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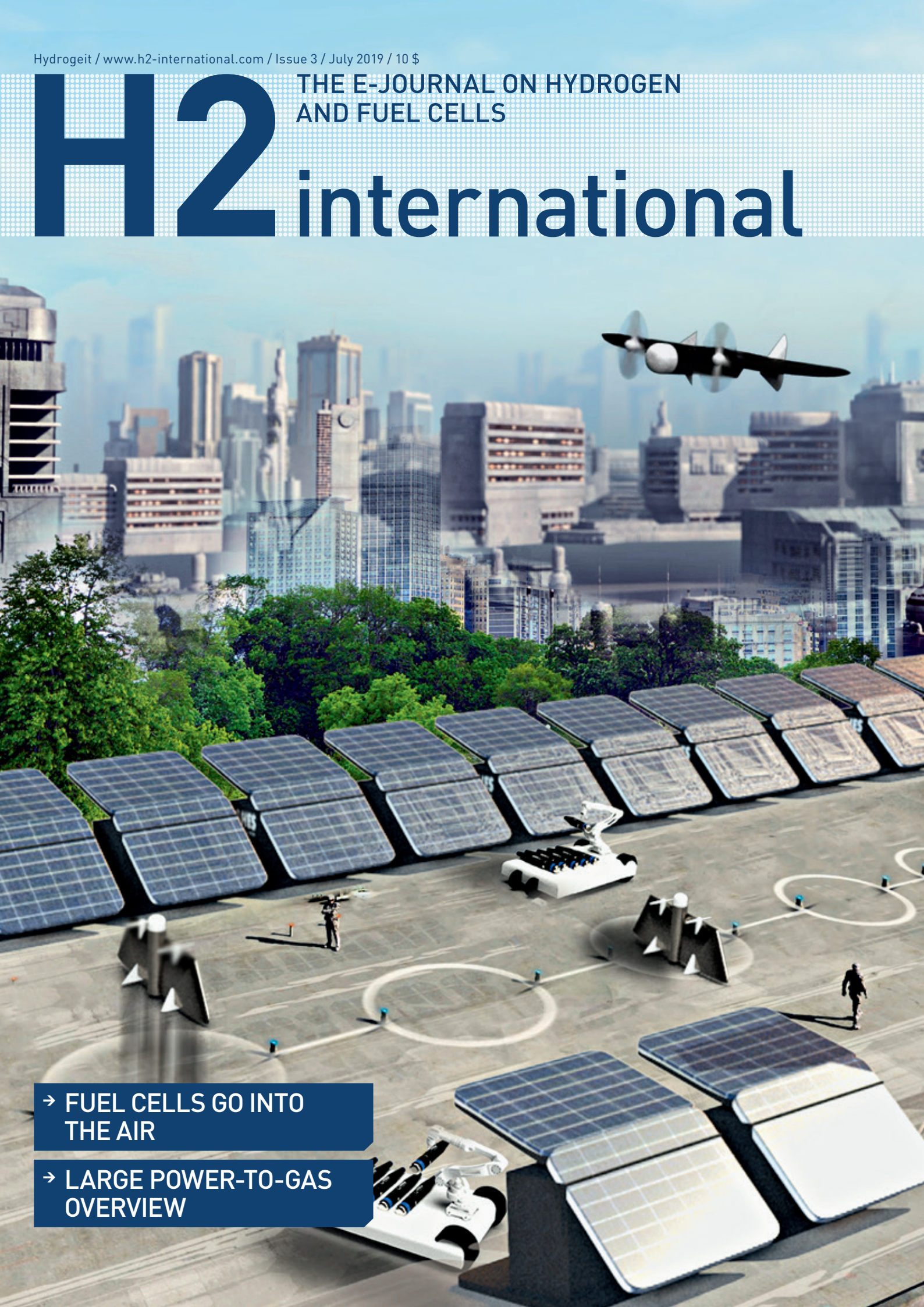
THE E-JOURNAL ON HYDROGEN AND FUEL CELLS



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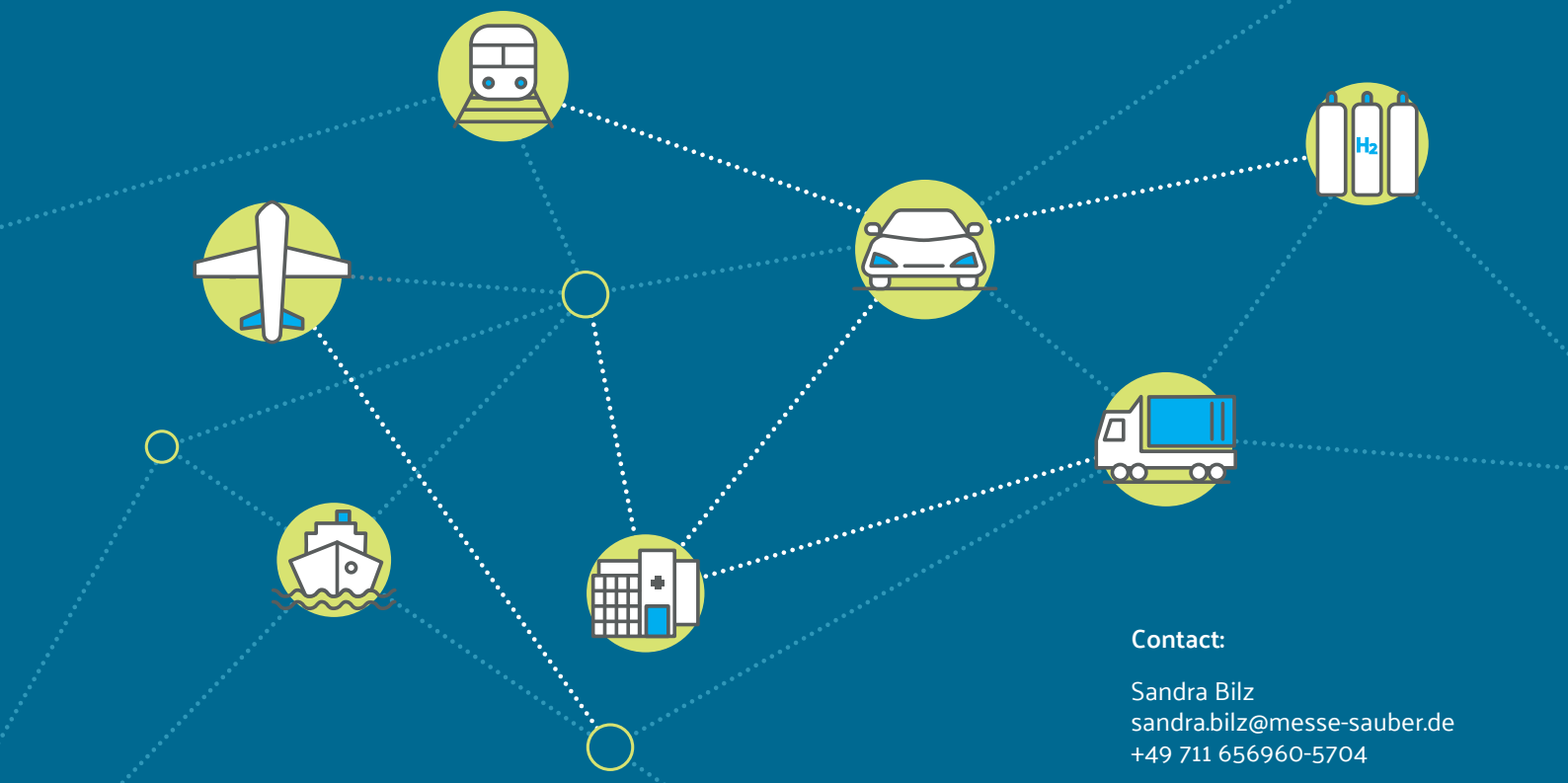

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H2-international

H2 international
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Cover image Vision of a fuel cell drone airfield [Source: HES Energy Systems, Singapore]

NEW PLAYERS

Dear Readers!

The signs are quite clear: Large manufacturers of classic combustion engines are gradually abandoning their traditional fields of activity and investing in hydrogen technology. In March 2019, for example, MAN Energy Solutions, a classic bus and truck manufacturer and subsidiary of the Volkswagen Group (MAN Diesel & Turbo until 2018; see p. 7), acquired a 40 percent stake in the electrolyser manufacturer H-Tec Systems. Deutz, for decades the epitome of large fossil-fuelled combustion engines, is now cooperating with Keyou and is now working on hydrogen aggregates (see p. 6).

But other major corporations are also gradually taking up positions – both in the gas sector and in the automotive industry: Almost simultaneously with the news described above, the gas company Linde announced that it was setting up a new subsidiary in Vienna called Linde Hydrogen FuelTech GmbH.

Shortly afterwards, the automotive supplier Bosch announced that it would build fuel cells in large numbers in the future (see p. 6). This could give rise to something in the FC sector comparable to the accumulator factory, which has been under discussion for months but is not really making progress.

Even the former oil companies are doing well: Shell management member Maarten Wetselaar announced this in March 2019: "We want to be the world's largest power company." In addition to the existing oil, gas and chemicals businesses, the electricity business is to be expanded into a fourth pillar over the next few years. This announcement means nothing other than that within a group of companies, what has so far only been considered, but hardly implemented in the energy sector, could be realised here: sector coupling.

Companies like Shell, which then have access to both the gas network and solar farms and wind turbines, can transfer energy from one sector to another on a large scale using hydrogen as a storage medium. Important economic sectors such as the refinery and steel industries are already involved.

On the other hand, the gas sector is currently lagging somewhat behind: While on the one hand the electricians for the so-called "all-electric-world" demanded the installation of a "copper plate" in Germany in order to distribute green electricity better and to be able to charge electric cars everywhere, on the other hand the gasifiers got increasingly buzzing because they – justifiably – had to fear that their gas network could become superfluous in the future.

Although the entire gas infrastructure will certainly not be uninstalled overnight, the gas associations will have to put up with the question of whether they have not held on to fossil natural gas for too long and thus given up a great deal of room for manoeuvre. Although the DVGW has now entered into cooperation with the DWV (see p. 8), active, transparent cooperation is not yet clearly discernible. For example, the DVGW was unable to answer some critical questions from the H2-international editorial staff about the association's motivation and objectives.

It should therefore be exciting to observe how the gas sector will further develop in the future. Gas producers in particular are facing new challenges, as the oversized former oil companies are pushing into their traditional business areas. There are voices suggesting that this too was one of the reasons why gas companies have not really pushed the hydrogen sector in the past.

