of the Helmholtz Association, added, "How to produce, store and deliver renewable sources of energy has turned into one of the biggest challenges that society is faced with today."

LOHCS ON TRACK In April, HI ERN scientists suggested using LOHCs in hydrogen trains. When the states' transportation ministers met in Nuremberg for their annual gathering, representatives for Jülich Forschungszentrum informed them about a EUR 3 million project launched in early 2018. Supported by Bavaria's economy ministry, it is said to be exploring the idea of rail-based LOHC applications over three years.

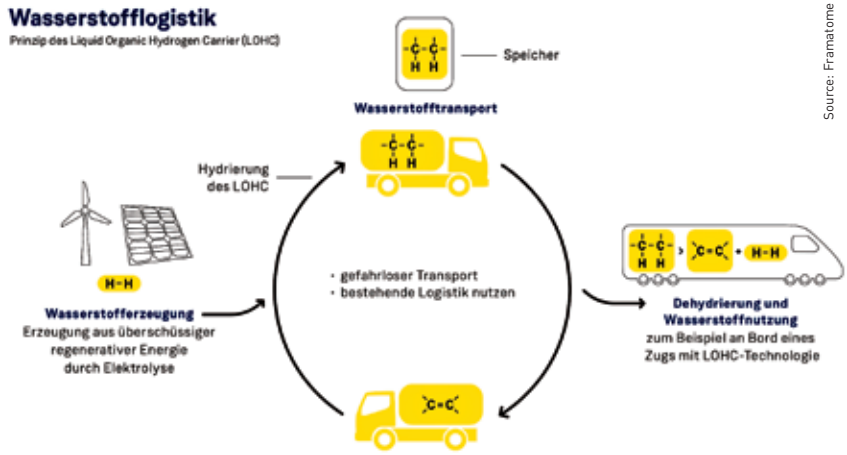


Fig. 2: The HySA system can run fully automated or based on manual input.

AWARD, TAKE TWO
Wasserscheid, a professor of chemical reaction engineering at *FAU*, has received his second Advanced Grant from the European Research Council. He is planning to use the EUR 2.5 million in award money to further his research into LOHC catalysts.

"Refueling points would need a complete overhaul to provide trains with high-pressure or ultra-cold hydrogen. LOHCs, on the other hand, make it possible to repurpose most of the existing equipment," Wasserscheid said. He added that, in contrast to standard hydrogen, the storage and supply of LOHCs was not limited in scale. Wasserscheid favors dibenzyltoluene, for which low toxicity has been observed.

Patrick Preuster, the project's coordinator, said about the plans of HI ERN, "Our aim is to put LOHCs straight into the fuel tank. From there, they can supply hydrogen to an onboard fuel cell, which will generate electric power during the train ride. Part of our project is to adapt the relevant equipment for vehicles." This, however, would first require a reduction in equipment size and weight and a fine-tuning of transient load behavior.

Besides onboard catalytic dehydrogenation, the scientists have been working on a Direct LOHC Fuel Cell for vehicle use. Preuster said HI ERN had

LOHC FUELING STATION
In late April, H2 Mobility announced that five hydrogen fueling stations would be built in and around Nuremberg. One of them, in Erlangen, would also be used to test innovative LOHC equipment and a solar-powered Siemens electrolyzer (see p. 31). H2 Mobility's Lorenz Jung said, "Via a Release Box, Hydrogenious Technologies will demonstrate how to generate hydrogen from LOHC supplies and feed it into the system."

	Dibenzyltoluene	N-ethylcarbazole	Toluene
Chemical formula	$C_{21}H_{20}$	$C_{14}H_{13}N$	C_7H_8
Energy density (volumetric)	1,9 MWh/Nm^3	1,9 MWh/Nm^3	1,6 MWh/Nm^3
Energy density (gravimetric)	6,2 %	5,8 %	6,2 %
Storage pressure charge / discharge	1–3 bar(s) / 30–50 bars	1–3 bar(s) / 70 bars	1–3 bar(s) / 10–50 bars
Temperature charge / discharge	300 °C / 150 °C	220 °C / 150 °C	350 °C / 50–100 °C
Toxicity	May be fatal if swallowed and enters airways; may cause long-lasting harmful effects to aquatic life	Causes skin irritation; causes serious eye irritation; may cause respiratory irritation or toxic if swallowed; may cause cancer	May be fatal if swallowed and enters airways, causes skin irritation; causes damage to organs through prolonged or repeated exposure; harmful to aquatic life with long-lasting effects
Flammability	low	low	high
Transport hazard	no	yes	yes
Costs	3–5 Euro/kg	> 40 Euro/kg	< 1 Euro/kg

Sources: Hydrogenious, u.a.

already started up a lab-scale prototype and a look at the preliminary results had shown that there was much potential. In 2019, the institute may launch a project to create a demonstrator, to be installed on board a train.

HEAT TRANSFER OIL TO STORE HYDROGEN In Erlangen, LOHC research has not been the exclusive domain of scientific institutes. Hydrogenious Technologies, founded in 2013, and Framatome's German subsidiary have both been committed to bringing LOHC technologies closer to commercialization. They favor dibenzyltoluene, which consists of aromatic, unsaturated molecules traded under the brand name Marlotherm. Primarily used as a heat transfer oil in industrial settings, the substance can store 9 moles of hydrogen, or 2.3 kilowatt-hours of electric power per kilogram. This is just one-fourth of the gravimetric and volumetric energy density of diesel, but a much more space-saving solution than gaseous hydrogen. Take MYRTE, a test facility on the island of Corsica, where Areva installed a demonstrator called Greenergy Box™ several years ago. Its LOHC tank requires 0.7 cubic meters for 1.5 megawatt-hours, compared to 14 cubic meters at 35 bars that a typical high-pressure vessel would need to offer the same amount of storage capacity.

Framatome's German subsidiary, formerly known as Areva, has spun off a company named Covalion to handle its LOHC business. Framatome is a nuclear energy company and part of the EDF Group, whose latest project involves the construction of an LOHC installation for HySA Infrastructure, a center of excellence in South Africa (see fig. 2). The new, custom-made container system was shipped to Johannesburg in early June and can store hydrogen at an hourly rate of 4 normal cubic meters in two 500-liter LOHC tanks.

N-ETHYLCARBAZOLE LOHCs have been an important field of research in other German cities, too. For example, Rhett Kempe, a professor of inorganic chemistry at the University of Bayreuth, and his team put the focus on N-ethylcarbazole, investigating catalysts for their hydrogenation abilities. The current material of choice in Bayreuth is a metal compound of palladium and ruthenium, applied to a silicon carbonitride, or SiCN, carrier. Daniel Forberg, a member of Kempe's team (see p.3, fig. 3), said in late 2016, "To date, there is no known catalyst that is more efficient when it comes to adding and removing hydrogen to and from N-ethylcarbazole molecules."

Moreover, thanks to this catalyst, the scientists have succeeded in creating an LOHC from lignin, a rarely used waste product of wood processing. Kempe said, "We're really pleased that our catalyst has enabled us to find an efficient and eco-friendly storage material that is available in abundance and has no value as food." He noted, however, that all his work was basic research, far removed from creating a product ready for the market.

LOHC TO FUEL YACHTS Likewise, attempts have been made to establish LOHC fuels in the maritime sector. In February, H2-Industries announced a partnership with Nobiskrug, a Rendsburg-based builder of superyachts, to develop and construct an all-electric LOHC-powered motor vessel. ||

Arlt, W., Kureti, S. (2018, June). Die Chance auf einen NO_x-freien Verbrennungsmotor. *Chemie Ingenieur Technik, 90*(6), 759-761.

USE IN INTERNATIONAL COMBUSTION

In September 2017, Energy Campus Nürnberg, FAU and NOW jointly presented the results of a feasibility study commissioned by the German transportation ministry. Its authors concluded that internal combustion engines would be on par with fuel cells if a hydrogen-infused LOHC were used. Internal combustion cars that ran on hydrogen produced neither soot, nor aromatic compounds, they stated. While the process did release nitrogen oxides, lowering their level could be accomplished more easily by using hydrogen rather than a combination of urea and water, better known as AdBlue. Lab results had indicated amounts below the limit of detection. The approach could become a promising route for zero-carbon heavy-duty transportation. When asked if it could be adapted for buses and smaller trucks, Arlt replied that it all depended on the market.

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

CAUTIOUS OR CLUELESS?

German automakers take a detour

When you ask auto experts which country has been in the driver's seat on the global electric vehicle market, they will point you to China. The number of EVs and plug-in hybrids sold in the People's Republic went from 507,000 in 2016 straight up to 777,000 a year later, according to the Center of Automotive Management. The United States ranked second, with 194,000 vehicles sold, while Norway came in third, with 62,000 purchases. Germany climbed from sixth to fourth place, with 54,000 units. EVs accounted for a remarkable 40 percent of all new vehicle registrations in Norway, up by 10 percentage points over 2016. Aside from the Nordic country and China, where EVs made up 2.7 percent of new registrations, growth was sluggish, with market shares of below 2 percent.

Several world regions have begun preparing for an all-electric future, but the chiefs of German automakers are apparently more interested in squabbling over details. After announcing a shift to electric transportation, they seem to have lost their appetite for action.

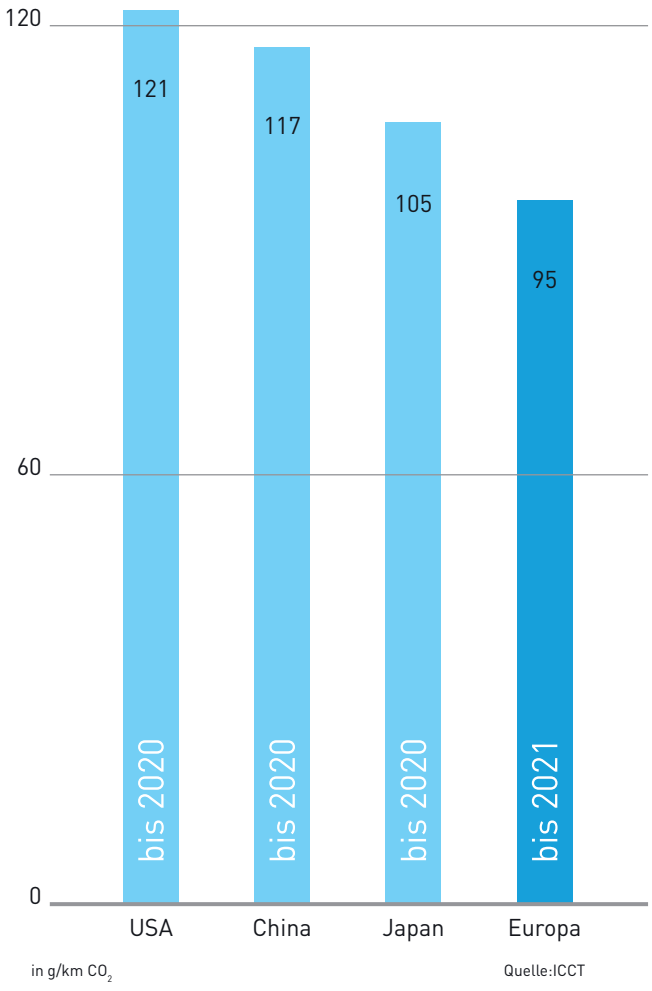


Fig. 1: Future carbon dioxide limits for new passenger vehicles (fuel mix)

> "Electric vehicles help keep the carbon footprint, but not the expenses, in check, at least for now."
> *Dieter Zetsche, chief executive of Daimler*

EUROPEAN UNION SETS CARBON DIOXIDE LIMITS Manufacturers should have enough incentive to make the transition, considering the growing constraints under which they operate. The European Union target is a fleet average of 95 grams of carbon dioxide per kilometer in 2020. Automakers failing to meet that target will be fined for each vehicle registered that year.

Fiat Chrysler as well as Hyundai Kia have their work cut out for them. Both have focused too much on SUVs and the sales of gas guzzlers has since turned into a boomerang. BMW and GM can hardly relax either, although the former is benefitting from the i3's relatively strong sales performance.

What route companies take to comply with emission limits is up to them. For example, Volkswagen is propping up CNG vehicles and has launched marketing campaigns for models such as Audi's A4 g-tron, a car that sold out in fewer than five months. Furthermore, it wants to inject Audi e-gas into Germany's pipelines to ensure that g-tron vehicles bought March 7 through May 31 are credited with an 80 percent reduction in fuel-related carbon dioxide emissions for three years.

Even if all these measures prove to be insufficient, prices for electric vehicles are bound to fall, likely by the end of the decade, if not earlier. Price cuts may eat into profits for a while, but stronger EV sales could prevent fines and a tarnished brand image.

COULD BIOFUELS BE PUSHED OUT? The fuel industry seems to be facing its own challenges. Small amounts of biofuel have been added to gas and diesel for years. In early 2018, the biofuel content of gasoline was 4.8 percent. The

GOVERNMENT SUPPORT

BAFA, the federal economic development and export authority, said that it had received 57,549 applications for its EV incentive program by March 31. A bit more than half of them listed the purchase of an all-electric vehicle, while the number of plug-in hybrids amounted to 24,000 and fuel cell cars had been bought 17 times. The most popular model was again the Renault Zoe, for which a grant was requested on more than 6,500 forms. Over 10,000 applications each had been submitted from Bavaria, Baden-Württemberg and North Rhine-Westphalia.

industry, however, is skittish about new EU directives that could drive down the proportion to 2 percent and increase the pressure on automakers. Biofuel is carbon-neutral in that it emits only what has been stored in the growing plant. If the percentage were to drop, companies would have to raise the fossil fuel amount in the mix, causing more carbon dioxide to be emitted.

As this would turn back the clock on eco-blends, the European Commission suggested adding up to 10 percent of second-generation biofuels, a group of synthetic products obtained from biomass sources, to the remaining 2 percent of first-generation fuels, of which the most prominent examples are rapeseed oil found in biodiesel and wheat in bioethanol (in gasoline).

This would affect, most of all, German biodiesel and bioethanol suppliers, which have helped turn the country into Europe's largest biofuel consumer in both relative and absolute terms. As may be expected, Dietrich Klein, the chief executive of BDBe, the association representing the national bioethanol industry, called the fivefold credit for electricity to produce fuel a sham, since there was no guarantee that, in practice, production would always lead to reduced carbon dioxide levels.

On top of this, Marl-based Natural Energy West announced in mid-April that it was reducing biodiesel output to about half for the time being. It explained its decision by citing growing competition from Argentina and Indonesia, from where biodiesel imports had been dumped into Europe at cutthroat prices since winter. The sector is in transition and uncertainty reigns.

CLINGING TO ICES In the meantime, the calls for a return to tried-and-tested engines are getting louder. One recent, yet far from the only, example of full-throated support for internal combustion engines was a statement made by Gennadi Zikoridse, a professor at the University of Applied Sciences in Dresden. At the Fuels of the Future conference, he said that electric engines could be an addition but not a substitute for internal combustion, which would remain the pillar of the transportation sector. During the same event, Rainer Bomba, the then-state secretary at the federal transportation ministry, affirmed that liquid fuels were the best option to store energy. Bomba was replaced by Gerhard Schulz in March, when the new minister for transportation, Andreas Scheuer, took office and put his own people in place.

While the Germans are still in a tug-of-war, other countries seem to have devised concrete plans. Australian Craig Knight, a founding shareholder in Horizon Fuel Cell Technologies, which has a major operation in China, has observed a gold rush mentality on fuel cells and hydrogen in the Asian country. "In the last two to three years, there is huge momentum around automotive applications for fuel cells. And, right now, [China is] 100 percent behind the use of fuel cells as range extenders in electric vehicles. Hydrogen is an accepted part of the eco-system for vehicles and is being seriously funded and sponsored by the Chinese government," he said at Hannover Messe.

He made it unmistakably clear that nearly all automotive businesses in the People's Republic had been working on fuel cell systems and had hired staff en masse. He couldn't fathom why Germany would seemingly want to pull out of the sector. ||

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

IS H2 MOBILITY A KEEPER?

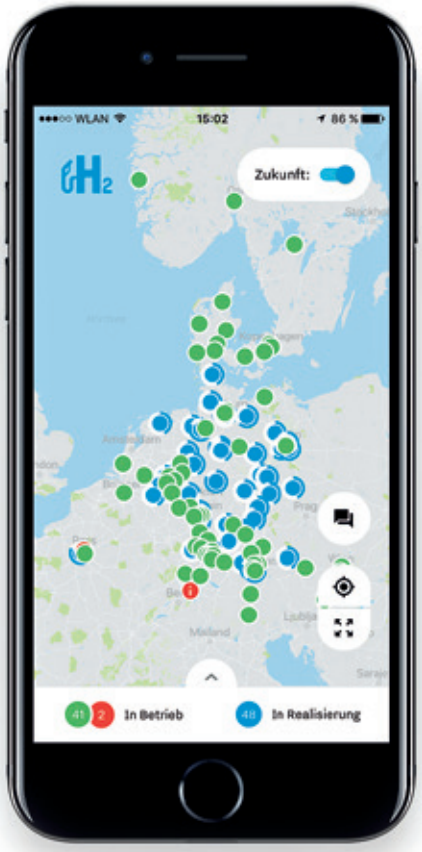
On to building a hydrogen infrastructure

Germany's network of hydrogen stations is growing slowly but steadily. This brings to the forefront a whole range of issues that need to be solved. Some are technological or logistical in nature; others are conceptual. At Hannover Messe, attendees and exhibitors could be heard discussing questions of site selection, funding approval and station management.

Those participating in the debate all shared the opinion that H2 Mobility had been put in charge of expanding the hydrogen infrastructure, a view that is not entirely accurate. After all, H2 Mobility is a business, and – like all businesses – its first responsibility is to its owners. Its shareholders have given Nikolas Iwan, the company's chief executive, a clear-cut task. He is to represent their interests during the expansion and sensibly manage the money entrusted to him.

On top of this, the federal antitrust agency restricted business dealings right from the start, as H2 Mobility had been formed by a group of companies that operated on the market and promoted a still emerging technology. The agency allowed the joint venture to construct a maximum of 400 hydrogen fueling stations to ensure that the market was not controlled by a single company, or its shareholders. Consequently, H2 Mobility staff has been skimpy on details about how to get to 1,000 systems.

What can be said is that the government spent around EUR 1 million on each fueling station in the beginning. Reportedly, economies of scale have since been realized, and costs are likely to drop further. Often, existing stations owned by OMV, Shell or Total have been upgraded by installing a hydrogen pump. Some sites have been built from the ground up and most of these have been managed by Air Liquide or Linde. H2 Mobility's shareholders have promised to keep the stations running past the planned end of the joint venture, both to turn a profit and to show that the government funds have been put to good use.



OPTIONS Other businesses can build their own hydrogen fueling stations, although few have seized the opportunity. One of them is GP Joule, which intends to construct two in Husum and Niebüll, along with five electrolyzers at wind farms, for supplying two fuel cell buses planned to stop in both cities, and possibly fuel cell railcars. Also, rumors have it that a northern German utility has been in talks with sera ComPress about a company-run station in Oldenburg, in the state of Lower Saxony.

The aim of QUARREE100 is to provide renewable electricity for an urban neighborhood in Heide, in the German state of Schleswig-Holstein. The showcase project is being supported with EUR 24 million in public funds.

Later, another system is said to be built in Heide as part of Future Filling Station, a QUARREE100 subproject (see H2-international, December 2017). Launched in February and coordinated by Baden-Württemberg state's Solar Energy and Hydrogen Research Center, it will receive, over five years, a total of EUR 1.3 million from Germany's economy ministry. The goal is to find the most efficient, cost-effective and demand-responsive way to dispense renewable electric power, hydrogen and methane through a multi-energy pump.

The researchers' top concern is storage efficiency. Grid power that is not used immediately to recharge electric vehicles will be directed into an on-site battery, at a loss of 10 percent or less. After all potential consumers have been accounted for, that is, when the battery is full and there are no EVs to charge, an alkaline high-pressure electrolyzer will begin producing hydrogen at 75 percent efficiency. Once the hydrogen tanks are full but no FCVs in sight, the system will switch to methanation, which stores energy at 60 percent efficiency. Ulrich Zuberbühler, who works at the research center, said that the unit would expand the list of grid consumers beyond electric engines, leveling the playing field for other renewables. A demonstration system is said to be tested in 2020.

H2.LIVE TO BECOME A HOUSEHOLD NAME When asked by H2-international, a spokesperson for H2 Mobility confirmed that, to provide a satisfying user experience, the joint venture's map and NOW's displayed all fueling stations mentioned above, including the ones built by others. She also stressed that the H2.Live logo could and should be used and that H2 Mobility would not assert copyright over it (see interview). NOW has been using the Clean Energy Partnership's map, which shows all stations funded during NIP 1 and NIP 2. This is said to change this year, as CEP has been on its own since spring. ||

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

FIVE QUESTIONS FOR H2 MOBILITY

Is it desirable that businesses as well as other organizations construct their own hydrogen fueling stations in Germany, independent of H2 Mobility?

H2M: Yes, it is. Moreover, it is essential. To employ a bit of hyperbole, H2 Mobility will have fulfilled its mission when it has been made redundant because enough other market players have taken over the tasks of planning, building and operating stations. By then, the size of the expanding infrastructure will have prompted significant cost reductions. Our goal over the next years is to establish a supply base – we're the ones making the down payment, if you will. H2 Mobility will pool expertise and create the numbers needed for economies of scale. No single stakeholder, not even a group of them, could do the same at this early stage without some collaboration, so we welcome opportunities to partner with other market players.

Should organizations intent on building their own stations contact you? If so, which kind of support could you offer them?

H2M: We would be delighted to hear from them. It's not just that we want our H2.Live app to show the most accurate map of publicly accessible stations for passenger cars. It's also important to see that we can all learn from each other. Of course, this doesn't mean we're here to divulge trade secrets. But, for example, we could share what we learned from filing applications. There might be some areas for collaboration, such as using the same logistics provider.

Would a station built by someone else show up on the map of the H2.Live app?

H2M: I think every hydrogen pioneer will agree with me when I say that we want the H2.Live app to display every hydrogen fueling station accessible to the public across the country, if not the entire continent. I'd also like to add that the map, and any future updates, can be integrated into websites at no cost.

Do you really want your map to show all locations?

H2M: Yes, we do – provided it's a public station with 700-bar, or 10,000-psi, fueling capability.

Who was responsible for the design of the H2.Live logo and how can or should it be used?

H2M: The rights to the logo remain with H2 Mobility. But, obviously, it is in our interest to provide a quickly recognizable symbol for hydrogen fueling. Feel free to use the logo. To prevent misuse, we only ask that you send us a note stating where it will be displayed. ||

CLEAN ENERGY PARTNERSHIP

Even long after H2 Mobility was formed, there was much uncertainty regarding the future of the CEP. It was to be dissolved at the end of 2016, before 13 partners decided to stay on (see H2-international, September 2017) and extend the project for a fourth time, until 2023, but without government assistance. The consortium once comprised 20 companies. That was before EnBW, Ford, General Motors, Siemens and Volkswagen announced their exit from the partnership, while only Audi joined it. Its new focus is a whole systems approach to making hydrogen and fuel cells widely popular on the market and among the public.

Category: Electric Transportation | **Author:** Niels Hendrik Petersen

PROFESSOR SCHUH'S E.GO

Electric minicar for EUR 10,000

Prof. Günther Schuh

Reservation lists have been popular with electric vehicle pioneers – look no further than Tesla's Elon Musk – and Günther Schuh, a professor and manufacturing expert, is no exception. Before he designed his urban car called e.GO Life, he had built electric vans for Deutsche Post, Germany's largest provider of mail and shipping services. Now, his minivehicle is going into production and Schuh's list shows as many as 2,900 preorders.

Schuh, who holds the chair of production engineering at RWTH Aachen University, is the founder and chief executive of e.GO Mobile, also based in Aachen. Since May, the company's Factory 1, said to be inaugurated in mid-July, has been spitting out the first e.GO Life cars, planned to be shipped late this year, to meet Schuh's production schedule.

The company is expected to sell 1,000 units in 2018, which means that many preordering customers will have to wait a little while longer. Like Tesla, Schuh is planning to ramp up production in a short amount of time, as the schedule calls for 10,000 vehicles to be manufactured in 2019. The last three months of this year would see the car being produced in two shifts, he said. "That means one e.GO Life every 10 minutes," he promised.

He believes that electric vehicles don't require the same range as their petroleum-burning counterparts. Consequently, the minicar has been designed primarily for short-distance travel and commuting. Based on the number of lithium batteries installed, the four-seater can go between 130 and 200 kilometers, or 81 and 124 miles, on a single charge. In a real-world urban setting, though, the range will be about 20 percent lower.

Besides a love for electric cars, the price will have had a major impact on reservation numbers. Schuh said that the 14.9-kilowatt-hour vehicle, which offers a range of 136 kilometers, or 85 miles, would cost EUR 15,900. Of course, the bigger the battery should be, the more money customers will have to spend: 17.9-kilowatt-hour and 23.9-kilowatt-hour units would be available for EUR 17,400 and EUR 19,900, respectively. But subtracting the VAT and the EUR 4,000 incentive that the German government grants for electric vehicles will leave buyers of the base version with only around EUR 10,000 to pay.

Schuh had aimed for a similar target price when creating an electric van called Streetscooter for Deutsche Post. The corporation subsequently bought the business he co-founded and is now producing 35 vehicles a day. "The production of the e.GO Life, a vehicle designed for everyday use by consumers and commercial fleet operators, such as senior care providers, has benefitted greatly from the wealth of experience we accumulated when manufacturing those vans." The urban car is powered by a 48-volt Bosch battery, employed by many automakers as a starter, so that e.GO drivers can turn to Bosch service stations for maintenance and repairs. "Compared to internal combustion engines, though, electric ones require much less servicing," Schuh said. Simply put, EVs have fewer moving and hot components.

To illustrate, Schuh said, "A BMW 5 has around 150 moving parts, while our e.GO Life has fewer than a dozen." Brake pads last longer, too. When the driver steps on the brakes, the electric engine acts as a generator and recovers kinetic energy to charge the battery.

Source of all figures: e.GO Mobile

NEXT UP, A MINIBUS But the startup is not resting on its laurels. Its next project is an electric minibus called e.GO Mover to transport up to 15 people around town. The vehicle has already been part of several pilot projects. It is planned to go into production in mid-2019.

Electric vans and buses can be hard to come by, especially if needed in bulk. This is what happened to Berlin's mass transit company, which requested bids for 45 buses but received just a single offer before having to extend the deadline. Representatives then traveled to China to look at automaker BYD's line of products.

Deutsche Post has been building its own vehicles for four years. Today, about 5,500 Streetscooter can be seen on the streets of German cities, which makes the successor to Germany's postal service also a leading electric van manufacturer. The corporation is said to be adding a fuel cell version to its product portfolio in the near future. Achim Jüchter, who heads Streetscooter's range extender system department, told H2-international, "Our objective is to integrate several hundred vehicles for testing purposes into the company fleet of the Deutsche Post DHL Group by the end of 2019." He didn't go into detail, but it is a good bet that reservations are already being accepted. ||

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

FUEL CELLS CERTAIN TO GAIN TRACTION AFTER 2025

Daimler and Ford end fuel cell partnership

Hannover Messe's show about electric transportation painted an all-too-familiar picture, with Hyundai and Toyota bringing fuel cell cars to market and German automakers being as cautious as ever. A good example was Daimler, whose employee at the H2 Mobility booth wasn't allowed to go into much detail when asked about the corporation's electric vehicle strategy. Instead, Christian Mohrdieck, head of fuel cell development at Daimler and chief executive of NuCellSys, had said shortly before the show, "We're still at the beginning of all of this. I think fuel cells will start to gain traction, particularly in the transportation sector, in the middle of the next decade, and certainly post-2025. I'm not talking about a sudden boom. Global sales will probably still be in the single digits. […] A technology needs to appeal to both customers and manufacturers for a breakthrough to occur."

Daimler did exhibit the GLC F-Cell at the shared Hydrogen + Fuel Cells + Batteries space but maintained that it was a preproduction car. There was no mention of a price or factory output. Moreover, the small number of units the automaker is expected to manufacture in 2018 will certainly not be for sale or lease but rent. It is not even sure that they will be delivered before next year. The corporation would only say that it was focused on getting the Mercedes-Benz GLC F-Cell ready for full-scale production, at the Mercedes-Benz factory site in Bremen, Germany. Estimates ranged from 10 to 1,000 units when talking to attendees in Hanover. In the end, though, the number will likely be in the low hundreds.