But while on the one hand more and more companies are discovering the H_2 and FC sector for themselves, the loss of knowledge seems to continue to advance among German automobile manufacturers. Since many employees in the FC sector in the Stuttgart area in particular once left the local car manufacturer and switched to suppliers, some observers are already asking themselves whether and how this migration of know-how can ever be compensated.

Ola Källenius, the new CEO of Daimler AG, will now have to find the answer. After his predecessor Dieter Zetsche gave up his executive chair in May 2019 after thirteen years, it is now up to the Swede to decide whether and from when fuel cell cars with a star will be leased in series not only in limited numbers, but in mass on the market.

Sincerely

Sven Geitmann
HZwei-editor

FURTHER CHANGE AT SOLIDPOWER

Fig. 1: Ballhausen

The SOLIDpower Group does not come to rest. After Alberto Ravagni left SOLIDpower S.p.A. in mid-February 2019 and made way for Dr. Andreas Pichler, who is from Austria, as the new Managing Director, Andreas Ballhausen also left SOLIDpower GmbH at the end of March 2019. He was replaced by Gerald Neuwirth, who will henceforth steer the fortunes of the German company as Managing Director and Sales Director of the Australian-German-Italian Group. On the occasion of the appointment of the trained business economist from the company management, it was stated that "the SOLIDpower Group is orienting itself for the future" in order to be able to better implement its expansion strategy.

Ballhausen had joined SOLIDpower in February 2017 and had taken over the position from Guido Gummert (see H2-international issue April 2017). According to company sources, Ballhausen left the manufacturer of high-temperature fuel cell devices at his own request, as his goals were not identical with those of the partly new investors. In 2017 SOLIDpower received "a strategic financial injection of 40 million euros" from an undisclosed investor and in mid-2018 entered into a long-term cooperation with Buderus Thermotechnik. Andreas Pichler, member of the SOLIDpower supervisory board, explained: "Together with Gerald Neuwirth as CSO, we will implement a new marketing strategy and, in particular, expand our field of business in Europe."

At the beginning of June, Ballhausen accepted a new position that is only indirectly related to fuel cells. ||

WIND RESCUERS AT THE MINISTER OF ECONOMIC AFFAIRS

Fig. 1: Dr. Buchholz (centre) surrounded by wind rescuer supporters

Not only the movement "Fridays for Future" has many supporters at the moment, also the "Windretter" have a lot of supporters behind them. On 10 April 2019, the initiator Sybille Riepe handed over an open letter with 4,105 signatures to the Minister of Economics of Schleswig-Holstein, Dr. Bernd Klaus Buchholz. Representatives from 36 companies and associations that had joined forces to form this energy storage campaign at the end of 2018 had appeared at the Berlin regional council of the energy-rich northern federal state in order to express their demand for an intelligent regulation for the economic use of renewable electricity.

In his statement, the minister expressly thanked Sybille Riepe, the managing director of the agency motum GmbH, and explained that he was entirely on her side. He said: "Regulations that may have been well thought out years ago need to be changed. [...] We're not the madmen from the north, we're the thought leaders. We can be pioneers – in Schleswig-Holstein and in Germany."

Dr. Martin Grundmann, "Windretter" supporter and managing director of ARGE Netz GmbH & Co. KG, expressly praised this "initiative of a citizen". Turning to politicians, however, he criticised the fact that this legislative period was now the third in which it would not go any further. Together with major partners such as Vattenfall and MAN, his company wants to invest around 100 million euros in Brunsbüttel as part of the HySynGas project, but is being held back by the current legal situation. He also referred to AdBlue® producer Yara, Europe's fifth-largest energy consumer, which also wants to enter the hydrogen business on a large scale, but is still waiting for the lack of planning security.

The wind rescuers want to create a greater awareness that the available resources of renewable energies are frivolously wasted and often remain unused, although there is an ever-increasing demand for energy, especially in stored form. In the next step, in the presence of Dr. Buchholz, the signatures of the supporters are to be passed on to Federal Economics Minister Peter Altmaier in order to give even more emphasis to their concerns. ||

NEW CONTACT IN HANNOVER

Basilios Triantafillos

The responsibilities of Deutsche Messe AG are changing: Benjamin Low, the former Global Director of the Hannover Messe, left the Lower Saxony trade fair company at the end of February 2019. His successor is Basilios Triantafillos, who previously headed Energy in Hanover. From now on, the graduate economist will be responsible for all energy topics as well as for compressed air and vacuum technology and global business and markets – in Hanover, but also in Asia and North and Central America. ||

SPI WITHOUT DEUTSCHE MESSE

Solar Power International (SPI) will take place this year from September 23 to 26 as part of North America Smart Energy Week in Salt Lake City, but without Hydrogen + Fuel Cells North America. As the organiser Solar Power Events confirmed to HZwei, the cooperation of the past two years with Deutsche Messe and Tobias Renz will not be continued. There will nevertheless be an H_2 and FC area under the title Hydrogen + Fuel Cells International. ||

THE H_2 ENGINE IS ALIVE

Fig. 1: H_2 engine in the foyer of the Deutz head office in Cologne-Portz, [Source: Deutz]

For a long time it was very quiet around the H_2 combustion engine. Only Keyou GmbH from Munich adhered to this technology. Now the team of former BMW employee and current Keyou managing director Thomas Korn is receiving support from a prominent source: Deutz AG signed a cooperation agreement with Keyou at the end of March 2019. In addition, the Cologne-based company announced that a first prototype using hydrogen as a fuel had already been developed. A six-cylinder diesel engine (7.8 l displacement) was used, which was presented for the first time in 2018 at bauma China and in April 2019 at bauma in Munich.

Deutz and Keyou are thus expanding their existing development partnership in order to jointly advance the industrialization and commercialization of CO_2 free hydrogen engines for off-road and on-road applications as well as power generation. Together they want to establish an alternative to fuel cell technology.

Dr. Frank Hiller, chairman of the Deutz board, explained: "The use of alternative fuels such as hydrogen is becoming increasingly important. We see this drive solution as a valuable addition to our electrification strategy and an important pillar for emission-free mobility in the future." Production readiness is planned for 2021/22. ||

BOSCH IS TO BUILD FUEL CELLS

At the end of April 2019, Bosch made a loud and clear commitment to fuel cells by announcing its intention to produce FC stacks for mobile applications together with PowerCell Sweden AB in the future. According to a press release, Robert Bosch GmbH wants to "prepare the breakthrough of technology for trucks and passenger cars". Dr. Stefan Hartung, Bosch Managing Director and Chairman of the Mobility Solutions division, explained: "We're going about it now and opening up the market."

The fuel cell of PowerCell, a spin-off of the Volvo Group with now has 60 employees, is based on the AutoStack, which was developed by ZSW in cooperation with European car manufacturers. This PEM stack is now to be jointly further developed to series maturity by Bosch and PowerCell and then produced by the Swabians under license for the automotive market – presumably in Germany. It is expected to be launched on the market by 2022 at the latest. The automotive supplier from Gerlingen assumes that "in 2030 up to 20 percent of all electric vehicles worldwide will be powered by fuel cells".

The partners see great potential particularly in the commercial vehicle market, as the European Union's fleet requirements for trucks envisage a reduction in CO_2 emissions of 15 percent on average by 2025 and 30 percent by 2030. "Through industrialisation and the spread of technology on the market, Bosch will achieve economies of scale and reduce costs," said Hartung.

Bart Biebuyck, Managing Director of Fuel Cells and Hydrogen Joint Undertaking (FCH JU), had recently explained during the Hanover Messe that this was one of the "best stacks in the world". However, he had also stated that Europeans had not yet recognised this, while others had. The US manufacturer Nikola, for example, used the PowerCell stack for the first H_2 trucks. Bosch was also involved in its implementation. At the beginning of April 2019, however, Nikola announced that it would no longer use this stack. ||

In August 2018, Bosch also entered into a strategic cooperation agreement with Ceres Power Holdings plc to advance technology development and the establishment of small-series production. The British company develops solid oxide fuel cells (SOFC). Bosch acquired four percent of the shares in the company. Dr. Hartung explained: "For Bosch, the highly efficient fuel cell with very low emissions is an important contribution to the security of supply and flexibility of the energy system."

NEW CEP BOSS IS STARR

Fig. 1: T. Bystry (l.) and J. Starr – CEP predecessor and successor

The election of the new chairman of the Clean Energy Partnership (CEP) had already taken place during the New Energy Days in Husum (see p. 14), but the first public appearance took place in Hannover. At the Public Forum of Hydrogen + Fuel Cells Europe the baton handover took place: Thomas Bystry, who took early retirement from Shell in May 2019, led the initiative for over three years. He said goodbye: "In the individual industries and companies, there is currently a growing awareness that the realisation of mobility with hydrogen can only be achieved with combined forces."

His successor is now Jörg Starr. The manager, who initially worked for Smart and Daimler and has been with Audi since 2007, explained: "The subject is complex and multifaceted, which is why we want to grow. And, of course, I'm always hoping for more impetus from new partners." In order for small and medium-sized enterprises to be able to join the CEP in future, a new financial concept with reduced contributions was recently adopted. In Hanover, Starr also emphasised that he would like to lead the merger "for longer periods of time" (more than two years) as spokesman, and expressly pointed out that the willingness of his company to "release" him for this office could certainly be understood as Audi's commitment to fuel cell technology. ||

MAN JOINS H-TEC SYSTEMS

MAN is a vehicle and mechanical engineering group and is commonly associated with combustion engines and commercial vehicles. This is now likely to change, as the subsidiary of Volkswagen AG has held 40 percent of the shares in H-Tec Systems GmbH, an electrolyser manufacturer, since the end of March 2019. However, Heinrich Gärtner, Frank Zimmermann and Dr. Joachim Herrmann will remain on the management board, while Ove Petersen, co-founder and CEO of the parent company GP Joule, will move from the management board of H-Tec Systems to the chairmanship of the advisory board, which will consist of representatives of GP Joule and MAN Energy Solutions.

Fig. 1: T. Bareiß, Parliamentary State Secretary at the BMWi (l.), in front of the GP Joule Electrolyzer at the Hannover Messe with F. Zimmermann

Gärtner explained: "The experience of our new partner in mechanical engineering as well as the worldwide presence in sales give us the opportunity to react even faster to the upcoming expansion of the market for electrolysers. Our technology, which is consistently designed for series production, will set standards even faster." Dr. Uwe Lauber, CEO of MAN Energy Solutions, said: "For us, the partnership with H-Tec Systems is a strategic step and the entry into the hydrogen economy. The importance of climate-neutral generated hydrogen as a fuel will continue to grow. [...] Hydrogen forms the basis for the production of e-Fuels via the Power-to-X process."

> "Power-to-X can be used to generate a large number of synthetic gases that are completely climate-neutral and whose use as fuel can drastically reduce the CO_2 emissions from global logistics and energy generation."
> *Dr. Uwe Lauber on the occasion of the change of name from MAN Diesel & Turbo to MAN Energy Solutions in June 2018*

Ove Petersen told HZwei in spring 2019 that GP Joule had repositioned itself in the last few months. Although one focus continues to be the classic project planning of projects in the wind, bioenergy and solar sectors, which are increasingly linked to mobility and heat issues, another important field of activity is now also the services segment. In North America, GP Joule is also increasingly assuming the role of an energy service provider including energy supply – like a modern municipal utility, says Petersen. Following the separation from H-Tec Education at the end of 2018, the subsidiary H-Tec Systems remains an important mainstay, but has been made much more independent.

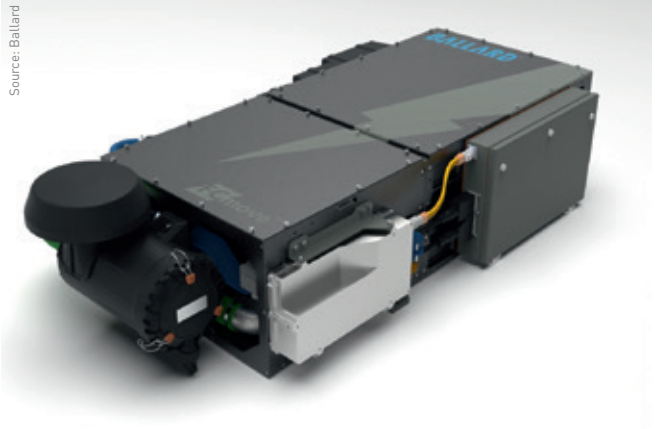
In line with the reorientation of its content already initiated in mid-2018, MAN Energy Solutions, ARGE Netz (see p. 5 and H2-international Jan. 2019) and Vattenfall jointly announced at the beginning of April 2019 that they intended to launch a large-scale industrial power-to-gas project in the Brunsbüttel industrial park. The HySynGas project aims to produce green hydrogen and synthetic gases using regionally generated electricity from renewable energies. The objective is to establish a power-to-gas hub for cross-sector decarbonisation in northern Germany, which is why the company has also applied as a real laboratory (see p. 20). ||

NEW STACK FOR H2BUS PROJECT

The Canadian fuel cell manufacturer Ballard Power Systems presented a new fuel cell stack at the UITP Global Public Transport Summit in Stockholm, Sweden, in mid-June 2019. The FCmove™-HD is specifically designed for the Heavy Duty Motive Market. According to the manufacturer, the compact, robust stack enables significantly more cost-effective operation and higher reliability with 50 percent fewer parts (40 percent volume and 35 percent weight reduction).

FCmove™ is the first element in a new product family designed to cover a wide performance range for different vehicles (commercial vehicles, trucks, trains). This fuel cell stack will be used, among other things, in the 1,000 planned fuel cell buses that will be put on the road as part of the European H2Bus project (see H2-international April 2019). First of all, the Polish bus manufacturer Solaris Bus & Coach will integrate the new units into its Solaris Urbino 12, which was also presented in Stockholm.

Randy MacEwen, president and CEO of Ballard: "Today, we see growing interest worldwide in the compelling performance promise that fuel cell electric vehicles alone offer in medium and heavy transport applications. With a 35 percent reduction in life cycle costs, the FCmove™-HD module represents an important step forward in the cost competitiveness of fuel cell solutions for this market." Technical Director Dr. Kevin Colbow added: "The fuel cell module FCmove™ offers attractive customer benefits through high reliability, simplified system integration and optimised operating parameters." ||



Source: Ballard

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

VOTE FOR A TWO-ENERGY SOURCE SYSTEM

DWV general meeting in Leipzig

The German Hydrogen and Fuel Cell Association (DWV) took a decisive step during this year's general meeting on 14 May 2019 to be able to make a stronger commitment in the future to the development of a green energy industry based on hydrogen as an energy source. The members present in Leipzig elected Alfred Klees, Head of the Gas Technologies and Energy Systems Unit at the head office of the German Gas and Water Association (DVGW), to the association's Executive Board as a further assessor, so that he can from now on act as a link between the two associations and set new energy policy accents.

As a new DWV board member, Alfred Klees is to work around thirty percent of his main working time for the H_2 and FC association. He will be supported by the lawyer Dr. Uwe Wetzel, the head of the Brussels DVGW office, who will also act for both associations. In return, DWV Chairman Werner Diwald is to become a member of the DVGW Executive Committee. Diwald had agreed these and other details with DVGW Chairman Prof. Gerald Linke in previous discussions.

The planned measures also include the DWV office moving into the premises of the Berlin representative office of the 700-strong Gas and Water Association during the year. The planned move will also be accompanied by further changes at DWV: It is becoming apparent, for example, that the long-standing secretary Dr. Ulrich Schmidtchen will probably not run for office again in the next board election in 2020, as he is retiring. The extent to which he will continue to support the association after that or whether further board positions will have to be filled by founding members is currently open.

THE BASIS OF A FUTURE ENERGY INDUSTRYN As a new advisory board, Klees is to convince both the members of the association and the public that a new era is about to dawn. The DVGW, which has hitherto mainly represented natural gas, is to become greener so that it can continue to have a say in the energy industry in the future. Natural gas is to be successively substituted by hydrogen, according to the new specification, which will henceforth focus on a two-energy source system. The extent to which this strategy is actually supported by all DVGW member companies is still unclear. What is certain, however, is that Klees' task will not be an easy one.

DWV and DVGW had already started bilateral talks at the beginning of 2018 and subsequently signed a cooperation agreement on 17 January 2019 (see H2-international issue April 2019). Since then, their declared goal has been to jointly "gradually transform the fossil energy industry into an increasingly climate-friendly energy supply system" by gradually replacing natural gas with synthetic gas and using hydrogen in combination with renewable primary energies as the basis for the energy economy of the future. Diwald had already declared the parallel talks with the BVES (Bundesverband Energiespeicher) (Federal Association of Energy Storage Systems) to be over during the Hannover Messe 2019, when HZwei was informed that the talks were over.

The fact that the natural gas and hydrogen industries have now joined forces offers, on the one hand, the opportunity to locate promising energy storage technologies specifically in the structurally weak or former coal regions of Germany. On the other hand, the replacement of a fossil fuel by a sustainable energy technology could be postponed indefinitely.

EXCELLENT MEMBRANE WORK Before the visit to the BMW plant in Saxony, the best submitted dissertation, master's thesis and bachelor's thesis were awarded the DWV Innovation Prize in the public part of the meeting. All three works had to do with membranes: The best dissertation was that of Dr. Martin Kopp from Freudenstadt. The industrial engineer had worked at the University of Kassel on the "optimisation of the operation of a PEM electrolysis plant on the electricity market side". He showed in theory and practice that the electricity costs of a power-to-gas plant can be reduced, the operating hours increased and the hydrogen removal optimised if different electricity procurement markets are used.

Peter Holzapfel received the Innovation Award for the best master's thesis, in which he also dealt with PEM electrolysers, but mainly with non-precious metal catalysts. Holzapfel also studied industrial engineering. As part of his work, he developed both a carbon supported platinum catalyst cathode and a non-precious metal cathode containing molybdenum sulphite, both of which showed considerable performance improvements.

The trained industrial mechanic and prospective mechanical engineer Jürgen Hahn received the award for the best bachelor thesis. He had succeeded in "realising a semi-automatic coating process for low-temperature fuel cell membranes". ||

Fig. 1: The DWV management extendedbyone observer (5th f. r.)

COOPERATION WITH MUNICIPALITIES
In April 2019, the City of Heidelberg announced that it was the first municipality in Germany to join DWV "to expand the network and support lobbying for sustainable hydrogen mobility". The DWV informed that further cities and municipalities are expressly welcome as members.

Category: House Energy | **Author:** Klaus Lehmeyer

FC HEATERS ARE A GOOD START

Letter to the editor from Klaus Lehmeyer

With great interest I read your article "The search for alternatives in the heating sector" in the e-journal H2-international issue January 2019.

I have had a fuel cell heating system for almost a year now. I spent quite some time looking for a new heating system for my building (built in 1955). As a certified energy consultant and efficiency expert, I have not made the task easy for myself.

Since I am a convinced hydrogen fan (participant at the JESS Summer School for Fuel Cells in Athens 2018), the fuel cell was my choice. After almost a year of practical experience, I am now able to come up with reliable figures.

The plant cost almost 30,000 euros with condensing boiler and fuel cell. The grant from the Kreditanstalt für Wiederaufbau (KfW) amounted to EUR 9,300. In my case, I also received a grant of EUR 926 from BAFA. So that I did not have to found a GmbH to be allowed to give the current surplus into the net, I selected the option of the one-off remuneration. As a result, the municipal plants added a further 1,800 euros as a lump-sum feed-in tariff. This lump sum is valid for ten years and serves as a replacement for the lost feed-in tariff (approx. 180 euros per year). And I spared myself the administrative act of founding a GmbH and also the annual reporting costs to BAFA.

My old low-temperature heating (also built in 1995) was replaced. The exchange against a conventional condensing heating system (condensing boiler, buffer storage etc.) would have cost me according to the offers available to me about 13,000 euros. Now the calculation was quite simple:

30,000 € – 9300 € – 926 € – 1,800 € = 17.974 €

With all the grants and subsidies I received, the fuel cell heating system, including the condensing boiler, cost me around 18,000 euros. A solar-assisted heating system costs around 13,000 euros plus around 8,000 euros (depending on the area of the solar modules), i.e. a total of around 21,000 euros. With KfW grants (approx. 12.5 %), the plant would have been roughly the same price. Due to the shading by surrounding trees, however, I would have had only a very moderate solar success. This was also the reason for me not to install a photovoltaic system.

The fuel cell (FC) has now been running for a year. In my case, it generated 3,903 kWh of electricity. I think that goes through certain measures but even better in the future. In summer I switched off the condensing boiler. So only the fuel cell was still running. It has an output of approximately 750 W_{el} and 1 $kW_{therm.}$ This is sufficient to loosely cover the industrial water needs of our family of four.

In my case there was a direct electricity consumption of 2,600 kWh on the part of the fuel cell. Multiplying this by approx. 29 cent/kWh yields a profit of 780 euros per year. In addition, the heating system required 5,573 kWh (approx. 10 %) less gas compared to low-temperature heating due to the use of the calorific value properties and the hydraulic balance, which means a cost reduction of approx. 300 Euro. All in all, this means a cost reduction of around 1,080 euros per year.