Hall 27 was also abuzz with rumors about the end of the corporation's joint venture with Ford in Canada. Based in Burnaby, in the province of British Columbia, and named Automotive Fuel Cell Cooperation, it had developed Daimler's fuel cell stack, made up of around 400 individual cells. It was manufactured at nearby Mercedes-Benz Canada Fuel Cell Division before being shipped to Germany, where the entire fuel cell system was assembled in the automaker's main plant in Stuttgart's Untertürkheim district. When the contract with Ford expired, some of the joint venture's staff reportedly found new employment with AVL List, headquartered in Austria. The supplier had announced the May opening of a new R&D site for fuel cells in Vancouver. The aim, according to AVL's Jürgen Rechberger, was to up the percentage of stack components manufactured in-house.

Daimler stated that the joint venture had achieved what it set out to do, namely to advance stack development at both automakers. Starting this summer, the two corporations would go their separate ways while continuing development on their own. Fuel cell technology would retain an important role in Daimler's and Ford's plans to create the next generation of engines, Daimler said. Both were considering creating another partnership.

The automaker also stated its intention to shorten the supply chain and have fuel cell production and assembly concentrated in the Stuttgart region. The work could go to Kirchheim's Nabern district, the base of NuCellSys, a wholly owned subsidiary. NuCellSys was the one that designed the fuel cell and storage units for the GLC F-Cell and built the first prototypes. Ford's fuel cell department, on the other hand, rarely makes the news these days, although the corporation is said to be more committed than it appears. ||

Fig. 1: Daimler GLC F-Cell exhibited at Hannover Messe in 2018

Category: Electric Transportation | **Authors:** Marie-Eve Reinert, Dr. Alicia Arce, Dr. Per Ekdunge

COST-EFFECTIVE FUEL CELL MANUFACTURING

INN-BALANCE – developing new balance of plant components

Launched in January 2017, INN-BALANCE, a project co-funded by the European Union's FCH 2 JU public-private partnership, intends to seek out Innovative Cost Improvements for Balance of Plant Components of Automotive PEMFC Systems. The objective is to enhance the design of production-ready balance of plant and fuel cell components to develop a new generation of highly efficient fuel cell systems and, most of all, lower the cost of current products. In the first year, the team, led by staff working at the Spanish Ayesa Foundation, drafted specifications for a new fuel cell system, designed a novel stack enclosure and devised operational strategies.

The design of the fuel cell unit has taken inspiration from partner PowerCell's prior work, a stack called S3. It was developed between 2013 and 2017, as part of FCH JU project AutoStack Core, to serve as a shared automotive stack base in Europe (see p. 39, fig. 3). The INN-BALANCE stack enclosure has been designed to match the orientation of the unit during installation and meet the requirements of the relevant Ingress Protection rating. The idea was to have all electrical connections on one side. Power output will range from 80 to 120 kilowatts.

What we call a pod is an adapter between the stack gaskets and the first parts of the subsystems. One aspect of the design work was to define the functions of the systems that were to be incorporated into the pod. Regarding the anode, almost all parts will be either integrated into it or attached to it. The cooling and cathode subsystems will have less pod integration because of their physical size.

In all, there will be six inlets and outlets for hydrogen, air and coolant at the bottom of an upright cell. Each fluid will enter different ports, although the inlet and outlet for every one of them will have the same shape and dimensions. The inlet for the coolant will be located next to the one for air, while the one for hydrogen will be on the opposite side, at the bottom of the stack. On the same side as the coolant outlet but at the top, a connection will bleed the cooling circuit to remove air bubbles that may have been trapped in it. The loop should see a minimum level of continuous flow to ensure that no air will be trapped inside the stack.

SYSTEM FUNCTIONS INN-BALANCE has led to the drafting of operational strategies for the anode, cathode and cooling subsystems.

As for the anode, an integrated ejector-injector unit will be used to operate the device without a recirculation pump. This compact solution can be placed in between the outlet and inlet of the anode. The system will also include a heat exchanger for preheating, so as to avoid condensation when dry, cold hydrogen is mixed with wet, warm nitrogen and hydrogen from the stack outlet. This will provide the anode with a mechanical interface in the direction of the high-temperature cooling loop.

The anode flow passing through the stack will be controlled by a highly precise and fast valve, upstream of the ejector-injector unit, and a stepper motor to power the injector needle. Both will manage the flow based on the pressure supplied to the ejector-injector unit and the adjustments made to the needle. The purge valve (used especially during start-up to fast-remove air from the loop) and the bleed valve, both on-off valves, will determine the quantity of hydrogen in the anode loop.

The cathode's main balance of plant component will be a high-speed turbo compressor by Celeroton. A "weather station" will be installed at the inlet, to record ambient conditions, and a special fuel cell air filter mounted in front of the station, inside the vehicle and connected to the inlet. Pressure at nominal load will be above 1 bar, which will result in high air temperatures at the compressor exit, making it necessary to add intercooling to protect the membrane humidifier from thermal damage.

At startup, compressor control will need access to 12-volt DC supply and a 400-volt DC battery before being able to make use of the variable fuel cell voltage. A fuel cell controller will govern pressure and flow via CAN. This subsystem will offer multiple functions, such as a continuous humidifier bypass to allow for the regulation of stack humidity. Likewise, a backpressure regulator can be used to adjust pressure and flow separately. Another function will make it possible to evacuate the cathode compartment during shutdown.

Last, there is the cooling subsystem, which will have the most complex interface of all three subsystems because of its high degree of integration into the other two and the vehicle itself. A low-temperature loop will cool the compressor, its controller and the intercooler. A second, high-temperature, loop will have an important connection to the stack, as the cold-start bypass system will require a minimal amount of coolant to heat quickly based on a lower limit of -40 °C. Stack cooling will be connected to the heater loop in the vehicle cabin, so that it can supply heat at a rapid pace. Thus, the

main connection of the cooling system will be made to the vehicle radiators. The system will need to govern the cooling pump flow rate (of all three pumps: freeze-start, low-temperature and main), and temperature sensors will be required to control radiator fan speed, electric heaters and three-way valves.

In the coming months, work will focus on the components and their related parts, such as a combined hydrogen injection and recirculation unit and an innovative turbo compressor, as well as on a production-friendly design (see box) to create market-ready and cost-effective products.

MANUFACTURING-ORIENTED DESIGN Supply chains and manufacturing processes are currently being simulated to prototype BoP components. This includes several aspects, such as product specifications, alternative materials, the number of parts, production tolerances and shapes. An optimization framework based on concurrent design methods will then be used to improve components. The first year of the project saw not only the creation of an overall strategy to enhance the fuel cell system by integrating supply chain with production and performance management but also the identification of main design parameters and the collection of manufacturing data. Now, the challenge is to expand the database and put expertise into practice. ||

PROJECT DETAILS
INN-BALANCE is being coordinated by Fundación Ayesa, in partnership with eight organizations: Brose Fahrzeugteile GmbH & Co. KG; AVL List GmbH; Volvo Personvagnar AB; PowerCell Sweden AB; Deutsches Zentrum für Luft- und Raumfahrt e.V.; Universitat Politècnica de Catalunya; Steinbeis 2i GmbH and Celeroton AG.
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HYDROGEN IN STEELMAKING

How feasible is a zero-carbon steel industry?

Considering the highly ambitious GHG reduction targets that both the German government and the European Union have announced for 2050, it seems hardly enough to transform only the electric power market. Each part of the economy must see dramatic changes if the goal is a zero-carbon future. This also includes the steel industry, which produces around 6 percent of the carbon dioxide emissions in Germany and will need to respond to great challenges to survive within the EU. One option to reduce its carbon footprint is the use of renewably generated hydrogen and electricity. While technically feasible today, such alternative methods of production would come at great cost that no steelworks could bear without some government assistance.

In partnership with ArcelorMittal Hamburg, the HAW – Hamburg University of Applied Sciences has studied the effects of using pure hydrogen, produced by a power-to-gas system, for the direct reduction of iron ore (see fig. 1). This approach will result in a zero-carbon process provided renewable electricity is fed into the installation. The gas will subsequently be mixed with re-cycled hydrogen and heated to about 900 °C, the temperature required for the relevant chemical reaction to occur.

Afterward, ore will be reduced to metallic iron inside the industrial furnace and compacted into a brick-shaped mass. The new product will also need a name: H2BI, or Hydrogen Hot Briquetted Iron. The reaction will prompt most, but not all, of the hydrogen to be oxidized to form steam. The remainder will be returned to the process, minus a small portion that will be burned when preheating the reducing gas, after condensation has led to the removal of the steam leaving the furnace.

The process is currently no more than a hypothetical scenario. It has much in common with conventional direct reduction, which ArcelorMittal Hamburg started to employ in 1971. The main difference to the current method is that the steam reformer will be replaced by an electrolyzer to use hydrogen only. Technical implementation should pose no difficulties from today's perspective.

Simulations have shown that one ton of H2BI will need around 635 normal cubic meters of hydrogen. If the >>

TRADITIONAL STEELMAKING
Top-quality steel, which is needed, for example, to manufacture auto parts, is produced from ores that are rich in iron oxides. Their high purity is the only way to ensure lightweight, high-strength products. Today, most steel is made by burning coke in a blast furnace. Despite being highly efficient, this process releases more than a ton of carbon dioxide for every ton of steel produced. Already, there are techniques that can achieve the same goal based on a hydrogen-rich blend. One of them is direct reduction, employed by companies such as ArcelorMittal Hamburg. It substitutes natural gas for coke and creates, inside a steam reformer, a reducing gas that contains about 60 percent hydrogen.

Fig. 1: ArcelorMittal Hamburg's direct reduction plant

aim is to produce 1 million tons a year, demand will amount to 80,000 normal cubic meters per hour. At 75 percent electrical efficiency, the power-to-gas system will therefore have to provide 375 megawatts. This figure is much higher than the individual capacity of today's systems, which typically range from 1 megawatt to 6 megawatts.

THE STEEL INDUSTRY'S DILEMMA The steel industry faces the same problem that the energy sector had around 20 years ago. Companies have innovative, and sustainable, ideas and plans, but there is no incentive to implement them in the current business environment. The following is hoped to explain why that is the case.

One important reason is the cost of electricity. The least expensive renewable resource to produce hydrogen is onshore wind, for which around EUR 80 is paid per megawatt-hour via the German Renewable Energy Sources Act. There also need to be guarantees that the H2BI plant will run for a good portion of the year. Overall, EUR 100 per megawatt-hour of electricity seems like a reasonable assumption to make. Thus, operating expenses will be about EUR 37,500 per hour, or EUR 300 per ton of H2BI. In comparison, iron reduction by conventional means costs about EUR 40, or one-seventh, per ton, which shows that the new process is far from economically viable at this point. The margins in the steel industry are too low to compensate, so that zero-carbon reduction would produce nothing but losses.

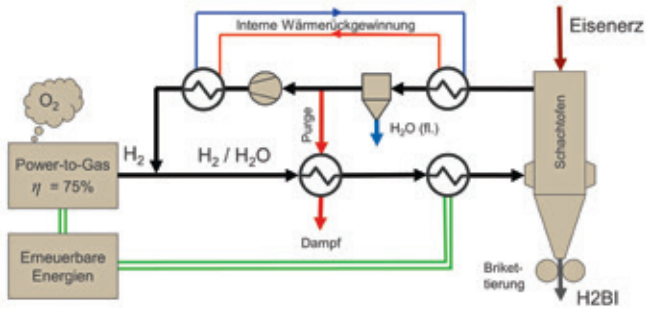

Fig. 2: Schematic design of hydrogen-based reduction

Capital expenditure also needs to be part of the calculation. A similar but conventional direct reduction plant to produce 1 million tons of steel a year requires around EUR 300 million. At an H2BI plant, the electrolyzers alone would come to about EUR 3 million for each megawatt of capacity and a total of EUR 1.12 billion. Here, too, it is quite clear that the new technology cannot compete in the current market environment.

The question that remains is which measures can be taken to increase the appeal of hydrogen steelmaking.

Electricity prices constitute a large proportion of the total, but there are few options to influence them. Even if they were brought down to around EUR 35 per megawatt-hour, which is the trading average on the European Energy Exchange, operating an H2BI plant would remain unprofitable. The target would have to be about EUR 13 per megawatt-hour, a level that cannot be achieved by anything short of political intervention. Raising prices in the cap-and-trade program could be one way to cause a dramatic spike in the cost of conventional steelmaking. But the impact of it would be felt in the European Union only and could undercut the global competitiveness of EU companies. Instead of bringing about a shift to hydrogen-based steel production, it would spell the end of European steelmaking.

Another option would be to introduce a carbon tariff, a tax to reflect the carbon footprint of each steel product on the EU market. This tariff could lead to hydrogen steelmaking becoming economically viable. Considering free trade and globalization, however, it seems as unlikely to succeed as the other two.

CONCLUSION From a technical point of view, renewably sourced hydrogen could help the steel industry create new and eco-friendlier products with a lower carbon footprint. While simulating one method to produce the hydrogen and evaluating the results, it has been determined that although the production is technically feasible, it needs to become much less expensive to be truly competitive and attract investors. To create a more favorable market environment, government policy needs to change. ||

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REVERSIBLE ELECTROLYZER UP AND RUNNING

GrInHy – Sunfire tests RSOC in Salzgitter

Even if renewable hydrogen is not yet economically viable, there have been some demonstration projects to test its general suitability outside simulated environments (see p. 36). One of these research endeavors is the EU's GrInHy, in which a consortium made up of eight companies based in the Czech Republic, Germany, Italy, Finland and Spain have been working together to make an RSOC, that is, a reversible solid oxide electrolyzer, part of the manufacturing process at German steelmaker Salzgitter Flachstahl.

GrInHy is short for Green Industrial Hydrogen via Reversible High-Temperature Electrolysis. Launched in August 2016 and funded by the EU's Horizon 2020 program, the project has been focused on testing solid oxide electrolyzer cells, or SOECs, for renewable hydrogen production in a real-life steelworks environment.

To this end, a high-temperature electrolyzer was installed in Salzgitter in June 2017 and brought online in October. The unit called SynLink SL 40 is a product by Sunfire, a manufacturer founded in Dresden, Germany, in 2010. It has 150-kilowatt of input and can operate in reverse. This means that the same unit can function not only as an electrolyzer to produce hydrogen but also as a fuel cell to reconvert the gas into electricity.

STEEL AND CARBON DIOXIDE PRODUCTION

In 2016, German steelmakers produced more than 42 million tons of raw steel. One ton releases an average of 1.34 tons of carbon dioxide, so that steel production caused about one-third of all carbon dioxide emissions in the German industrial sector and around 10 percent in all of Germany.

Sunfire said that hot steam, generated from the waste heat during steelmaking, was used for electrolysis inside a 20-foot container and had raised the electrical efficiency to 80 percent. The hydrogen gas is injected into the pipelines of the integrated steel mill at a rate of 3.7 kilowatt-hours per normal cubic meter and 40 normal cubic meters per hour. The electrolyzer can be operated as a fuel cell to produce 30 kilowatts of electric power from hydrogen but also run on natural gas. This electrical energy can be used to stabilize the power grid or support load management on-site. The thermal energy generated at the same time will be returned to steelmaking via a CHP process.

Hydrogen is likewise used in the industry to form a reducing atmosphere inside furnaces, to prevent steel from oxidizing during heat treatment. Natural gas reforming, previously the method of choice for hydrogen supplied to steel mills, is being replaced by renewable solutions that create a more environmentally sustainable product with a lower carbon footprint (see box above). Comparable Sunfire ROSC systems were shipped to Boeing in the United States and a Total station in Karlsruhe, Germany, where it supplies the hydrogen pump (see H2-international, October 2017).

Source: Sunfire; Salzgitter Flachstahl

PLANT IN LINZ TO COME ONLINE IN LATE 2018 Austria has seen similar levels of commitment. In April, the H2Future business consortium began constructing a system at voestalpine, a Linz-based manufacturer of industrial goods (see H2-international, October 2017). The company stated that the 6-megawatt Siemens-brand electrolyzer, planned to come online late this year, would become the world's largest electrolysis plant to produce green hydrogen for steelmaking. The aim, according to Wolfgang Eder, chairman and chief executive of voestalpine, was to find genuine breakthrough technologies that could be used at large scale in around two decades' time. The EUR 18 million trial to produce 1,200 cubic meters of hydrogen per hour is scheduled to start in early 2019 and run for two years.

TOWARD RENEWABLE STEELMAKING In June 2017, LKAB, SSAB and Vattenfall, three Swedish businesses operating in the mining, steel and energy industries, formed a joint venture called HYBRIT – The Way to Fossil-Free Steel. The corporations have since been sharing equal parts in the work to replace coke and coal with hydrogen. Jan Moström, president and chief executive of LKAB, said: "Forming a joint venture to develop HYBRIT is proof of our conviction that it is possible to create a supply chain, from mines to steelworks, without the use of fossil fuels. If we're successful, we will achieve a technological breakthrough, a global contribution to mitigate much of the impact of climate change." >>

SALCOS®

Like ArcelorMittal (see p. 36), Salzgitter Flachstahl employs a direct reduction process. The medium-term goal is to replace coke with natural gas and hydrogen to reduce carbon dioxide emissions. The steelmaker, which hails from the German state of Lower Saxony, has initiated a string of projects, collectively named SALCOS – Salzgitter Low CO_2 Steelmaking. It will report on the progress made with GrInHy at the European SOFC and SOE Forum, which will take place July 3 through 6, 2018, in Lucerne, Switzerland.

One aim of the joint venture is to wean Sweden off fossil fuels by 2045. The plans on how to accomplish this are said to be mapped out until 2035, during a research endeavor supported by the Swedish Energy Agency. The project began with the commissioning of a pre-study, which will be followed by research trials and pilot systems until 2024 and the startup of a demonstration system by 2035.

HYDROGEN FOR SINTERING HyGear, a Dutch electrolyzer manufacturer, is also beginning to shift its attention to the metal industry. In mid-April 2018, it signed a long-term deal to supply hydrogen to a globally operating metal producer, which intends to make large-scale use of the gas for sintering. Plans are to install a HyGear Hy.GEN® electrolyzer to guarantee base supply and meet short-term peaks in demand through fuel trailers. "Signing this contract helps solidify our foothold in the metal industry, our third most important sales market after flat glass and food processing," said Niels Lanser, the company's director of sales and marketing.

When sintering metal powders at high-temperature, pure hydrogen is thought to be the most effective way to create a reducing atmosphere during the compaction stage. It helps maximize corrosion resistance and vital densification properties while also reducing the formation of impurities and oxides inside alloys and on their surfaces, respectively. ||

"If coal is no longer an option to consider, then it has to be hydrogen. [...] We offer the government a system for widescale use that can help reduce emissions."
Heinz Jörg Fuhrmann, chief executive and chairman of Salzgitter Group

"The technology is just one part of it. Whether low-carbon steelmaking will be successful or remain a vision for the time being will ultimately hinge on two factors, namely government policies and economic viability."
Salzgitter Flachstahl

"This project will provide initial momentum for a debate in parliament."
Olaf Lies, Lower Saxony's environment minister

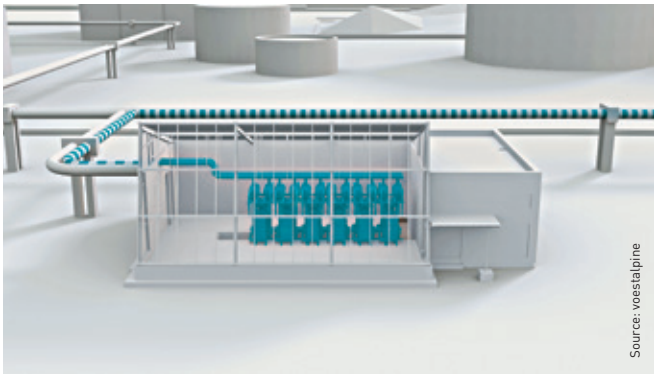

Fig. 2: The hydrogen system is integrated into the steelworks in Linz.

Category: Research & Development | **Author:** Sven Geitmann

GRAPHITE VERSUS METAL

Bipolar plates: the backbone of fuel cell stacks

Bipolar plates are core components of PEM fuel cells. They control not only hydrogen and air supply but also the release of water vapor, along with heat and electrical energy. Their flow field design has a major impact on the efficiency of the entire unit. Plates can come in several sizes and can be manufactured using a variety of production techniques.

In principle, the bigger the plates are, the greater is the current of individual cells. As the size increases, so does the PEM surface area. This means that more hydrogen is produced in the same amount of time.

Each cell is sandwiched between two bipolar plates – one letting in hydrogen on the anode and another air on the cathode side – and produces about 1 volt under typical operating conditions. Raising the number of cells, like doubling the number of plates, will increase the voltage.

Besides fluid control, the plates manage electricity and heat generation. The chemical reaction in a fuel cell releases heat, which must exit the stack and be utilized as much as possible. Likewise, the generated electricity must be transmitted at minimal loss. In the meantime, the membrane needs to

- Number of stack cells determines voltage.
- Membrane surface area affects current.
- Stack size decides performance.
- Tank size governs lifetime.

be humified at the anode, while the reaction product, water, must be transferred out of the system at the cathode. The reactant gases and the coolant fluids also require separation, and the entire system needs to be tightly sealed.

Multiple materials possess sufficient electrical and thermal conductivity, as well as a long enough lifetime, to meet those requirements: either high-density graphite or graphite-polymer composites, or even metals.

GRAPHITE Carbon materials provide good electrical conductivity. Graphite, however, has a special, very brittle molecular structure, which means it must be handled with care. For example, it can break easily if subjected to vibrations or uneven screw tightening. Despite these drawbacks, graphite plates are a popular choice for fuel cell systems, especially stationary applications, where installation space is not a limiting factor. Typical methods used to create their flow fields are extrusion, hot pressing, machining or injection molding.

Businesses such as Centroplast Engineering Plastics or Eisenhuth, which both exhibited at Hannover Messe this year, have been developing composite materials that combine graphite and flame-retardant polymers for safe use in aggressive environments. The biggest challenge is lifetime, as plates need to last between 30,000 and 50,000 operating hours in stationary applications, while 5,000 hours is often good enough for vehicle systems. Graphite plates take a bit longer to produce than metal ones, but manufacturing several at once can get the job done in minutes.

METALS Metal plates are more robust, which is why they are more often used in, for example, the automotive industry. In a typical system, two plates have been welded together, so that the coolant fluid runs in a right angle to the flow field.

One well-established, longtime supplier of these plates is headquartered in Belgium: borit, founded in 2010 as a spin-off from OCAS and borit Leichtbau-Technik. It employs a hydroforming technique called Hydrogate™, in which water at up to 1,800 bars of pressure, distributed as evenly as possible across a material, forces metal sheets against the surface of a die. This process allows for the design of complex geometric shapes, even in low-volume production. It also reduces tool wear, as the two metals are not in direct contact with each other. Plates can often be formed in one go, while deep-drawn parts may need to be processed six times. Hydrogate has been patented and is based on an invention by Dirk Bohmann, chief executive of borit Leichtbau-Technik.

AUTOSTACK TO NIKOLA The core business of Dana, a US automotive supplier, may be combustion engine components. But the globally operating 25,000-staff corporation has had its eye on the electric powertrain market for years. Via its German subsidiary Reinz, located in Neu-Ulm, and based on its wealth of expertise in laser welding, Dana manufactures fuel cell equipment, or, more specifically, bipolar plates made of either stainless steel or graphite composites.

One example of its work is the plate designed for Auto-Stack CORE, launched in 2010, and optimized during the follow-on project Autostack Industry. The goal of these initiatives was to cut the costs and increase the quality of fuel cells used in the automotive sector to provide more opportunities for mass production. In late 2017, it was reported that Swedish PowerCell, the partner licensed to sell the plates, would deliver its S3 stack, which is based on the Autostack design, to hydrogen truck manufacturer Nikola Motors, among others.

Fig. 2: Dana supplied the bipolar plates for projects such as Autostack.

Another market player of note is Gräbener Maschinentechnik, an industrial equipment manufacturer based in Netphen's Werthenbach district. While its main business is production equipment, frequent requests have led the company to extend its product and service portfolio to include, besides hydroforming systems, services for the entire metal plate fabrication process, from sealing, cutting, welding and measuring to coating and finishing.

COATING TO REDUCE FUEL CELL WEIGHT One new approach to stack production originated with Vitali Weißbecker and his team. Together with engineer Andreas Schulze Lohoff and materials researcher Klaus Wedlich, he established Precors in March 2016. Shortly thereafter, the three won Aachen's entrepreneur competition AC², which netted them a starting capital of EUR 10,000, and were presented with the f-cell award (see H2-international, February 2017) for achieving an 80 percent and 60 percent reduction in fuel cell weight and size, respectively.

Indeed, weight and size are two drawbacks of graphite plates. An 85-kilowatt stack for a fuel cell car comprises around 350 bipolar plates and adds up to about 150 kilograms. By contrast, metal plates are lighter and smaller but are prone to corrosion in the acid and humid stack environment. The researchers' solution was to create an ultrathin protective layer that can be spray-coated onto the plates. Unlike Aperam, Impact Coatings, Sandvik and others, they chose a coating base made of carbon.

Weißbecker conceived the idea when writing his chemistry dissertation on carbon-based coatings. He had examined several materials before a stroke of luck seemed to have provided him with the formula of the new composite, which remains a closely guarded secret. He would only reveal that it had been synthesized in-house and closely matched the high conductivity of gold.

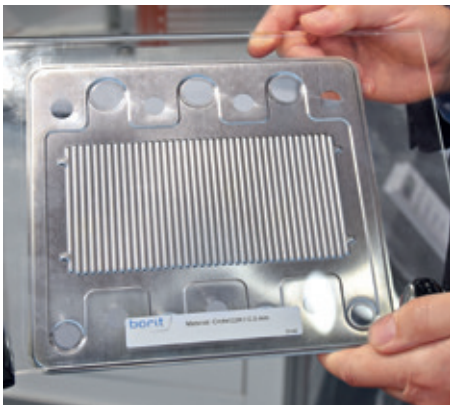

Fig. 3: Joachim Kroemer, marketing and sales manager at borit, presents one of the company's metal plates.

The three graduate scientists then founded the startup Precors, named after the project. In the first 18 months, they received funds from EXIST, a program by the German economy >>

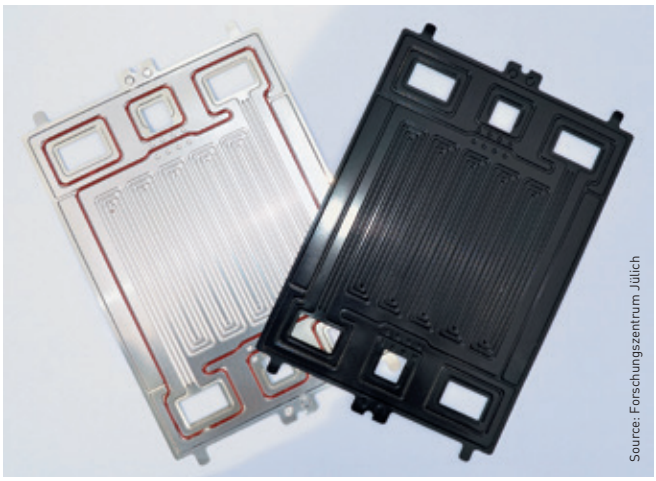

Fig. 4: Bipolar plates coated with graphite materials (right), compared to uncoated metal ones (left)

ministry to support research spin-offs. The money enabled them to set up a pilot system for manufacturing bipolar plates at the Forschungszentrum Jülich research center. The company relocated last October, when moving into its own building. The pilot, with the capacity to produce up to 200,000 plates a year, has since been moved as well. Professor Werner Lehnert, the project's mentor, called the move "courageous and timely."

The business, which currently employs five people, has been on its own since the startup funding ended a few months ago. Weißbecker told H2-international, "All of ours was gone from Jülich in March. We've had our own orders and projects to work on ever since. Some of them receive public support, while others have the backing of venture capital firms."