The entire system (condensing boiler with fuel cell) thus cost around 5,000 euros more than a condensing boiler. In my case, this means that the system pays for itself in around five years and achieves an interest rate of around 20 %. Due to the high energy efficiency, I also save about 1.4 tons of CO_2 per year just by using the fuel cell.

Although the natural gas reformation with H_2 splitting is not yet "the cherry on the cake", it is a good start. The decentralised power generation with simultaneous heat utilisation has a high efficiency and also relieves the public power grid.

Hydrogen is the fuel of the future, especially if it is produced from renewable energies. For the sake of the environment and peace, we should replace fossil fuels with green hydrogen as soon as possible. ||

Fig. 1: Installation work in the cellar [Source: Lehmeyer]

Graduate Engineer (FH) Klaus Lehmeyer is energy consultant of the German Energy Agency and expert according to §2 ZVEnEV for planning, evaluation of systems for heating, hot water and ventilation as well as structural and energy-saving thermal insulation of the Bay. Chamber of Construction Engineers. In addition, he is an expert according to §21 EnEV according to DIN 18599 non-residential buildings.

Category: Exhibitions | **Author:** Sven Geitmann

HYDROGEN WILL COME

Hydrogen + Fuel Cells Europe bigger than ever before

It was full in Hannover, at least so full that almost all the halls on the exhibition grounds were occupied. Dr. Jochen Köckler, CEO of Deutsche Messe AG, put the number of exhibitors at 6,500 – just as high as in the comparable year 2017. At 215,000, the number of visitors was somewhat higher than in 2018, but significantly lower than two years ago. It was remarkable, however, that Hydrogen + Fuel Cells Europe set a new record with 185 exhibiting institutions in its 25-year history.

The aisles at the back of Hall 27 were full, the orange carpet was barely visible at times. The mood was correspondingly positive – both among the exhibitors and among the visitors. Although there were not really many commercially available products to see this year, most of them weren't even interested in that. Much more important were making contacts, talking shop and discussing the potential of hydrogen and fuel cell technology.

The predominant topic was, of course, the statement of VW boss Herbert Diess, who had only shortly before spoken out against open technology and in favour of a pure battery drive in the passenger car sector (see below).

25 YEARS IN HANNOVER The central point of contact was once again the Public Forum, which was surrounded by a number of larger stands. Otherwise, the picture was dominated by many smaller presentations, since despite increased bookings, the total area of 5,000 m² remained the same as in previous years. For example, Forschungszentrum Jülich, which had been represented at the then comparatively small joint stand for hydrogen and fuel cells since 1996, was no longer present. The EnergyAgency.NRW, which for the first time in many years had not organised a large cross-sector joint stand in the Energy Hall, but concentrated entirely on hydrogen and fuel cells, exhibited at its traditional location.

Fig. 1: Lots of movement in Hall 2

On the occasion of the 25th anniversary, Tobias Renz, the organiser of Hydrogen + Fuel Cells Europe, was presented with a large birthday cake by Deutsche Messe AG. However, Arno A. Evers, the founder of the joint stand, who was also present in Hanover (see Fig. 2), was annoyed about this, as he had not been invited to the official tribute and therefore felt passed over.

Renz explained to HZwei: "Together with Deutsche Messe AG, we decided to give up the word 'joint stand'." He justified this step by stating that joint stands would normally have ten exhibitors, with a maximum of thirty. In view of the 185 exhibitors, it now seems time to talk about having your own exhibition at the exhibition, says Renz.

VDMA IS CONFIDENT In keeping with tradition, the Fuel Cell Working Group of the German Engineering Federation (Verband Deutscher Maschinen- und Anlagenbau e. V. (VDMA)) presented its report on the state of the FC industry in Germany at the Hanover Fair. As Chairman Dr. Manfred Stefener explained, "sales fell well short of the two previous years and expectations because important suppliers left the market and individual companies have reoriented themselves. He also noted that "business with stationary systems continued to decline sharply".

Managing Director Gerd-Dieter Krieger then stated that the sales figures had returned to the previous level. He went on to say: "In 2018, around 1,400 people were working in the areas surveyed. For the current year, companies expect an increase to 1,500 employees."

EDF FOUNDS H_2 SUBSIDIARY HYNAMICS The energy supplier Électricité de France (EDF), which exhibited at Hydrogen + Fuel Cells Europe at the French joint stand, used the industry show to announce the establishment of a new subsidiary. Hynamics will develop a wide range of H_2 solutions for industrial and mobility customers. Among other things, components from the partner company McPhy Energy, in which EDF has been the main shareholder since 2018, are to be used (e.g. at H_2 filling stations of FC commercial vehicles).

Christelle Rouillé, Managing Director of Hynamics explains: "Collaborating with industry and different regions by supporting their decarbonisation projects is a challenge that Hynamics is facing with a solution to produce hydrogen without CO_2 emissions, with multiple use and economic efficiency."

DISCUSSION CONCERNING DIESS In the neighbouring Electric Lounge, an extremely exciting round of discussions took place on the topic of "Battery versus fuel cell". This particularly concerned the announcement by Herbert Diess, Chairman of the Board of Management of Volkswagen AG, that his Group would concentrate entirely on battery-powered e-mobility with immediate effect. His demand to turn away from technological openness provided plenty to talk about, not only here,

but everywhere at the stands and in the corridors of the Energy Hall. However, the initial uncertainty was quickly replaced by the certainty that this statement was primarily a well-considered and well-placed political statement in order to win buyers for VW's upcoming market offensive in 2020.

Fig. 2: Arno A. Evers, founder and long-time organiser of the joint stand for hydrogen and fuel cells

Prof. Henning Kagermann, Chairman of the National Platform on the Future of Mobility (NPM), said it was very clear: "No, you don't have to make up your mind early. I am still in favour of open technology. A location must be open to technology – a company can decide differently." With regard to fuel cells, he noted: "With hydrogen, we are where we were with battery-powered electric mobility six years ago. That'll come, too. "There's no other way with regards to heavy goods, rail and sea transport."

This year's report on development progress in the electromobility sector was much more concise than in previous years, but no less dramatic. Thus Kagermann explained that a "fundamental transformation" lay ahead of us. He pointed out that, contrary to the current trend, CO_2 emissions must be reduced by 40 percent within eleven years and questioned whether this could be achieved with hybridisation, which had previously been favoured by conventional car manufacturers. The NPM boss also made it clear that new suppliers are acting completely differently from conventional car manufacturers: "The one who's disruptive starts with the robot vehicle."

TEST DRIVES WITH FC CARS – NO BEVS

It was somewhat surprising that only a few fuel cell cars from the Clean Energy Partnership as well as a battery-powered minibus and a load wheel for test drives were offered this year on the Ride+Drive course on the open-air site. Battery Electric Vehicle (BEV), which had attracted numerous visitors in recent years, was missing this time. And in the shuttle operation between the halls – as in former times – almost only diesel buses were used.

Dr. Wolfgang Haselrieder, Managing Director of Research and Development at Battery LabFactory Braunschweig, announced that "the hybrid will certainly not be combined with the combustion engine for long, but with the fuel cell". Also Nicolas Iwan reported that a battery manager had explained to him that it made no sense to drive around 800 kilograms of accumulator mass. Instead, he assumes that the plug-in hybrid will soon disappear in China because hardly anyone there loves charging.

A little off the beaten track in Hall 4, WätaS Wärmetauscher Sachsen GmbH presented bipolar plates developed in-house (see H2-international issue July 2018), which are to be mass-produced from October 2019 on the planned production line. These plates are to be used in stacks with an output of 1 and 5 kW.

The next Hannover Messe will take place from 20 to 24 April 2020 – with Indonesia as the partner country. ||

Fig. 3: Exciting discussion about batteries and technology openness in the Electric Lounge

Category: Exhibitions | **Author:** Sven Geitmann

INTERSOLAR INTEGRATES NEW ENERGY SECTORS

5th Electrical energy storage in Munich

A trade fair is usually conceived of as an exhibition of manageable size, where some experts present very special products which are then critically examined by a moderate number of visitors. The Intersolar isn't like that. Instead, it is large, colourful, aimed at both consumers and professionals, and offers a host of interesting products and services from the entire energy industry, as the original solar show has now been expanded to include energy storage, electromobility and charging infrastructure.

Intersolar Europe is – according to the organiser – "the world's leading trade fair for the solar industry and its partners". A few years ago, when the steady growth of the industry gave way to a wave of bankruptcies, Solar Promotion, the organiser of this event, was looking for new topics that could absorb the decline in exhibitor and visitor numbers. They were found both in electric mobility and in energy storage. The team led by Managing Director Markus Elsässer thus initially integrated battery technology as well as power-to-gas and later also electric cars and charging stations.

The Pforzheim-based event company created "The smarter E Europe" from this quad-constellation. Behind this somewhat cumbersome term today are the Intersolar Europe, electrical energy storage Europe (ees), Power2Drive Europe (p2d) and EM-Power. This time, they came together in ten exhibition halls at the Munich Exhibition Centre, with a total of 1,354 exhibitors (2018: 1,172) and 100,000 m² with 50,000 visitors. There were 250 presenting institutions at the ees trade fair alone.

As in the previous year, there was a special area in Hall C2 where mainly the H_2 and FC companies, which were already represented at many energy trade fairs, gathered – right next to the Tesla stand. Companies such as Siqens were also present, in this case at the Bayern-innovativ stand. The Southern German company, which has now grown to 22 employees, presented a commercially available, self-sufficient energy supply unit that has a high-temperature fuel cell but uses methanol instead of hydrogen as an energy storage medium.

The special feature of this EcoCabinet, designed for 500 W continuous output, is that no elemental water occurs in the system, which can be scaled up to 15 kW, so that it can be operated at temperatures down to -20 °C. Company spokes-woman Katrin Fischer sees areas of application in all conceivable off-grid applications, for example for measuring purposes. As she reported, a private customer was already found during the trade fair who wants to use the 24,000 euro system to live energy self-sufficiently despite the existing power connection.

Fig. 1: Lively activity – not only in solar, but also in H_2 companies

Fig. 2: EcoContainer with PEM fuel cell, reformer and methanol canisters

SIGNS POINT TO GROWTH AGAIN For those who have never been to Intersolar before, it almost seemed a bit irritating that things can get so turbulent at a trade fair with a very special theme. Most of the aisles as well as many of the stands were full, and the exhibitors were mostly well occupied. The mood was positive, even relatively relaxed, although not so long ago the solar industry was in a depressive mood.