One government-funded project is PRECOIL, which was launched in early 2018 and will be supported with about EUR 470,000 under the transportation ministry's NIP 2 program until the middle of 2020. The objective, according to Weißbecker, was not merely to set up a lab system but to "coat metal coils in roll-to-roll processing, so they can be reshaped and combined into double-wall bipolar plates." He explained, "Our unique elastic and heat-resistant coating material is what makes reshaping possible. Thanks to our expertise in synthesizing and coating, we are able to customize properties for specific applications."

INNOTEAM
InnoTeam is a Saxony state funding program that supports collaborations between businesses and universities or research organizations intent on designing and commercializing new products or production methods. Funds are available to InnoTeams consisting of 3 to 12 members who graduated with a degree in economics, the natural sciences or engineering.

HZWO:DRIVING SAXONY FORWARD
The goal of HZwo, established in 2015, is to attract innovative PEM fuel cell companies to Saxony, for example, to promote research on mass-market components and electric powertrains. Led by the Chemnitz University of Technology, this state-sponsored initiative, has seen collaborations between several industrial companies, mainly SMEs, and research institutes. The namesake HZwo association was founded late last year. The first meeting for the HZwo:Driving Saxony Forward cluster was held May 30, 2018, in Chemnitz.

SAXONY'S INNOTEAMS The eastern German InnoTeam HZwo:BIP has taken a similar route. As part of an interdisciplinary collaboration, supported with EUR 3.6 million in public funds, scientists at the Chemnitz University of Technology started work on bipolar plates that could be mass-produced to reduce the cost of FCVs. The main goal is a production-ready design, to be incorporated into a safe and simple manufacturing process for components and tools.

In April 2016, the university partnered with Steinbeis Innovation Center – Joining Technology and five companies from the German state of Saxony to establish HZwo:BIP – Bipolar Plates from Saxony. The aim of the endeavor is to create a stack prototype by March 2019. Professor Birgit Awiszus, who holds the chair of virtual production engineering at the university, said that the challenge was to find an inexpensive method for a zero-damage tight-tolerance reshaping of ultrathin-coated metals.

"We need to get the individual components ready for mass production today. The HZwo family of projects can, beginning with bipolar plates, jump-start a value chain that would allow for the manufacturing of other fuel cell car components in the state. Our project is an important contribution to the long-term growth of an FCV cluster in Saxony," said Thomas von Unwerth, also a professor at the university and the manager of the project.

One partner to HZwo:BIP is WätaS Wärmetauscher Sachsen, based in Olbernhau, which intends to use a highly automated production line to offer stainless steel and titanium bipolar plates available in common thicknesses from 0.07 to 0.1 millimeters. Torsten Enders, WätaS' chief executive, told H2-international that his company had invested a sizeable sum of money into the idea, with an eye on full-scale manufacturing. The aim is to apply expertise gained from making heat exchangers to bipolar plate production, so that the plates can be manufactured for EUR 20 in the span of seconds (see also p. 11). ||

Fig. 5: Chief executive Enders (middle) in conversation with a customer at Hannover Messe

COATINGS WORTH THEIR WEIGHT IN GOLD

During this year's Hannover Messe, Swedish manufacturer Impact Coatings unveiled the latest generation of its Inline-coater™ FC (see image and p. 38), able to cover over 1 million stainless steel plates a year. The conductive and corrosion-resistant material increased PEM fuel cell efficiency and lifetime, the company stated. Short coating cycles would also make it possible for the unit to be integrated into assembly lines. Henrik Ljungcrantz, the founder and chief executive of Impact Coatings, said that his company could guarantee high output at little cost to satisfy the technological needs and quality standards of auto industry customers around the world.

New features are faster gas removal from the vacuum chamber, a higher chamber rotation and the quicker deposition of nanomaterial. The coating base is an inexpensive material called Ceramic MaxPhase™ , which the company said lacked any precious metals but had many qualities superior to gold. Impact also affirmed that it inspected each individual plate post-production.. ||

NEW FUELING STATION SOLENOID VALVE IN DEVELOPMENT

Eugen Seitz, based in Wetzikon, Switzerland, was founded in 1958 as a manufacturer of valve products for selected industries. Under its Seitz Valve brand, the company also offers units for alternative fuel equipment: The ProValve and Hy-Valve series have been designed specifically for the feed and discharge lines of natural gas and hydrogen compressors, storage units and pumps at fueling stations.

Seitz likewise offers custom solutions that meet the requirements of 2014/68/EU, which governs the use of pressure equipment, and 2014/34/EU, which regulates the operation of devices in a potentially explosive atmosphere. Fabian Seitz, the company's third-generation owner, told H2-international, "We're in the process of developing a high-pressure solenoid valve for use with up to 1,000-bar fueling systems at hydrogen stations. A prototype will be available in the coming months. There has never been a product like this on the market." ||

(Source: Eugen Seitz AG)

CNG and H2 Single Valve for fueling stations up to 450 bar

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

RISING OIL PRICES TO BOOST FUEL CELL MARKET

Sven Jösting's stock report

Looking at oil prices these days may have you thinking that the sky's the limit. However, what's unfavorable, or even detrimental, to one side can benefit the other. Price hikes will just pump more money into alternative energies and R&D. Specifically, green hydrogen and its use as a source of electric power, heat and cooling energy could, along with carbon capture, see unprecedented growth, especially after it took so long for the world to start waking up to its potential.

One country's love for fracking won't be able to satisfy global demand. By using the new technique, the United States is now able to extract about 10 million barrels from the ground each day. Elsewhere, though, production is falling. President Donald Trump's shredding of the Iran deal, followed by the threat of renewed sanctions, is just one of the reasons.

Global consumption could reach 100 million barrels a day in 2018. Countries such as China are buying up all the black gold they can get their hands on. In 2017, at an average 8.4 million barrels per day, the People's Republic became the world's top crude oil importer. A key factor in creating the massive demand has been the increase in vehicles: North of 25 million are registered in China per annum.

Up until a few years ago, large consulting firms had projected that batteries would attract much less capital than electrolyzers. For example, the Boston Consulting Group had published a study showing investment in electrolyzer research and development to top USD 150 billion in the coming decades. Battery technology, on the other hand, would have to make do with USD 70 billion. At first sight, the projections may no longer hold true, as automakers, or their automotive suppliers from Asia, have invested a great deal in developing more advanced batteries. However, continued price hikes for energy supplies, specifically oil, will prompt research to come up with more efficient and powerful electrolyzer designs.

I've heard from sources with profound knowledge of the Chinese market that there are no plans for some type of shift in electric transportation, but that fuel cells will be given more attention. It'll be interesting for sure to see what happens then. It would force carmakers to rethink their approach to fuel cells and catch up to Toyota and others (see p. 28).

Fig. 1: Historical prices of five relevant companies
Source: wallstreet-online.de, Retrieved on May 30, 2018

BALLARD POWER AND THE ALL-IMPORTANT YEAR-END

Canadian manufacturer Ballard (Nasdaq: BLDP) ended the first quarter of 2018 on a total revenue of USD 20.1 million. During the same period a year ago, it generated USD 6.2 million in one-time revenue from technology transfers and engineering support. This amount needs to be taken into account, that is, taken off, if the goal is to paint an accurate picture of year-over-year growth. Still, the company's gross margin was 33 percent. Randall MacEwen, Ballard's chief executive, said that the first half of each year was usually slower than the second, his reason for sticking to a revenue target of USD 120 million for 2018. In the meanwhile, backlog reached USD 220 million and is expected to grow further. I think that the loss, said to be over USD 5 million, or minus USD 0.03 per share, was a product of multiple R&D efforts, which all required money. And with USD 52.5 million in cash reserves, Ballard has a bright future.

In collaboration with several partners, the company has been working on the development and construction, or integration, of a variety of fuel cell prototypes. These projects need cash at a time when big orders and mass production aren't at the top of the agenda. An unknown customer, which could be Toyota Tsusho, has provided Ballard with more than USD 4 million to design air-cooled fuel cells planned to be integrated into forklift trucks. Likewise, the corporation inked a supply and collaboration agreement with Hyster-Yale, a global heavyweight in forklift truck manufacturing. The deal could result in stack quantities several times the contract val-

Fig. 2: Randy MacEwen and Hu Chunhua, China's Guangdong Province Party Secretary

ue of Plug Power's bookings – at the high point of Ballard's and Plug's collaboration. A few years ago, Hyster-Yale acquired fuel cell producer Nuvera and has reportedly invested around USD 100 million in its R&D facilities. But the agreement with Ballard seems to indicate the Canadian supplier has more to offer than the Italian subsidiary.

OPERATING ON SEVERAL FUEL CELL MARKETS Large delivery service companies such as UPS and FedEx Corp. want to add more EVs to their fleets, and not all will be fully electric courier vans. The two corporations are also testing range extender prototypes and other fuel cell solutions. Past a successful trial stage, these systems mean big business for Ballard, as well as Hydrogenics and Plug Power. As I see it, the new megatrend called fuel cells will drive growth at Ballard, especially over the next two years – prototypes are vital to generating large orders. Right now, the stock market is all but ignoring the Canadian business. But as investor legend Warren Buffett says, patience is a virtue for successful investing. In addition, you should know the company whose shares you intend to buy and be fully convinced that it's the right decision to make. It would be time for Buffett to invest in fuel cells himself. Apple, a company in which he owns a major stake, has been doing so for years.

HYDROGENICS AND WHY THE FIRST QUARTER ISN'T THE LAST

Like Canadian competitor Ballard, Hydrogenics (Nasdaq: HYGS) has made investments in several markets, most of all, China, where demand for fuel cells is projected to rise. Both have entered into agreements with Alstom and Siemens. That the latter two have founded a joint venture to merge their railroad divisions suggests to me that keeping two experienced suppliers on board is part of their failsafe system. Ballard has also partnered with China's CRRC, the world's largest rolling stock manufacturer. And, like Hydrogenics, it is upgrading locomotives and trucks, replacing diesel with hydrogen fuel. In short, a healthy dose of competition never hurt anyone. Both companies have proved why they're the crème de la crème of the fuel cell industry and that they are operating on high-growth markets. Besides China, India is shaping up to be a promising candidate for expansion. Plus, and in contrast to Ballard, Hydrogenics has a strong electrolyzer business.

On to the results. The first quarter brought in USD 8.1 million in revenue, compared to USD 8.7 million one year ago. Net loss improved and was below USD 2 million, or USD 0.13 per share, whereas cash reserves amounted to USD 19.4 million. Backlog exceeded USD 140 million. Daryl Wilson, Hydrogenics' chief executive, regarded the first quarter results as "not reflective of the potential for top line expansion this year and beyond." With a temporary price drop behind us, now is a good time to buy Hydrogenics stock to cushion a well-diversified fuel cell portfolio that promises medium-term gains.

FUELCELL ENERGY CONVINCES CONNECTICUT

FuelCell Energy (Nasdaq: FCEL) increased its lobbying of lawmakers, helping to make them see the great potential that fuel cells have. In Connecticut, its determination has paid off. The state has set a 40 percent by 2030 renewable target, with fuel cells said to be playing a major role. It'll be interesting to see what size power plants will show up on the books. The state government had requested bids for projects worth more than USD 1.6 billion altogether, the company said. FuelCell Energy's stock price could skyrocket in the aftermath of winning these bids. The manufacturer also has the means to finance such deals, as credit facilities and convertible preferred stock are readily available.

PLUG POWER: HIGH GROWTH, STRONG BACKLOG

Plug Power's first-quarter results were well received by stock market analysts. Net loss was USD 0.07, less than expected, while revenue surged 90 percent year over year, topping USD 29.1 million. At year's end, earnings are expected to be between USD 155 million and USD 180 million. It has been reported that multiple new, and large, corporations were now part of Plug's customer base. One of them is said to be a food company that ranks among the top five in the United States. Backlog remains strong. One caveat, though, is the net loss: USD 19.8 million, which included many non-recurrent items.

Overall, I'm not yet bought on Plug's current strategy. Through a private debt sale, it is offering USD 100 million of senior convertible notes at 5.5 percent nominal yield. Some of the deal's components, as in the right to exercise or convert the notes and the use of capital, are less than clear to me. The intent is to get 14 million shares off the market, which means that the deal will net Plug as little as USD 52.5 million, while it must pay USD 5.5 million in interest each year.

Plug (Nasdaq: PLUG) should focus on turning a profit from the strong, and growing, backlog. It is trading in the unfortunate sale and lease-back agreement with Walmart for more profitable arrangements with Amazon and Home Depot, which will get the company back on track. It is also very invested in improving its fuel cell stacks, aiming to offer more powerful units at cheaper prices. Nevertheless, those efforts should bring about a higher profit margin. In the end, that is what really matters. >>

I think Plug will continue its success on the fuel cell forklift market, as it has upgraded over 17,000 vehicles to date, and keep building the necessary infrastructure. What it should consider is to produce and sell renewable hydrogen, besides its offerings of service and maintenance contracts, to become less dependent on industrial gas suppliers. A big advantage has been the extension of the fuel cell tax incentives and deductions for material handling equipment in the United States. They have made attracting large bookings that much easier. Plug is reported to have gained two, still unnamed, food industry customers, and its USD 89 million in cash is a solid foundation for project finance.

However, the company seems to employ some, say, creative financial strategies, as in the above example of the convertible notes. I will continue to observe Plug but prefer Ballard for investing. Like the former, Ballard is serving the forklift truck market in several ways, in partnership with others, and used to be Plug's sole supplier for a long time. I'll revisit the situation should Plug be able to catch up or outperform Ballard, technologically. It has announced that, in the coming months, it would present fuel cell stacks that it had developed in-house and would rival the Mirai's performance specs. China, where the company is seeking an experienced partner, could offer new opportunities for growth. The same goes for the courier van market – see FedEx, for which Plug is hoping to upgrade an entire fleet.

40 TESLA AND WHY IT'S HARD TO KEEP THE LID ON

Tesla's first-quarter report showed another record loss, USD 700 million, which lowered its cash by a whopping USD 600 million. Considering this, it seems unimportant that revenue jumped to USD 3.41 billion or that Model 3 production is being ramped up to full capacity. Tesla has been burning through massive amounts of money. It could be forced, despite its chief executive's vehement denials, to raise capital at least once before the end of the year. Some debt securities, that is, bonds, are going to mature in the next 12 to 18 months, and the total of accounts payable hit the USD 2.6 billion mark. At the end of the quarter, Tesla (Nasdaq: TSLA) had a cash balance of about USD 2.7 billion, which includes close to USD 985 million in customer deposits for all models.