Photovoltaics is still relatively popular among the population, even though the number of employees has fallen since 2010 from 133,000 at that time to 35,000 today. The valley of tears seems to have passed after a certain market shakeout, so that Carsten Körnig, Managing Director of the German Solar Industry Association (BSW), was pleased to note: "The signs are finally pointing to growth again." On electromobility, he said: "There is no way around their triumphal procession. We are delighted that the new Power2Drive trade fair is taking up this theme. [...] Solar energy, storage and e-mobility will play a decisive role in the energy system of the future – decentralised and intelligently networked in ways previously unimaginable."

POWER-TO-X CONFERENCE ALSO IN 2020N As befits such an industry meeting place, several conferences are organised every year at the International Congress Centrum Munich (ICM). The ees Europe Conference took place on 14

and 15 May 2019, supplemented by three side events on 16 May, each lasting two hours, on the topic of Power-to-X. Jorgo Chatzimarkakis, Secretary General of Hydrogen Europe, once again shone as a moderator and energy world declarer at the session explicitly organised by Hydrogen Europe on the subject of hydrogen. Together with Dr. Tobias Brunner from Hynergy GmbH, who was invited as a speaker, he explained the necessity of storing green electricity in hydrogen to the 45 or so listeners, some of whom come from the solar industry.

In his discourse, Brunner fired a lot of data and facts at the audience in his usual staccato, who in turn seemed to absorb all the information gratefully. The former BMW manager showed his almost overloaded information slides only briefly, which is why many listeners photographed everything using their mobile phones. At the same time, Brunner explained the sometimes complicated backgrounds quickly, but clearly and comprehensibly, proving once again that he is a valuable addition to any podium with his research, but at the same time charming appearance.

Finally, Chatzimarkakis announced that Hydrogen Europe would probably continue to be active in Munich in the future, the next time the solar and energy storage industries would meet again in 2020 from 19 to 22 July. ||

"The dream of endlessly generating energy from the sun and transporting it cheaply as hydrogen via the existing gas networks can become reality. Solar and gas could become a dream couple in the future. The power-to-gas technology is mature, let's get started!"

Jorgo Chatzimarkakis, Hydrogen Europe

Category: Exhibitions | **Author:** Sven Geitmann

ENERGY STORAGE SYSTEMS ARE CRUCIAL

8th Energy Storage Europe in Düsseldorf

The core statements of Messe Düsseldorf were contradictory: On the one hand, Hans Werner Reinhard, the managing director of the trade fair company, explained: "A new industry is emerging here. [...] We want to have the central platform for energy storage in Germany." On the other hand, he stated that the exhibitor figures for 2019 were "rather in a horizontal movement": The rented space remained almost the same as in the previous year, but this time there were ten fewer exhibitors than in 2018, with around 160 institutions exhibiting, and around ten percent fewer visitors came to the exhibition hall. Meanwhile, the industry figures presented in Düsseldorf document that the topic of energy storage is gaining further momentum and has a great deal of development potential.

"Politicians recognise the relevance of storage facilities for decarbonising a secure energy supply system. The further development of power-to-x technologies such as green hydrogen production is an important approach here."

Urban Windelen, BVES Federal Managing Director

Reinhard described the Energy Storage Europe (ESE) as a "still very small plant", although the energy storage event from 12 to 14 March 2019 took place for the eighth time in the Rhine metropolis – the third time in Hall 8. Urban Windelen, Federal Managing Director of the Bundesverband Energiespeicher (BVES), stated that there are currently comparatively few companies in this sector in Germany. BVES, which was co-founded by Messe Düsseldorf in 2013, has a membership of just 220 institutions, many of which were also represented in Düsseldorf.

SCHOOL COMPETITION TO CONTINUE The conference programme this year was much clearer than in previous years. There was neither a StorageDay nor the Power-to-Gas Congress organised by the OTTI College, which went bankrupt in 2016. Since the German Hydrogen and Fuel Cell Association (DWV) was not available as a cooperation partner for the first time this year, there was also no Power2X workshop. However, the EnergyAgency.NRW once again organised the traditional teachers' seminar, as well as the award ceremony for the FuelCellBox student competition, although H-Tec Education is no longer available as a hardware supplier due to its company insolvency.

Parallel to the 8th Energy Storage Europe Conference and 13th International Renewable Energy Storage Conference (IRES), which were held in a separate lecture area, gave various exhibitors and actors an insight into their projects and presented best-practice examples in the freely accessible exhibition forum. Mortimer E. Schulz, for example, who had come to >>

BVES INDUSTRY FIGURES

During the press conference on the first day of the event, BVES presented new market figures. The Energy Storage Association had commissioned Team Consult, a management consulting agency for the energy industry, to conduct a survey among the approximately 200 members of the association as well as interviews with experts in order to ascertain not only sales and employment figures but also the mood within the storage companies. The responses, which were sent back by around a quarter of the members, showed, for example, that the industry recorded an increase of nine percent in the number of employees to 12,100 at the end of 2018.

For Jörg Blaurock of Team Consult, it was particularly remarkable that sales revenues in the area of storage technologies (excluding pumped storage) rose by almost nineteen percent from EUR 2.7 billion in 2017 to EUR 3.2 billion in 2018. However, power-to-gas plants currently contribute only EUR 70 million to total sales (2018: EUR 5 billion, incl. pumped storage).

BVES boss Urban Windelen explained on the occasion of the presentation of the industry figures: "We want to demonstrate that energy storage systems are economically relevant. The industry is growing." At the same time, however, he warned that there was a danger that this "surprisingly small industry" could migrate before it had established itself in Germany. The export share is already comparatively high today, as obvious obstacles in the domestic market stand in the way of further development, which is why growth is increasingly taking place outside the Federal Republic.

When asked about the main market barriers, 86 percent of those surveyed mentioned primarily the regulatory framework conditions that provide for the classification of storage facilities as consumers and producers. According to Blaurock, this was a "great burden for market participants".

Diapers added: "We need a CO_2 price based on the polluter." He also called for storage to be established as the fourth pillar of the energy industry alongside generation, transport and consumption, and for the regulations to be revised accordingly.

Düsseldorf from Frankfurt a. M. in a fuel cell car, reported on his practical experience from numerous trips with an H_2 car. As part of the "Energy Tours" he himself organised, the independent energy and financial consultant has already travelled thousands of kilometres across Europe, providing information both online and at industry events. The Vienna-based hydrogen fan and photographer Lars Regge undertook this trip to the ESE in a Toyota Mirai to test different H_2 filling stations on the way.

ESE HEAD CHANGES On the very first day of the event, the exhibition management announced that a change of personnel would take place in Düsseldorf during this year: Since mid-2019, the new head of Energy Storage Europe has been Dr. Andreas Moerke, the former Managing Director of the Tokyo-based Japanese subsidiary Messe Düsseldorf Japan Ltd. His predecessor Bastian Mingers, who has been in charge of the energy storage trade fair since March 2015, will in future be responsible for the ProWein exhibition.

On the third day of the conference, Prof. Andreas Pinkwart, Economics and Energy Minister of North Rhine-Westphalia, also appeared at the ESE and explained: "Stores are crucial to the success of the energy turnaround. They make an important contribution to the flexibilization and integration of growing proportions of renewable energies and contribute to security of supply" ||

Category: Exhibitions | **Author:** Sven Geitmann

REFINING RENEWABLE ENERGIES

New Energy Days in Husum

"Let's refine renewable energies – we as an industry would be ready." With these words Mai-Inken Knackfuß, Managing Director of watt_2.0, opened the New Energy Days, which took place from 21 to 24 March 2019 in Husum. The H2.0 conference was the prelude to this event. More than 120 participants came to the NordseeCongressCentrum to inform themselves about a green hydrogen economy in the regions. This was complemented by the public trade fair New Energy Home and the trade fair New Energy Expert, which brought both consumers and experts up to date in the energy sector with a total of around 90 exhibitors.

Jan Philipp Albrecht, the Minister for Energy Turnaround, Agriculture, Environment, Nature and Digitisation in Schleswig-Holstein, came to the exhibition grounds in a hydrogen bus. In his opening speech, he reported that the percentage share of renewable energies in gross electricity consumption was 36 percent nationwide, compared with 156 percent in his state. Furthermore, the Statistics Office North had determined that in Schleswig-Holstein in 2016 around 19,000 people were employed in the field of renewable energies. At the same time, he made it clear: "Nobody wants to have wind turbines for them just to stand still." For this reason, Albrecht said, the country would work to abolish discrimination and make use of existing potential.

The program of the H2.0 conference, which had been compiled by the industry association watt_2.0, subsequently offered a varied sequence of numerous exciting contributions,

which were accompanied in the usual professional and entertaining way by the longstanding expert moderator Ulrich Walter. The progressive atmosphere that prevailed during the event is particularly noteworthy. For example, the conference topics often gave a round of applause when striking sentences fell and speakers criticized the political framework which is still missing. Even in the well-attended seminars, it was noticeable that the mostly expert listeners were almost greedy for new information. All in all, it turned out once again that the North Frisians are extremely open to renewable energies and do things without much feather reading. To do, not just to snap about it, that was the motto here.

A highlight was the presentation of a total of eight German hydrogen regions, which presented their activities as well as their visions of the future in the H_2 and FC sector within the framework of best-practice examples. The unanimous opinion of the regional representatives from Hesse, Lower Saxony, North Rhine-Westphalia, Hamburg, Saxony and Schleswig-Holstein in the ensuing debate was that there was no competition between them, but that all were striving together in the same direction.

The New Energy Expert trade fair took place parallel to the congress. A lively exchange between numerous experts from the energy industry took place in the congress area of the exhibition together with the forum. On the second day of the event, the New Energy Home followed, where numerous interested laymen, users and schoolchildren also cavorted in the adjacent exhibition hall and had many conversations.

HIGH LOCAL ACCEPTANCE Ove Petersen, Managing Director of GP Joule and Chairman of watt_2.0, told HZwei right away about the compromise reached by the Coal Commission (see H2-international April 2019) that he could live with the time axis specified therein. It was important to him, however, that "a direction had finally been set". However, he still lacks a further expansion of renewable energy capacities.

Petersen, who manages numerous other companies in addition to GP Joule, emphasized both in Husum and in Hanover: "High added value in the region promotes acceptance." He referred to the joint project eFarm (see H2-international issue Jan. 2019) and the activities of wind energy pioneer Reinhard Christiansen (see HZwei issue April 2019). He answered the question "Why does it work there today?" as follows:

Solar and wind power is currently traded at 3 to 5 cents per kilowatt hour. For grey hydrogen, which is partly produced from natural gas by steam reforming, 25 cents per kWh are paid at H_2 filling stations. This means that a difference of 20 cents per kWh is available, which can be invested in electrolysis, compression, transport and distribution. GP Joule hardly pays any levies as part of its pilot project, as the total of five planned electrolysers are located directly at wind farms and the public power grid is therefore not used.

The trained farmer also reported a high local affinity for H_2: "Not so many have yet jumped on classic battery-operated mobility, but many want to invest in hydrogen when appropriate filling stations are set up." At the same time, however, he noted that there was currently a lack of availability of H_2 vehicles. ||

Fig. 2: "This is how we imagine the future," explained GP Joule CEO O. Petersen to Energy Turnaround Minister J. P. Albrecht (centre); right: Exhibition boss A. Petersen

EES

Peter Helms from Erneuerbare Energien & Speicher e. V. reported during the conference about an event of the Kiel CDU local association, which had invited to the topic "Hydrogen". Instead of the twenty participants who would otherwise appear at such meet_ings, around 230 guests attended the meeting. There was also openly spoken about what some had already suspected before: "Most politicians have no idea about hydrogen."

"It is not comprehensible why one needs a complete BImSchG permit (Federal Immission Control Act) from the first gram of hydrogen produced, but does not need a 5 MW combined heat and power unit."

André Steinau, GP Joule

Fig. 1: Current overview of previous PtX plants in Europe

Category: Energy storage | **Author:** Matthias Altmann

STATUS AND PERSPECTIVE OF PTX

LBST analyses development in Germany

Evaluations of the Power-to-X database of Ludwig-Bölkow-Systemtechnik (LBST) [1] show that the technology is increasingly mature and finds commercial applications. The new version of the Renewable Energies Directive will set out the main framework conditions for this in detail over the next two years. More than 50 PtX plants with a total electrical output of over 55 MW are in operation or in planning throughout Germany. Two German consortia have already announced further major projects in the triple-digit MW range, and projects of this magnitude are also being considered in neighbouring countries. The generation of liquid fuels from renewable electricity is slowly picking up speed.

Already today more than one third of the electricity generated in Germany comes from renewable energies, more than half of it from wind and photovoltaics. The further increase in fluctuating power generation leads to an increasing demand for flexibility in the electricity supply system, an increased use of electricity storage facilities and increasing sector coupling, in particular linked to the supply of transport with renewable fuels. In order to support and accompany this, adapted framework conditions are important.

RENEWABLE ENERGY DIRECTIVE (RED II) AND CERTIFICATION OF GREEN HYDROGEN In December 2018, the EU adopted the Renewable Energy Directive (RED II), which is to be transposed into national law by mid-2021. Article 25 sets an objective of 14 percent renewable energies in transport by 2030, to which hydrogen from renewable electricity and fuels synthesised from it can contribute in addition to biofuels. The use of renewable hydrogen in refineries for the production of conventional fuels [2] can now also be taken into account. However, the criteria according to which hydrogen is recognised as one hundred percent renewable are only partially defined in Article 27.

In order to create additional renewable capacity for power generation in the transport sector, the European Commission is developing a framework for additionality and its calculation in the transport sector. Furthermore, the European Commission will adopt a delegated legal act by the end of 2021 which will specify the detailed conditions under which green hydrogen can be counted as 100% renewable.

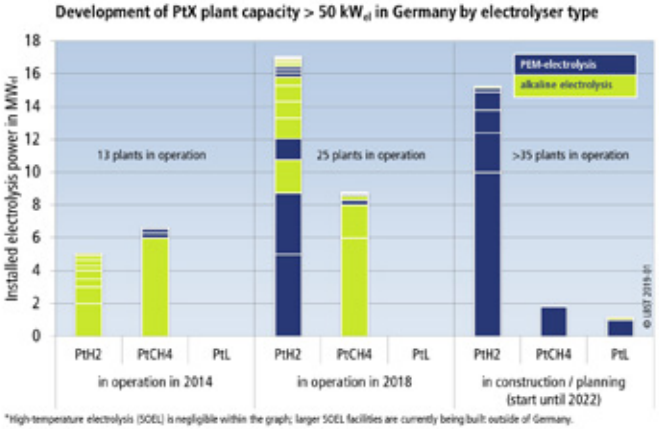
As part of the CertifHy initiative (see H2-international Jan. 2018), a European certification system for green hydrogen has also been established in recent years. This is to be further developed in such a way that the RED II criteria are covered and thus a system is available which enables fuel suppliers to market green hydrogen and fuels produced from it and to have these credited towards the target achievement of 14 percent renewable fuels by 2030.

POWER-TO-X SYSTEMS Power-to-X technology converts electricity in an electrolyser into hydrogen (PtH_2), a gaseous energy source. Based on this, methane ($PtCH_4$) can be generated in a further process step together with carbon dioxide (CO_2) . Alternatively, liquid fuels (power-to-liquids – PtL) can also be produced from H_2 and CO_2 using suitable synthesis processes. When using electricity and CO_2 from renewable sources, the resulting chemical energy sources are practically CO_2 neutral. Possible pollutant emissions depend in particular on PtX use (fuel cell, combustion engine, and gas turbine). The technology thus offers a promising option for longer-term energy storage and makes it possible to interconnect the electricity, gas and transport sectors in sector coupling.

Common to all Power-to-X concepts is the first step of hydrogen generation from (renewable) electricity via the electrolysis of water. In principle, many CO_2 sources are suitable for use in PtX facilities. It is produced during biogenic conversion processes such as ethanol production or the upgrading of biogas (gas mixture of methane and CO_2) to biomethane or is produced during the combustion of biogenic or fossil raw materials. Alternatively, carbon dioxide can be extracted from the air, which, however, requires more energy than the CO_2 extraction methods mentioned above.

PTX IN GERMANY Ludwig-Bölkow-Systemtechnik GmbH has been following the development of corresponding projects since 2011 and maintains a database in which more than 180 worldwide activities are now recorded. Whereas initially only smaller plants with electrolysis capacities in the kilowatt (kW) range were used for research purposes, today projects with electrical capacities of several megawatts (MW) are implemented. Even larger plants are being planned. In Germany, more than 50 projects (see Fig. 1) are currently underway in which PtX technologies are being researched, further developed and used in regular operation. 35 plants with over 50 kW installed electrolysis capacity, which are either in operation or in planning, were analysed by the LBST (see Fig. 2).

The number of PtX projects has risen sharply. By 2022, 35 plants should be in operation in Germany alone. The total installed electrical capacity of the PtX plants is currently 26 MW and has more than doubled since 2014. The majority of the projects use so-called polymer electrolyte membrane electrolysers (PEM), which have certain advantages over the established alkaline electrolysis technology in dynamic operation. The projects planned in Germany rely almost exclusively on PEM electrolysis.



Remarkable for the German projects is the growing focus on the generation and use of hydrogen without further processing it into other energy sources. This is due to the increase in corresponding applications of green hydrogen, for example as a raw material in refineries or as a fuel in transport.

To date, PtX projects have been developed in Germany in particular. But other European countries have also recognised the opportunities offered by PtX and are developing a great dynamic towards commercialisation. Both the European "Hydrogen Valleys" tendered by the FCH JU and the "Real Laboratories" tendered by the Federal Government form the next step to supporting the development of the framework conditions entrepreneurially and to develop the commercial opportunities.

PTL PROJECTS Projects with high-temperature electrolysers, which are primarily discussed in connection with power-to-liquids (PtL) processes, are currently planned particularly outside Germany, but with German participation. High-temperature electrolysis has efficiency advantages over PEM or alkaline electrolysis when high-temperature waste heat is available. This is particularly the case when subsequent synthesis processes are used for the generation of methane or liquid fuels. This waste heat can also be used to extract CO_2 from the air.

In particular, liquid renewable fuels are of great interest in transport applications that require high energy density and have to store a large amount of energy on board, such as air traffic (see H2-international Jan. 2017 and [3]) or international ocean shipping. In road freight transport, competition from PtL fuels with hydrogen fuel cell propulsion can be expected in the future.

So far, there are only very few concrete PtL projects in Germany, so that no significant PtL projects are to be developed before 2021. In mid-2017, Sunfire generated three tons of synthetic crude oil ("Blue Crude") in continuous operation of the demonstration plant in Dresden over a period of more than 1,500 hours. The new generation of high-temperature electrolysis has now been put into operation as part of the Hypos project. Based on the Sunfire PtL process, the first commercial 20 MW plant is to go into operation in the Norwegian industrial park Heroya from 2020 with a production of 8,000 tons of synthetic crude oil per year. A further pilot plant for synthetic diesel with a capacity of around 400,000 litres per year is planned in Laufenburg, near the border in the Swiss canton of Aargau. ||

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Category: Energy storage | **Author:** Joseph DiRenzo

THE WASH2EMDEN PROJECT

A Hydrogen Project in the German port of Emden

The Port of Emden located close to the German / Dutch border, recently announced plans to study the technical and economic feasibility of converting excess wind energy into hydrogen.

KICK-OFF PLANS ANNOUNCED Over the next several years, the International Maritime Organization (IMO) will continue to place pressure on the marine industry to reduce greenhouse gas emissions through standards laid out in Annex VI of the Marine Pollution regulations. Based on these additional demands, ports throughout the world are starting to look for creative ways of curtailing emissions. Ports in Northern Germany, including the port of Emden nestled along the Wadden Sea, find themselves in a unique position. These ports are located in close proximity to sources of clean renewable energy from wind turbines, but unable to fully utilize these sources of energy due to network bottlenecks in the electrical power grid. To address this disparity, 5 major maritime and energy partners in the port of Emden launched the WASh2Emden project. The goal of this project is to study innovative ways to better utilize renewable energy in port operations through power-to-gas conversion technology. According to a project summary titled *Innovative and Environmentally friendly Hydrogen Applications in Seaport Emden*, the aim of the project is to conduct a feasibility study over the next 18 months to determine if it is technically and economically feasible to convert excess wind energy to hydrogen, to support port operations in Emden.