Fig. 3: Semi by Tesla

The company will require a lot more financial support to meet its July goal of 5,000 Model 3 cars a week, a fact that many analysts seem to gloss over. Nomura's even welcomed a planned reduction in investment during the year. By contrast, there are those who think that Tesla will need another large infusion of capital, so that Model 3 sales can generate enough cash flow to meet all financial targets.

Meanwhile, it seems as if the company's chief executive, Elon Musk, is growing weary of analysts' opinions. He cut them off during Tesla's first-quarter conference call, after skipping two questions he said were "so dry" that they were "killing him." He then went straight to YouTube for a retail investor Q&A and refused to return. Wall Street wasn't all that happy about the incident and sent the stock down 5 percent overnight. One question he didn't answer was about the number of deposits for Model 3. There could be as many as 450,000 or as little as 250,000. Tesla has been under intense scrutiny after crashes involving its Autopilot feature, so some potential buyers may have asked for their money back to get a competitor's vehicle, of which there are more and more to choose from.

Regarding the accidents, the National Transportation Safety Board and other agencies involved must have been furious with Musk for leaking investigative information to the media, as well as reportedly attempting to spin their preliminary findings in Tesla's favor.

NIKOLA MOTORS CLAIMS PATENT INFRINGEMENT On top of this, Nikola Motors, a manufacturer of fuel cell hybrid trucks, has filed a USD 2 billion lawsuit, claiming Tesla's Semi infringed on several of its patents, including design features. Indeed, putting the companies' trucks side by side reveals a striking similarity. Rumors have it that Tesla had also tried to poach its competitor's staff.

Meanwhile, Moody's has downgraded the corporation's credit rating to B3 and a class action lawsuit is opening the way for an investigation into its SolarCity takeover. Not too long ago, Musk spent about USD 10 million on Tesla stock to demonstrate that he hasn't lost faith in the company, although the figure does little to impress, considering that he previously used 13 million shares as collateral for personal loans. Is he planning a squeeze to uproot the many short sellers, who are betting on prices to fall?

FIRST-RATE TALENT SAYS GOODBYE Doug Field, a former Apple employee and the company's senior vice president of engineering, has taken a leave of absence. Now doesn't seem like the most opportune time for the head of Model 3 production to be away for weeks, and it's uncertain whether he will return. Matthew Schwall, who had been director of field performance engineering, left the automaker in mid-May to join Alphabet's Waymo. Of note is that Schwall was reportedly the one speaking to the authorities about the accidents alleged to have been caused by using the Autopilot feature.

In China, Tesla has set up a new subsidiary in Shanghai. Some speculate that the company's aim could be to construct a second battery production site in the People's Republic, to gain easier access to the market. Will Panasonic join in before the Gigafactory in Nevada is complete and is running as expected? On June 13, Musk also announced that the company would shed 9 percent of its workforce, or around 4,100 mostly salaried jobs. Let's see where this will lead.

One last, yet crucial, point is that the end of the first quarter left Tesla with about USD 543 million from its USD 1.8 billion credit facilities. Expecting cash-intensive months

ahead, it has recently put up its Fremont factory as collateral. Interest rates have shot through the roof and could, but this is mere speculation on my part, amount to USD 600 million for the whole of 2018. GAAP net loss was USD 4.19 per share, and if it were not for the sale of USD 50 million worth of zero-emission vehicle credits, about USD 0.30 would have had to be added to it. The question that remains is whether Model 3 can bring in enough cash for Tesla to turn a profit.

MUSK'S ONE-MAN REGIME Institutional investors, such as retirement funds or union-affiliated investment groups, have announced to keep a close watch on chief executive and major stockholder Musk from now on. The board of directors is filled with his friends and relatives, including his brother, Kimbal Musk, and billionaire friend James Murdoch. The director and executive boards, however, are supposed to be made up of people who don't have some apparent conflict of interest. Sometimes, they seem to be there only to rubberstamp, not question, the chief executive's PR stunts and business decisions. Posts as important as these should go to impartial and experienced people, regardless of whether Musk likes the arrangement. We'll see what happens at the next shareholder meeting [which will take place after the editorial deadline].

In my opinion, Tesla needs to restructure several of its debts and get a tighter grip on its organization. The cash drain will continue throughout the second quarter. Let's see whether the company can earn a profit in the third or fourth, as predicted by Musk, which mainly depends on Model 4. The stock has made an impressive recovery following a slump to USD 270. But in the long run, and despite Model 3, prices should start trending downward again, as the risks don't seem to be worth the rewards. ||

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 | **Author:** Sven Geitmann

BIG HIT OPENS ON ORKNEY ISLANDS

Deploying green hydrogen systems in remote areas

Orkney, a group of sparsely populated islands in northern Scotland, will soon become the site for a whole systems installation to test a hydrogen supply chain. The project about producing, storing, delivering and utilizing the gas in heat and electricity production, as well as transportation, was inaugurated May 15 through 16 in Kirkwall.

More accurately, there are two projects. The first is the Surf 'n' Turf initiative (see H2-international, September 2016). Supported with GBP 1.5 million from Scotland's Local Energy Challenge Fund, it laid the groundwork for BIG HIT. Although the initiative was officially launched no earlier than last September, its members began to get the wind and tidal power plants on the northern island of Eday ready for producing hydrogen in April 2016. At the start of BIG HIT, short for Building Innovative Green Hydrogen Systems in an Isolated Territory, ITM then installed a 0.5-megawatt PEM electrolyzer in Kirkwall and a 1-megawatt one at Shapinsay's wind turbine, which was commissioned in 2011. Both sites produce and store about 50 tons of hydrogen before it is transported by five Calvera trailers and shipped off the island to Kirkwall.

Kirkwall is situated on Orkney's main island, called Mainland, and lies about 6 kilometers south of Shapinsay. It has a seaport heated and powered by a 75-kilowatt Proton Motor fuel cell unit that is made up of three PM 400 stacks. Soon, the system, which was installed by Arcola Energy last year, may additionally be used to power the onboard systems of three ferries, to reduce local emissions while they are at berth.

Likewise, the hydrogen is planned to drive a fleet of electric vans, via a fueling station in Kirkwall. Symbio added a

Source: BIG HIT

5-kilowatt fuel cell to each of 10 Renault Kangoo Z.E. Maxi vehicles, usually equipped with a 22-kilowatt-hour lithium-ion battery pack, to double their range. In all, the project has 12 partners based in six EU countries. ||

→ www.bighit.eu; www.surfnturf.org.uk

Category: Global | **Author:** Alexandra Huss

H21 – LEEDS TESTS SWITCH TO HYDROGEN

InTEGReL – first whole systems facility in the UK

In the 1960s and 1970s, the UK put in enormous efforts to replace the ubiquitous town gas with natural gas supplies. The former, manufactured locally, contained more than 50 percent hydrogen. The proportion dropped to zero once the network was converted and about 40 million appliances were adapted for natural gas, delivered from the country's North Sea fields. But today, something old could be new again, as one city is planning to switch its pipeline system to pure hydrogen and serve as a model for the rest of the country.

Leeds, the UK's third-largest city, commissioned a study to determine whether the nationwide pipeline system could be converted in this way. The idea was born with the Iron Mains Replacement Program, implemented in 2002 to substitute polyethylene, which is thought to be well suited for transporting pure hydrogen, for cast iron pipes.

"If we consider the 19th century to have been dominated by town gas, the 20th century by natural gas, what if the 21st century could be dominated by hydrogen?"
Dan Sadler, H21 program director

When creating the study, Dan Sadler and his team aimed for a fully decarbonized energy system to achieve the national target of 80 percent lower carbon dioxide emissions by 2050 compared to 1990. This goal would require electricity, heat and transportation to be based entirely on zero-carbon sources. Up to now, those markets have relied on fossil fuels, such as natural gas and oil, all of which produce carbon dioxide, heat and water. Burning hydrogen would result in heat and water but no carbon. In principle, they said, the network was suitable for delivering hydrogen instead of natural gas. Since both were indeed gases, the pipeline diameter would remain unaffected.

Fig. 1: H21 Leeds City Gate

"Power-to-gas technology has the potential to answer some of our key energy storage challenges because of the gas network's sheer size and flexibility. This study has delivered some compelling results and insight into how a whole systems approach and green hydrogen can facilitate decarbonization across all energy vectors. [...] By bringing gas and electric together, there is an extremely valuable opportunity to drive down costs for customers, increase resilience and improve sustainability."
Mark Horsley, chief executive of Northern Gas Networks

Sadler, the director of the H21 program to transform Leeds' energy resources, works for Northern Gas Networks, a supporter of the project and the gas supplier for the north of England. The company said in a statement, "We have shown that this goal is technically feasible and can be done at a realistic cost." The study, called H21 Leeds City Gate, had proved that the gas network had enough capacity for conversion, and gradual implementation of the plans could minimize disruption to customers and ensure that there would be little impact on utility bills.

ENOUGH MONEY AND OFFICE SPACE In theory, Leeds could offer pure hydrogen while the rest of the UK would see a gradual upgrade. On Oct. 6, 2016, representatives for Northern Gas Networks came to the city to present their ideas about how to convert a large chunk of the country's pipeline network. One year later, it opened an H21 project office in Leeds to ensure that the ambitious plans are being implemented.

The opening came in the week following the UK's pledge to support hydrogen-powered home heating. "We are delighted with the government's announcement of a GBP 25 million program," Mark Horsley, chief executive of Northern Gas Networks, said. He added that it would provide much of the critical evidence needed to allow for a policy decision on converting the network. "By opening our dedicated project office, we are taking a further step toward our hydrogen future and [are] sending a signal to the government and the rest of the industry that we are ready to work with them to deliver it," he said.

Last November, the company was awarded GBP 9 million, via the annual Gas Network Innovation Competition, by the UK's energy regulator Ofgem on behalf of all British gas distributors, which will contribute an additional GBP 1.3 million. The GBP 10.3 million total is said to be used in stage one to fund controlled testing. Stage two field trials will reportedly require another around GBP 5 million, although it is unknown where those funds will come from.

Sadler's team is now investigating hydrogen behavior in customers' meters, pipes, stoves and boilers while also attempting to find out whether it makes sense at all to replace the network's natural gas, or, more specifically, methane with zero-carbon hydrogen. Other objectives are to

Provide concrete and compelling safety evidence for converting the gas network to hydrogen.

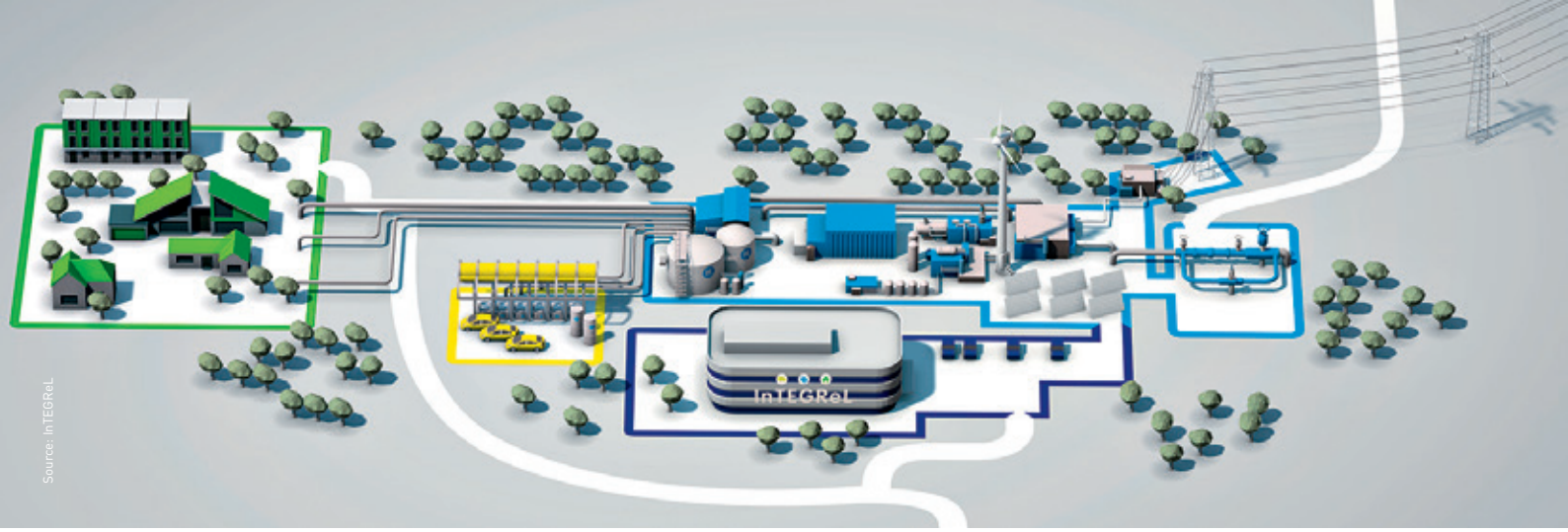

Fig. 2: InTEGReL in Gateshead

Create guidance to adapt modeling methods for use on other metropolitan areas in the UK.
Consider alternative solutions for hydrogen production and network storage.

POLITICAL BACKING Rachel Reeves, UK parliament member for Leeds West, said during a conversation with Sadler, "[Northern Gas Networks'] innovative H21 project shows how the private sector can lead the way in helping reach our 2050 emission reduction targets. It is crucial the government backs business with an industrial strategy that has a plan to create jobs and foster investment across the country at its heart."

H21 CITY GATE

In July 2016, H21 Leeds City Gate published its report. In it, the authors confirmed that converting the UK's gas network to deliver hydrogen was both technologically feasible and economically justifiable. As the initiator and head of H21, Sadler presented his ideas in late February, at an event titled "H21 Leeds City Gate – Moving from Natural Gas to Hydrogen." The lecture was hosted by the EU-supported Energy Technologies Research Institute of the University of Nottingham, where it also took place.