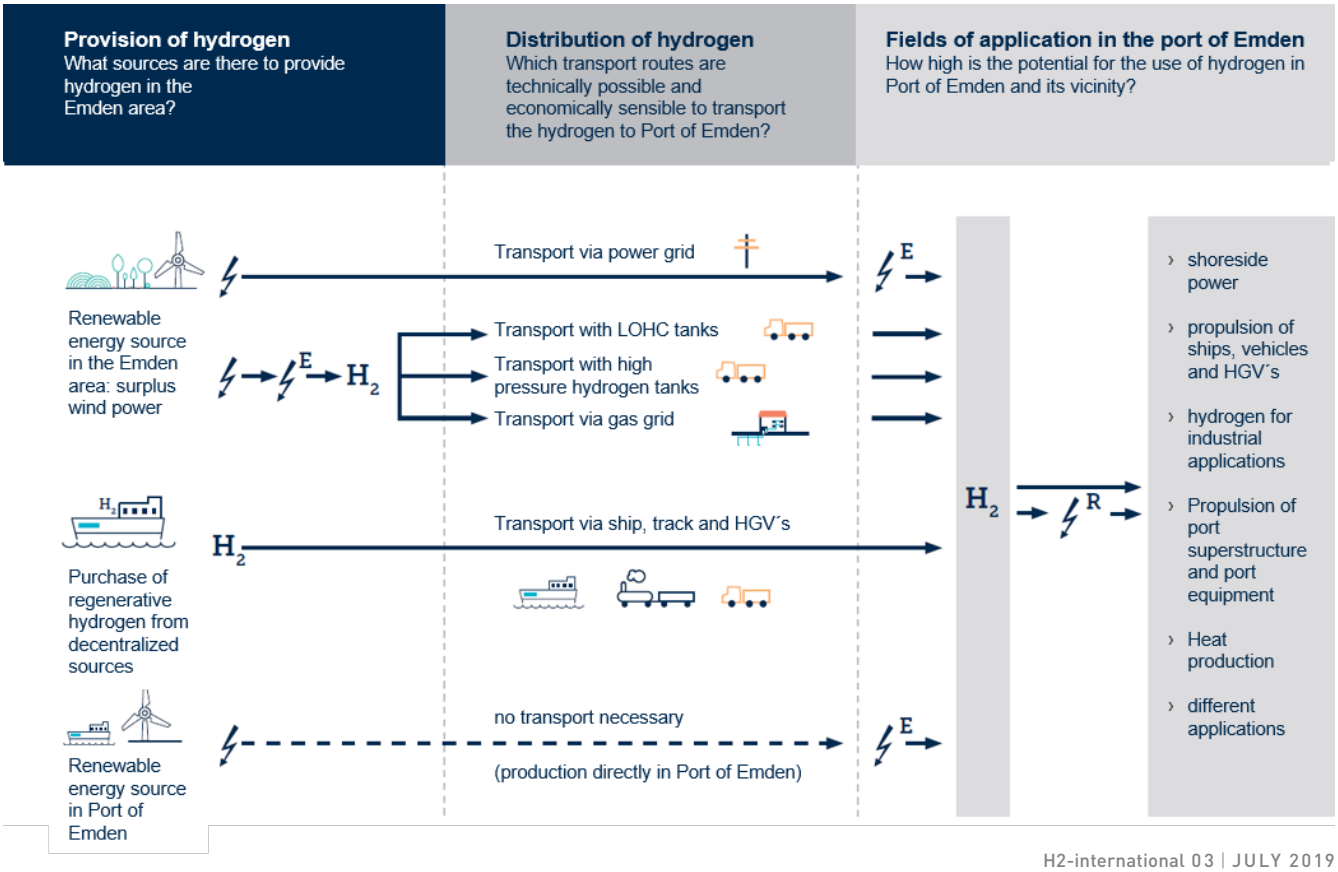
THE PORT OF EMDEN As the third largest North German sea port, the port of Emden consists of two different industrial complexes, including the outer port with direct access to the North Sea, and the inner port which provides service to inland German trade. Niedersachen Ports (NPort), which owns and operates the port in Emden as well as a number of other maritime complexes in the coastal region of Lower Saxony, is the lead organizer for the WASh2Emden project. According to a summary provided by NPort, Emden is "one of Europe's most significant RoRo ports" and serves as the base port for the Volkswagen Group. "RoRo" is an acronym for a roll-on/roll-off vessel which is designed to carry wheeled cargo such as cars and trucks. In addition to bulk goods like timber and liquid chalk, the port of Emden also serves as a major

transportation hub for offshore wind turbine components. Like most major ports across the world, a number of energy intensive operations occur within the port complex, such as cargo handling, shore power delivery for moored vessels, and fuel bunkering operations. To provide context, the port of Emden boasts an impressive maximum cargo handling capacity of up to 6.2 million metric tons annually. Unlike other major ports which depend on utility power from nearby cities, Niedersachsen Ports owns and operates its own electric utility company within the Emden Port complex, allowing it unique autonomy in exploring innovative renewable energy solutions.

To accomplish the WASh2Emden feasibility study, Niedersachen Ports teamed up with the Tyczka Group, DBI Gas-und Umelttechnik, abh Ingenieur-Technick, and MARIKO. The group is also receiving technical support from EPAS Ems Ports Agency & Stevedoring Bet. GmbH & Co. KG and the University of Applied Sciences Emden / Leer. According to a press release from the Tyczka Group, the project specifically deals with "answering questions of how hydrogen production can be managed using various sources such as grid electricity and wind energy". Additional funding for the project comes from grants from the German Federal Ministry of Transport and Digital Infrastructure for Innovative Port Technologies.

HYDROGEN AND WIND POWER – A GOOD PARTNERSHIP On a macro-scale, one of the often-quoted critiques of wind turbine technology is the periodic disparity between production and demand. During periods of low wind energy production, the remaining demand placed on an energy grid needs to be supplemented with an additional source of energy to address overall demand placed on the electrical grid. On a localized scale, the coordinators of the WASh2Emden are quick to point out the disparity between the excess wind energy available in the coastal region and the required energy for port operations. For example, NPort alone consumes around 5,000,000 kWh of energy per year along and produces approximately 1,600 tons of CO_2 annually.

With the increasing improvement in efficiency of reversible power-to-gas systems, hydrogen technology is being seriously considered for a number of wind turbine projects throughout Germany. To satisfy the tremendous amount of power to operate a port, a number of different hydrogen technologies are being considered for the project, including high efficiency fuel cells and internal combustion engines which would be located within the port complex. The WASh2Emden project is also considering external sources of clean energy such as better optimization of grid power and the purchase of "regenerative hydrogen from decentralized sources". If found to be economically and technically feasible, the WASh-2Emden may not only satisfy emissions requirements from the IMO but also be a groundbreaking first step in supporting Germany's national goal of becoming a "zero emission society". ||



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

GREAT DEMAND FOR HYSTARTER

A lot of movement at regional level

The real laboratories are now to give fresh impetus to new energy technologies. Greater room for manoeuvre in regional projects should enable local business concepts to be tested first and then implemented on a larger scale nationwide. There's a lot of interest in it: By the beginning of April 2019, project outlines could be submitted and, as has been confirmed by various parties, the call was oversubscribed several times.

No wonder – all the companies that have been researching and developing future technologies for years now want to benefit from the start-up financing and the regulatory freedoms, even if both are limited in time and space.

REAL LABORATORIES OF THE ENERGY TURNAROUND The Federal Ministry of Economics and Energy (BMWi) initiated the introduction of real laboratories in order to develop a suitable legal framework with their help without sacrificing sensible and necessary standards. Thematically, this is particularly concerned with the areas of "sector coupling and hydrogen technologies", "large-scale energy storage in the electricity sector" and "energy-optimised neighbourhoods", which will receive annual funding of up to EUR 100 million until 2022.

> "In selected real laboratories, we support companies and researchers in Germany in unfolding their innovative strength and contributing to the implementation of the energy turnaround in the regions."
>
> *Federal Minister of Economics Peter Altmaier*

After initial scepticism, voices are now increasing, which are quite positive towards real laboratories. It is important that funding is provided and that it can be used both for research and development and for market preparation or access. The R&D activities have never been completed anyway, according to the unanimous opinion. However, in the laboratory stage, H_2 and FC technology is no longer used, but is much more advanced in some areas.

"As of April 5, 2019, 90 project outlines had been submitted, which are currently being evaluated from a technical point of view," the BMWi stated in response to a request from HZwei. The commitments for the four selected sites are expected to be sent in mid-July. A second invitation to tender could follow in 2020, possibly accompanied by a doubling of subsidies. Officially, it was said: "How the budget will further develop in the future will be decided by Parliament in the framework of the budget establishment procedure."

In concrete terms, projects such as the Sperenberg multi-energy power plant (MEKS, see H2-international Oct. 2016) could benefit from such regional funding. Brandenburg's Economics Minister Prof. Jörg Steinbach (see interview in H2-international April 2019) recently stated that his ministry was currently investigating whether this project would be suitable as a real laboratory. He went on to say: "Despite the unclear situation regarding wind turbines, it is planned to convene an industrial consortium in the near future." The MEKS project, which was to create a new power plant with a combination of wind, solar and hydrogen, was put on ice in 2017, as the targeted area lies outside wind suitability areas.

Fig. 1: Stephan Weil (2. f. l.) demanded during the Hannover Messe: "Hydrogen technology from Lower Saxony for Lower Saxony and the rest of the world – all over the world."

Northern Germany is also applying with NEW 4.0 as a real laboratory. The project coordinator Prof. Werner Beba, who also heads the Competence Center for Renewable Energies and Energy Efficiency at HAW Hamburg, explained to the newspaper Welt: "At the Wedel site, it would also be possible to build a powerful combined heat and power plant, powered by wind power from Schleswig-Holstein and hydrogen, in addition to the replacement plants for the coal-fired power plant planned so far by the environmental authorities in Hamburg

NORTH GERMAN H_2 ALLIANCE As already reported several times in HZwei, Northern Germany in particular is currently advancing wind-hydrogen technology anyway (see H2-international Jan. & April 2019). A further example of this is the meeting of the heads of government of the federal states of Bremen, Hamburg, Mecklenburg-Vorpommern, Lower Saxony and Schleswig-Holstein at the beginning of May 2019 in Hamburg City Hall. There they presented a joint strategy paper which states: "Northern Germany should be established and consolidated as the leading region in Germany with a complete added value chain of a green hydrogen economy."

The rather sparsely populated North, which has so far played only a subordinate role in industrial policy, is predestined as a pioneer of a new, clean energy storage technology due to its high share of green electricity in the electricity supply. For this reason, the Minister Presidents now want to make an even stronger case for the necessary legislative changes at federal level.

Heinz-Uwe Lewe from the Ministry of Economics, Innovation, Digitisation and Energy of North Rhine-Westphalia reported in March 2019 during the New Energy Days in Husum (see p. 14) that his federal state had also

launched its own competition in autumn 2018. Under the motto "Model Region H_2 Mobility", a total of ten initiatives applied for a leading position in the field of hydrogen with their actors. A jury selected three of them at the beginning of this year: Firstly Düsseldorf/Wuppertal/Rhein district Neuss, secondly Cologne with Brühl, Hürth and Wesseling as well as the Rheinisch-Bergischen and Rhein-Sieg districts and thirdly the district Steinfurt. A winner is to be found by the end of 2019.