Sadler added, "The H21 project was born in Leeds and based in Leeds, but its scope ultimately involves the entire country. Hydrogen can play a key role in helping the UK meet the challenges of the Climate Change Act: reducing 1990 carbon levels by 80 percent by the year 2050." He said that a future energy system would need a mix of different technologies, be they gas, electricity or renewables, to achieve that target. H21 had shown that a UK-wide conversion of the network would reduce heat emissions by at least 73 percent and help decarbonize transportation and localized power production.

INTEGRATED RESEARCH SITE To put ideas into practice, Northern Gas Networks has partnered with Northern Powergrid as well as Newcastle University and its National Center for Energy System Integration, primarily funded by the country's Engineering and Physical Sciences Research Council, to build an entirely new kind of installation on 15 hectares, or 37 acres, at the Low Thornley site in Gateshead, north of Leeds. Based on a whole systems approach, InTEGReL, short for Integrated Transport Electricity and Gas Research Laboratory, will allow scientists and engineers to test several energy generation technologies at large scale and in a real-world environment. Hopes are to see breakthroughs in the decarbonization of heat, energy storage and transportation. Construction started last year. Reportedly, a 50-megawatt power-to-gas demonstration system may be added to the facility. ||

Category: Global | **Author:** Alexandra Huss

HYDROGEN'S ROLE IN ENERGY SYSTEMS INTEGRATION

Interview: IPHE Executive Director Tim Karlsson

IPHE, the International Partnership for Hydrogen and Fuel Cells in the Economy, was set up in 2003 to expedite the transition to clean and efficient energy and transportation systems based on fuel cells and hydrogen, or FCH. As an intergovernmental organization, it offers a global platform for discussing policies, initiatives, technological advances, and codes and standards to accelerate the adoption of cost-effective solutions. It also provides stakeholders as well as the public with information about the benefits and challenges of commercializing FCH systems at large scale.

H2-international: Mr. Karlsson, governments are mapping out national policies to achieve the Paris Agreement's 2050 targets for limiting global warming. Will this affect the development and use of hydrogen and fuel cell technologies? And if so, how?

Karlsson: People increasingly recognize the role that zero-carbon hydrogen will have in energy generation, transportation and manufacturing, as well as the built environment. The method or source that is used to produce the gas is very important when you focus on the environmental aspects. To achieve the targets set out in the Paris Agreement, hydrogen will need to produce net-zero or close to net-zero greenhouse gas emissions. Today, there are two methods to meet this requirement. One is to produce the gas via electrolysis from renewable or other zero-carbon sources, for example, nuclear power. The other is to use fossil fuels for the same process, coupled with carbon capture and sequestration.

While the Paris Agreement has provided several countries with an incentive to act and forge ahead with their plans to establish hydrogen as a key component of future energy and transportation systems, it is not the only factor at work. Security of supply, energy systems management, innovation and economic opportunity are all driving renewed interest in the gas. Some are looking to diversify their sources of energy, while others have already taken the first steps toward a renewable future but know that they will need to dispatch and manage energy more effectively – which hydrogen, as a storage medium, will allow them to do.

There are also countries that are rich in energy but have unique innovations or resources that strongly favor hydrogen and its related technologies, be they fuel cell systems, electrolyzers or the parts going into these systems. The Paris Agreement has been an important reason for the growing focus on hydrogen, but it is not the only rationale for deploying the technology.

Thanks to the Paris Agreement, governments and industries are discussing how the gas could help bring about a drastic reduction in emissions in sectors as varied as transportation, heat and electricity. In what way does IPHE contribute to these debates?

Karlsson: The focus of IPHE is on the accelerated development and deployment of fuel cell and hydrogen technologies. As an intergovernmental partnership, it provides stakeholders with opportunities to share information, gain insights into what programs and initiatives are underway and why, and keep up on current events in their jurisdictions. It helps them make informed decisions about how to expand the use of hydrogen in their economies.


Source: IPHE

Each country in the European Union has a unique set of conditions and priorities, be they innovation and economic growth, environmental sustainability, or improved energy self-sufficiency, security and efficiency. IPHE's response, regardless of the individual circumstances, is to promote an exchange of information and points of view. Understanding the national situation of an IPHE member and the plans moving forward, as well as the decisions that were made and the lessons that have been learned, can help guide outcomes elsewhere. What we call sector integration, hydrogen at scale, and the hydrogen society are all ideas that describe an integrated and valuable supply chain reaching across sectors, a recurring theme in IPHE's work.

You've mentioned hydrogen at scale and sector integration, key terms in current discussions about adapting energy systems to future needs, especially to mitigate emissions. What needs to be done so that H_2 and FC technologies can fulfill the promises that these terms encapsulate?

Karlsson: The idea behind sector integration, H2@Scale and the hydrogen society is that this energy carrier can add value to electricity storage, both to facilitate the use of clean power in more than one sector and allow for new solutions in manufacturing, which will contribute to meeting energy security, resiliency and environmental objectives.

The opportunity of using hydrogen to create an integrated energy system across multiple sectors has a far-reaching impact on not only the physical infrastructure but also market policies, regulations, and codes and standards in numerous jurisdictions. In some, the market could expand while encountering few hurdles. In others, there could be new industry leaders showing the way. Take electric utilities, for example, which have often been required by law to ensure heat and power are available to citizens. Now, what if the utility were a producer of hydrogen? What effect would this have on competition policies, regulatory oversight as well as communities that place their trust in a new energy, transportation and industrial structure?

IPHE members are beginning to consider some of the potential implications for their economies. The cost effectiveness, robustness and commercial viability of hydrogen technologies is steadily improving. Over the last few years, the cost of some electrolyzers has dropped to one-fourth of what it used to be. Initial commercial deployments have

shown that hydrogen is a reliable and effective means to cater to the needs of multiple sectors. A crucial next step will be to discuss how best to integrate the gas into the economy and promote an understanding that each jurisdiction has its own requirements.

IPHE is currently comprised of 18 EU countries and the European Commission. All of them have differing ideas, approaches and conditions when it comes to introducing H2FC technologies. What benefits can they derive from participating in a partnership such as IPHE?

Karlsson: IPHE members have a set of economic, environmental, social and energy-related objectives, of which hydrogen can be an important component. Understanding how and why their views differ will get them closer to their goals. Membership in IPHE offers several advantages, including the sharing of road maps, progress, lessons learned and best practices.

This exchange of ideas and approaches helps members decide on how best to accelerate the development and deployment of hydrogen and fuel cell technologies. Participating in IPHE also means that you can work together with other countries on issues of mutual concern, be they related to codes and standards, communication, analysis and outreach, or research and demonstration. IPHE's website offers member countries and other stakeholders a list of reports and an event calendar. Those interested in staying informed about the latest developments can register via a link on the website.

Could you provide some examples of the ideas, and requirements, that IPHE members have for introducing and commercializing H2FC technologies?

Karlsson: Several intriguing ones come to mind. The far-ranging use of fuel cell forklifts in North America is an example where regional and national circumstances matter. Major North American logistics centers operate 24 hours a day, seven days a week, so the ability to refuel in minutes, maintain performance and minimize a fleet's carbon footprint often makes the business case for investing in the technology.

By comparison, the European market has grown at a slow pace. There are various reasons for this, but one that may not be obvious at first is the difference in logistics systems. Europe limits hours of operation, which means less emphasis is placed on fast refueling or recharging and the forklift trucks could become a harder sell.

H2FC technologies are also proving their worth in the backup power market in India and other emerging countries, where the leap to cell phones makes it vital that cell towers be reliable. Additionally, the remote Raglan Mine in northern Quebec in Canada has been using an energy system comprised of a wind turbine, a flywheel, batteries and a hydrogen unit, supported by diesel generators. This system is turning out to be very effective at significantly reducing the shipping cost of fuel and the environmental footprint of mining operations.

In South Africa, a national research institution called HySA has designed a 2.5-kilowatt fuel cell and combined the unit with a solar field and an electrolyzer to provide power for a rural school – a remote-site application that could be of substantial benefit to the local community. In China and Europe, there is considerable interest in hydrogen fuel cell buses. Factors such as air quality, zero-emission targets and fast fueling at transit companies have all contributed to plans for several hundred buses over the next few years.

Hydrogen is perceived as a clean and zero-emission energy carrier provided green electricity is used to produce it, and it is also being considered for storing surplus renewable energy. It looks as if the gas could be an ideal solution for future energy systems predominantly based on renewables. But what about current barriers – nationally, in Europe and globally – to widespread use?

Karlsson: There are a number of technical issues with using hydrogen, and governments and industry are addressing them in joint research, development and demonstration projects. Current barriers include the cost of hydrogen production, distribution and storage, and the lack of an infrastructure and a robust supply chain. Specific examples of what needs to be investigated are the impact of hydrogen on pipeline materials and valves, methods to lower the cost of compression, dispensing and bulk storage, ways to increase the efficiency of liquefaction, and the suitability of codes and standards. These topics are all technical in nature and sustained R&D will be needed to find answers.

A broader issue is the path from demonstration or pilot projects to early implementation, a process that should be guided by a longer-term vision of hydrogen's role in the economy. There are excellent transportation initiatives and fueling infrastructure programs out there, in addition to systems that demonstrate new ways to make use of hydrogen in industrial settings and building heating and cooling. They are crucial to ensuring the efficient, safe and secure integration of this energy carrier into numerous applications and essential to supporting the deployment of the technology.

The question is how to move beyond demonstrations and early market development, toward robust and comprehensive infrastructures. The full potential hydrogen has for transitioning to sustainable energy production and consumption can only be exploited if countries and regions know what it means to produce, distribute and use net-zero hydrogen in quantities that can help them achieve their objectives.

To date, renewable hydrogen is often faced with market or infrastructure issues – too much generation during periods of low demand or grid congestion. The gas comes with efficiency gains, flexibility and, to some degree, energy independence because of its ability to provide longer-term storage and connections to electric power and natural gas systems. But in the longer term, producing net-zero hydrogen will need to become an objective by itself, either for national or regional consumption or for export to countries and regions that will use the clean energy carrier.

This transition will require that governments and industry craft major policies and commit much capital to the >>

effort. Countries are starting to look at the issues involved in moving to a system where hydrogen can add value and, in some cases, replace fossil fuels, such as natural gas.

IPHE is an intergovernmental organization for exchanging information on H2FC development on a ministerial, that is, policy-making, level. How can you assure industries that their needs are part of your discussions?

Karlsson: Via our forums, held on the heels of the steering committee's semiannual meetings, IPHE regularly talks to major players in the hydrogen and fuel cell market about the latest initiatives and installations. We travel to member countries around the world to speak to leading companies in a region, inviting them to present and discuss their most current advancements.

A while ago, IPHE joined the Stakeholder Forum organized by the Fuel Cells and Hydrogen Joint Undertaking in Brussels to discuss the current situation of early commercial FCH products, the initiatives to facilitate installation, the key non-R&D barriers that industry and governments can address, and ways for industry and agencies to accelerate deployment. Previously, at Hannover Messe, we held a panel discussion, attended by public and private sector representatives, where we had a lively debate about the issues, including a closer look at them from both sides.

IPHE is also collaborating with the Hydrogen Council and other industry organizations, such as the various hydrogen transportation initiatives in leading countries. It is crucial to hear and understand the views of companies in the sector, as they develop H2FC technologies in response to market demand and government action. Unexpected challenges, not necessarily related to H2FC, can arise – for example, zoning or standards issues – and they must be overcome to establish a hydrogen infrastructure. ||

→ www.iphe.net

Category: Global | **Author:** Alexandra Huss

CANADA, THE INDUSTRY'S NEW BENCHMARK

How a country's image changed from polluter to protector

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Canada has been the biggest driver of a commercial hydrogen and fuel cell market over the past 30 years. It has come as far as it has without political pressure to invent new technologies to protect the climate and the environment, provide security of supply or create jobs and stimulate growth. Early on, hydrogen and fuel cell companies such as Ballard and Hydrogenics recognized the market potential for vehicle applications. Back in the 1980s and 1990s, they had developed systems the big automakers could and would integrate into their vehicles. Prototypes of zero-emission buses and cars for eco-friendly transportation created a hype that led to skyrocketing levels of growth, with the dotcom boom in the late 1990s and early 2000s doing the rest.

But Canada's industry could not yet sustain the success. When the financial crisis hit and the hype died down, the market was left in a very vulnerable position. Companies only survived thanks to new investors and business models and a renewed focus on core activities, that is, technology research.

Nevertheless, several demonstration projects in the United States and Europe and a simultaneous low-volume production of fuel cell cars and buses provided proof that the technology is a viable option for everyday use. It prompted users to pour more resources into getting their own products ready for prime time. The decision on entering new markets was made easier by changes in policy, especially in the United States, or, more precisely, in California, where the state government called for a quota on zero-emission vehicles. In Europe, multiple bus projects brought the technology closer to mass production. Consequently, Canada's manufacturers went global and focused on exports right from the start, while people at home showed little interest in the market.

BALLARD AND HYDROGENICS, TWO SHOWCASE COMPANIES Today, the world's most flourishing fuel cell and hydrogen businesses are Ballard, based in Burnaby, in the state of British Columbia, and Hydrogenics, headquartered in Mississauga, Ontario. It needs to be said that these two have provided the fuel cell system for nearly every successful demonstration project ever carried out in Asia, Europe or the United States. Their experience and expertise have created cutting-edge solutions around the globe.

Over the past years, a new generation of Canadian companies has sprung up around them. By now, they cover almost the entire value chain, from filling stations to complete fuel cell systems. Examples are Greenlight Innovation, HTEC Hydrogen Technology & Energy Corporation and Powertech Labs, all hailing from British Columbia. This province on the west coast is home to the biggest hydrogen and fuel cell cluster in the country. Others can be found in Alberta, Ontario and Quebec, according to a Canadian Hydrogen and Fuel Cell Association survey.

BALLARD POWERS BUSES In the early 2000s, Ballard had provided Evobus, a Daimler subsidiary, with fuel cell stacks for 33 transit buses. Three of those were for a demonstration program in Perth, Western Australia. The remaining 30 were used in 10 cities in Europe as part of the EU demonstration programs CUTE, ECTOS and HyFLEET:CUTE, which laid the foundation for the continent's commitment to zero-emission mass transit in regions and cities and resulted in the formation of Europe's first fuel cell purchasing association, supported by the Fuel Cells and Hydrogen Joint Undertaking, in 2016.

In 2006, three more Evobus vehicles demonstrated their capabilities during line runs in China's capital Beijing. Ballard also supplied the fuel cell systems for 20 New Flyer transit buses, used by the British Columbia Transit Authority for the Olympic Winter Games in 2010 in Canada.

HYDROGENICS POWERS CARS AND TRAINS Today, Hydrogenics is one of the most important suppliers of PEM electrolysis and fuel cell equipment. As an example, auto-

maker Opel decided on a Hydrogenics system for its first-ever fuel cell car, HydroGen 1, built in 2000. Likewise, Alstom's new railcars will be equipped with the supplier's fuel cells to run on non-electrified tracks in the German states of Baden-Württemberg, Hesse, Lower Saxony and North Rhine-Westphalia in the coming years. The company's third business division these days is power-to-gas.

CANADA ADDRESSES CLIMATE CHANGE HEAD-ON Cars and buses are still two of the key markets for hydrogen and fuel cells worldwide. Current drivers of demand are government policies, especially climate-related legislation, and strategic shifts in industries no longer willing or able to rely on fossil fuels for economic and environmental reasons. This includes energy producers and energy equipment manufacturers, but also the oil and gas, the chemical and the maritime industry.

In November 2015, when the now-governing Liberal Party under Prime Minister Justin Trudeau came to power, Canada put climate protection back on the agenda. Just in time for the Paris accords, it once again became a member of a global community intent on mitigating the effects of climate change. In 2008, it had withdrawn from the Kyoto Protocol to avoid substantial penalties. Instead of a 6 percent reduction, as set out in the agreement, the country saw a 25 percent jump in emissions between 1998 and 2008. Faced with the prospect of having to pay billions in fines, Canada simply exited out of the deal.

Trudeau's government is taking climate change much more seriously. Besides ratifying the COP21 agreement, it has presented a national road map, the "Pan-Canadian Framework on Clean Growth and Climate Change." At its core, the plan relies on carbon pricing, which is thought to boost economic growth and technological advances. Canada, the world's second-biggest country by total area, has classed hydrogen and fuel cells as being green technologies, allowing the national industries to solidify its position as the global leader of the pack.

The funds granted in connection with the Pan-Canadian Framework also cover hydrogen and fuel cells. There is the Innovation Superclusters Initiative, a five-year CAN 950 million program running from 2017 to 2022, or the CAN 1.26 billion Strategic Innovation Fund and the CAN 2 billion Low Carbon Economy Fund, both available during the same period. Other support measures, focused on zero-emission transportation, are being offered in the provinces of British Columbia, Ontario and Quebec.

The "Canadian Hydrogen and Fuel Cell Sector Profile" study published in 2016 showed total sector revenues of CAN 220 million in 2015, of which CAN 125 million were from product sales and CAN 84 million from the provision of services. The industry spent CAN 173 million on research, development and demonstration, and employed nearly 2,000 people, many of them highly qualified individuals. At the time, Canadian organizations had been involved in 18 demonstration projects and were part of 98 strategic alliances and 222 research partnerships – no small feat for a country with a population of only 36 million. ||

Source: Daimler

Fig. 1: One of 36 buses powered by Ballard fuel cells

Category: Global | **Author:** Sue Vorenberg

NEW TECHNIQUE COULD TRIPLE CAPACITY

Increased efficiency of hydrogen fueling stations

A new technology developed at the U.S. Department of Energy's Argonne National Laboratory could significantly lower the cost of building new hydrogen fueling stations as well as expanding the fueling capacity of existing ones. The new method could reduce the need for expensive equipment and help bring down the cost of station upgrades by re-tasking compressors to serve more than one dispenser at a time and always allow for a fully pressurized and filled cylinder to be available on-site.

Argonne has been modeling hydrogen fueling for more than a decade. Scientists had estimated that a new technique, called pressure consolidation, could save stations up to 30 or 40 percent of their compressor costs, said Amgad Elgowainy, team leader and principal energy systems analyst with Argonne's energy systems division.

"What we want to do is beef up the storage that feeds the compressor by consolidating hydrogen between storage cylinders," Elgowainy said. "So, with the same compressor stations in place today, they can fully serve two dispensers side by side instead of just one."

The new method could cut fueling costs at a dispenser in California from between USD 13 and USD 16 per kilogram to between USD 3 and USD 4, Elgowainy explained. One kilogram of hydrogen had the same energy as one gallon of gasoline, but it could deliver more than twice the miles when used in fuel cell electric vehicles.

"When you look at hydrogen fuel cell vehicles, one major challenge is the cost of fueling infrastructure," the analyst said. "This technology can reduce the barrier to market by decreasing fueling costs."

The compressor is the most expensive fueling component, but it's often oversized and not used to its full potential at hydrogen stations. Large units are a popular choice for dispensing hydrogen more effectively during peak hours, but they then go underused or idle during off-peak times.

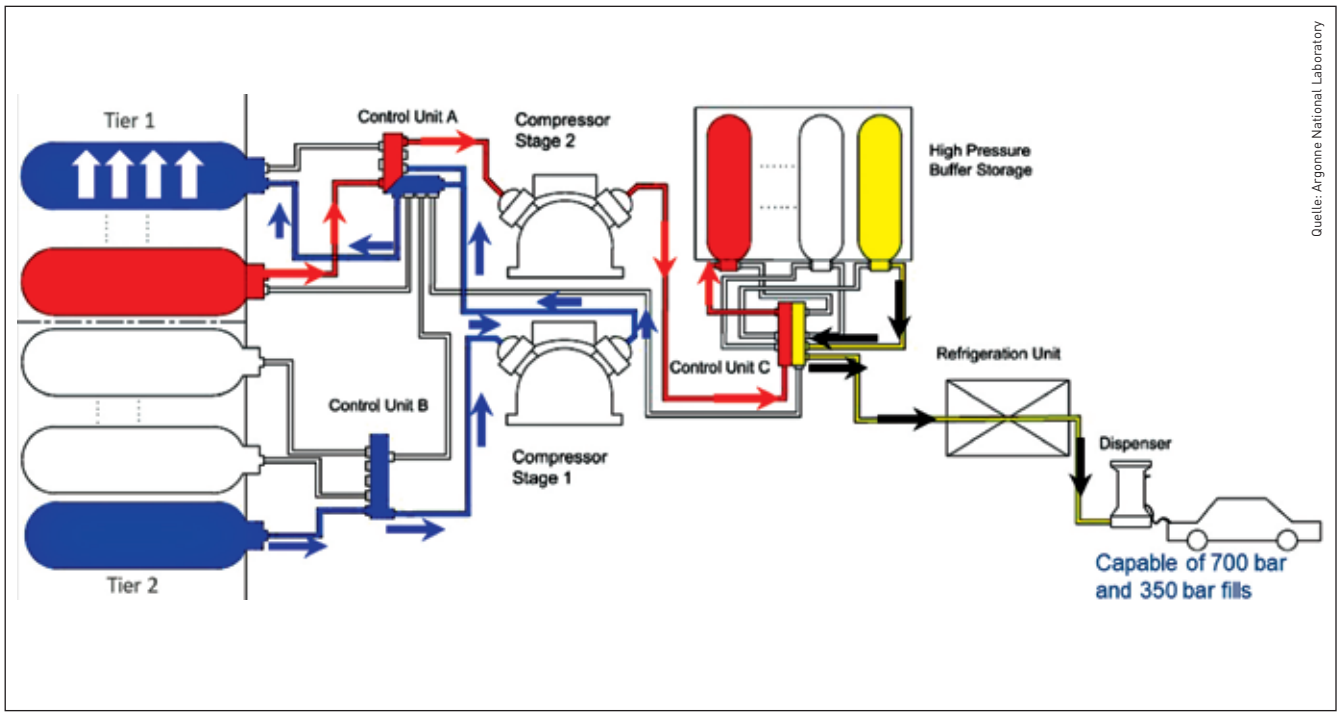
Typically, the compressor is supplied from ground storage. When hydrogen is drawn from the ground-stored cylinders, the pressure delivered to the compressor also drops, resulting in low throughput.

Pressure consolidation will prevent this pressure from dropping indefinitely. Instead, during off-peak hours, the compressor will keep at least one bank of cylinders always charged to ensure high throughput during peak demand hours. The technology also allows for up to three dispensers instead of one.

"The compressor basically keeps running and continues preparing some cylinders to be ready at high pressure for high throughput compression," Elgowainy said. "So, really, you don't need a big unit to do the same job." New stations equipped with the technology could lower capital costs by 25 to 30 percent, he said.

Expanding the capacity of a station will save costs as well, as only one compressor is required for an additional dispensing position. Moreover, the developed operation schema will help lessen the impact of the unit's start-and-stop routine and, thus, improve its reliability.

"Alternatively, with a compressor already in place, the new method can double or triple the throughput," Elgowainy explained. "And it can work for existing stations as well." The technology also didn't affect the fueling experience in any way, he said.



"The target is to fill up the tank in the same amount of time," the author of many papers said. "It's the key to the smart implementation of compression plus storage." The technique could also be used with any type of gaseous fuel, including compressed natural gas, he added.

Not that long ago, the lab had gotten financial support from the Department of Energy's Technology Commercialization Fund to bring the technology to market, said Munidhar Biruduganti, principal research engineer with Argonne's technology commercialization and partnerships division. "The TCF award gave people quite a bit of exposure to what Argonne can support to get this technology out on the market," he explained.

Argonne received its first patent on the technology in 2017. A second one, still pending, was filed in 2016. This year, the laboratory is planning to test the efficiency of the new method at a commercial station.

"In the near future, we will partner with a commercial entity to demonstrate the technology at one of its fueling sites," Elgowainy said. "We are in talks with potential partners interested in the technology." ||

→ https://hdsam.es.anl.gov/

The work is being funded by the Fuel Cell Technologies Office, or FCTO, within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, or EERE for short. The technology is available for licensing. Parties interested in learning more about how they can benefit from these Argonne innovations should send an email to partners@anl.gov.

Category: Global | **Author:** Robert "Bob" Rose

UNITED STATES: MORE R&D MONEY THAN EXPECTED

Nikola Motors, which is developing Class 8 semitrucks that use fuel cell range extenders, announced an order for 800 units from Budweiser while suing Tesla for USD 2 billion, alleging patent infringement. Nikola's announcement got so much attention that FedEx Corp. put out a notice on the receipt of a fuel cell delivery van.

Nikola's choice of name by itself (Nikola is Tesla's first name) shows a sense of humor and an "in-your-face" attitude – the company certainly seems to be having fun. In effect, this battle is being waged for the heart and soul of the hydrogen vehicle marketplace.

Tesla CEO Elon Musk's spectacularly engineered Wall Street success have endeared the company to the opinion leaders in California's environmental community. In turn, this bromance has had an influence on prominent environmental organizations in the northeastern states, which tend to be skeptical of hydrogen anyway. But market forces are shifting, and it appears that heavier vehicles will present an opportunity for fuel cells to gain market share and command both respect from NGOs and financial and other support from governments.

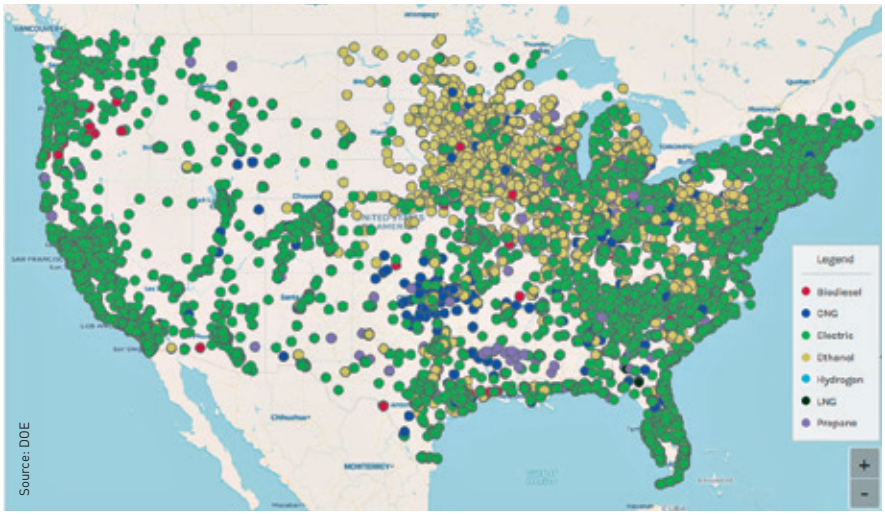


Fig. 1: Alternative stations in the United States

Meanwhile, the U.S. Department of Energy has updated its Alternative Fuels Data Center, which shows vehicle charging and fueling information, complete with an interactive map. At present, the number of green battery charging stations is overwhelming, but the downside is that it takes quite a while to "fill up."

The department has also been scrambling to solve an unusual problem: more R&D money than expected in fiscal year 2019. Only a wildly optimistic enthusiast would have believed that the U.S. Congress would approve USD 104 million, more than USD 30 million more than either the House of Representatives or the Senate had set aside. The outcome is the result of friends in high places, namely the number one Senate Democrat.

There are still large gaps in DOE's management structure, 18 months into the Trump administration. This suggests that the current approach, that is, having mostly career managers plus a few top-level executives, will continue through November 2018 midterms. This means uncertain times ahead – but bureaucracies are tough. ||

→ www.afdc.energy.gov/fuels/electricity_locations.html#/

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www.ees-europe.com
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Vairex air systems, 3048 Valmont Road, Boulder, CO, 80301, USA, Phone +1-303-994-2047, info@vairex.com, www.vairex.com

GAS DIFFUSION LAYERS (GDL)

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HYDROGEN DISTRIBUTION

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

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

REFORMERS

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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*

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ElectroChem Inc., 400 W Cummings Park, Woburn, MA 01801, USA, Phone +1-781-9385300, *www.fuelcell.com*

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

Kerafol Keramische Folien GmbH, 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*

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

SYSTEM INTEGRATION

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Framatome GmbH, Paul-Gossen-Str. 100, 91052 Erlangen, Germany, Contact: Mrs. Gemmer-Berkbilek, Phone +49-(0)9131-90095221, *www.framatome.com*

TESTING

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 +31-501-6877, h2sales@resato.com, *www.resato.com*

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