PROJECT FUNDING IN THE DISTRICTS At the same time, the National Organisation for Hydrogen and Fuel Cell Technology (NOW) recently invited tenders for the two-year HyLands funding project with three sub-programmes (see H2-international Jan. 2019): HyStarter, HyExperts and HyPerformer. This is about supporting local authorities on their way to the hydrogen economy. The objectives are to create more "visibility and public acceptance of hydrogen and fuel cell technology" and to support "actors with leverage in this context".

Especially for the newcomer variant, many more interested parties than originally expected registered by the submission deadline at the end of February 2019: 138 local authorities (most of them from Bavaria), some of which were still completely inexperienced in this field, would have liked to participate. For example, the Brandenburg districts of Oberhavel, Ostprignitz-Ruppin and Prignitz. So far there have only been isolated demonstration projects here (e.g. the PtG plant in Falkenhagen). Based on this, the three district administrators intended to facilitate entry into new field of business. For example, an initial mobility analysis and a potential study have now been commissioned in Ostprignitz-Ruppin, and work is underway on a nationwide catalogue of measures. Nicola Krettek of Regionalentwicklungsgesellschaft Nordwestbrandenburg mbH explained this to HZwei: "In our administrative district a larger interest had crystallised from the agriculture. The starting points here were both the producer and the user perspective: (Smaller) electrolysers at wind turbines (instead of repowering, if necessary), synthetic methane, fuel for agricultural machinery." >>

"The development of a green hydrogen economy not only has an important ecological dimension (energy turnaround, climate protection, air pollution control, noise reduction), but also an economic dimension (addead value, location security, corporate profits, tax revenues) and a social dimension (jobs)."
Strategy paper of the North German federal states

"The regulation must now make it possible to produce hydrogen from surplus electricity without us having to pay double and triple EEG levies and grid fees for this use of surplus electricity, because the economic viability of such concepts and thus also the driving force behind the innovation behind them will be lost
Peter Tschentscher, First Mayor of Hamburg

"It is currently the case that the production and transmission of hydrogen is subject to the EEG levy twice, and this prevents meaningful further ecological and economic use. We believe that the federal government would be well advised to do more at this point."
Stephan Weil, Minister President of Lower Saxony

Originally, however, only six local authorities were to receive a permit. Due to the high demand, the number has now been increased to nine according to NOW. These local authorities receive organisational and technical advice as well as support in drawing up initial concept ideas. During the selection process, care is taken to ensure that different topics are covered: Coastal region (wind energy), lignite mining area (structural change), automotive industry (jobs), metropolitan region (mobility), medium-sized region (willingness to invest) and border region (European networking).

For HyExperts and HyPerformer, the competitive phase did not start until spring 2019.

EU SUPPORTS HYDROGEN VALLEYNN The Fuel Cells and Hydrogen Joint Undertaking (FCH JU), too, has been stepping up its activities in the regions for some time now. 81 million is available under the Hydrogen Valley programme, for which the submission deadline was April 2019. The focus here is on the funding of sector coupling projects in which partners from different EU member states should be involved as far as possible on a transnational basis.

Great Britain receives the most support, but since 2016 nine regions (Baden-Württemberg, Bremerhaven, Heide, Rhineland – HyCologne, East Germany – Hypos, Steinfurt district, North Rhine-Westphalia, Recklinghausen, Saxony-Anhalt) and the city of Hamburg have also been supported in a wide variety of application areas in Germany. Altogether there are now 91 regions and 22 cities in which 76 H_2 and FC companies are active. More than half of the funds invested (1.8 billion euros) go to Germany. ||

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

A HYDROGEN VILLAGE IN BITTERFELD

HYPOS project H_2 network started

Hydrogen is considered by many to be the energy source of the future. It can be generated from renewable energies and utilised in different sectors for material and energy production, which is referred to as sector coupling. However, the distribution of hydrogen in particular is the subject of numerous discussions. So far, the industry has focused on the natural gas grid. Currently, an admixture of 2 or 5, sometimes 10 % by volume is permitted by law. In April 2019, the DVGW announced that it was working towards a regulation for 20% by volume. At least in certain network sections, even higher concentrations can be expected in the medium term. But what about a network with 100 % by volume hydrogen? What must such a network be like? Which system technology has to be replaced or adapted? And how can such high concentrations be distributed safely and efficiently to the end user? These questions will be investigated in the HYPOS project H2 Netz.

In order to find answers to these questions, the regional gas distribution network operator Mitnetz Gas officially put its so-called hydrogen village into operation in the Bitterfeld-Wolfen Chemical Park on 10 May 2019. This "village" is located on an approximately 12,000 square meter site in the middle of Germany's oldest chemical park. By the end of 2021, the project partners hope to have gained comprehensive insights into the transport of 100 % by volume hydrogen.

Fig. 1: System components of the H_2 infrastructure: above-ground pipe bridge and gas pressure regulator station [Source: Michael Setzpfandt]

The hydrogen village initially consists of a gas pressure regulating and measuring system. All associated equipment ensures corresponding control behaviour and high measurement accuracy in order to achieve usable results. In addition, an approximately 1,200 metre long pipeline network was laid on the site. Since this is to be an exemplary distribution network, the laying of expensive and costly steel piping was dispensed with. Instead, high-density metal-plastic composite pipes (MKV, PE-Xa) and high-tension crack-resistant polyethylene pipes (PE 100-RC) from the company Rehau are used.

The installation was carried out using the drilling mud process and by trench-laying. In addition, a 70 metre long pipe bridge was erected above ground. The various distribution network sections have pressure stages DP 25, DP 16 and DP 1. In order to guarantee the necessary safety, a special micro-odorization system was installed in addition to the line technology.

In addition to the network, there is a corresponding infrastructure on the site for testing subordinate systems and users. The DBI tests standard gas flow monitors and gas meters in a test bench for their suitability for 100 % hydrogen by volume. The knowledge gained in this way will also flow into other HYPOS projects such as H2-PIMS.

In addition, a specially developed combined heat and power unit will be installed and tested at the site as a hydrogen end user. This is a plant developed in the HYPOS project H2-Home, consisting of a fuel cell (5 kW_{el}, 14 kW_{therm}) based on PEM and an additional heat generator (40 kW_{therm}). The H_2 network also has additional connection options, so that other users can also integrate their end devices into the network and test them for practical suitability.

OPERATIONS AND RESEARCH For the so-called cold commissioning in February 2019, the hydrogen network was first flushed with nitrogen and tested for leaks. Since April 2019, 100% pure hydrogen has been flowing through the entire network. However, the volume flow rate of 3 to 12 m³/h can be classified as very low. The company Linde with its supra-regional hydrogen steel pipeline in the immediate vicinity of the gas pressure regulator station will initially serve as the supplier for the hydrogen.

The heterogeneous concept of different laying methods and piping materials should enable the project consortium to quantify different environmental parameters and their influence. The laying of the pipes by drilling fluid alone causes special stress and can therefore also affect the operational suitability. Part of the research on the H_2 network is therefore also to prove the suitability of the laying methods for these materials under the given conditions.

In addition, numerous devices were attached to the pipes to measure permeation processes. The underground pipes are accessible via shaft openings. The above-ground pipe bridge, on the other hand, is intended to provide information on how UV radiation and seasonal temperature fluctuations affect the integrity of the pipeline.

For the odorization, an in-house system had to be developed first. Conventional systems are not suitable due to the low volume flows in the H_2 network. The in-house development now allows smallest dosages in the most constant injection possible (< 3 µl/min). Different substances are to be qualified as odorants for hydrogen, which can contain sulphur or be sulphur-free. Here, too, the low volume flow in the overall system must be taken into account in order to ensure constant distribution in the overall network.

One of the most important topics in the construction of such a decentralised hydrogen distribution network structure is safety. TÜV Süd has therefore been closely integrated into the H_2 network project right from the start. For example, a comprehensive catalogue of documents on explosion-protection and risk assessment was drawn up in the run-up to construction.

Experience with the use of hydrogen is still very limited, so that a constantly high safety level is necessary. With the aid of measurement and control technology, the entire plant is permanently monitored for pressure and temperature fluctuations. A possible gas leak would be detected at any time by a gas warning system. The entire system is circulating and does not have a separate outlet.

Even before the end of the research phase, the first results for the project can already be mentioned. The notification to the authorities for the construction of the H_2 network was made in accordance with a §-5 process under the ordinance on High Pressure Gas Pipelines (GasHDrLtgV) and was guaranteed without further conditions. The process is therefore similar to that for natural gas projects. The suitability of existing facilities must also be emphasised. With the exception of in-house developments (piping, odorization), only commercially available equipment and materials were used, so that no special designs were necessary. The use of plastic pipes is already estimated by the project consortium to have a cost reduction potential of thirty percent.

CONCLUSION The H_2-network project is part of the hydrogen initiative HYPOS. By the end of 2021, the suitability of special plastic piping and commercially available gas network elements for 100 % by volume hydrogen is to be investigated.

Fig. 2: Dr. Reiner Haseloff, Minister President of Saxony-Anhalt, Dr. Joachim Wicke, HYPOS e. V., Dr. Adolf Schweer, Mitnetz Gas, Prof. Dr. Hartmut Krause, DBI (l. to r.) [Source: Michael Setzpfandt]

The objective of HYPOS is the long-term construction of an integrated hydrogen economy in the Central German region. The newly opened H_2 network provides application-oriented results to enable favourable distribution network structures. These offer the possibility of transporting hydrogen cheaply and efficiently to small and decentralised end users in order to be used for the provision of energy. ||

HYPOS E. V.

The HYPOS Hydrogen Power Storage & Solutions East Germany e. V. is an open network for all interested parties in the hydrogen economy. With more than 100 members, HYPOS combines the potential of innovative SMEs with the expertise of industrial groups, universities and research institutions to create a common cross-sector green hydrogen economy.

HYPOS PROJECTS

Currently, almost thirty different consortia are researching green hydrogen in projects along the added value chain. In the topical areas of chemical conversion, storage and transport, utilisation and distribution, as well as strategy and safety, these projects objectives to achieve further improvements in terms of cost-effectiveness, acceptance, safety and integration into the supply network.

H_2 NETWORK PROJECT

The project partners are Mitteldeutsche Netzgesellschaft Gas mbH, DBI Gas- und Umwelttechnik GmbH, Rehau Unlimited Polymer Solutions AG + Co, TÜV Süd Industrie Service GmbH and the Leipzig University of Economics, Technology and Culture HTWK. The project budget is around EUR 3.8 million. The funding comes from the 2020 HYPOS project financed by the Federal Ministry of Education and Research (BMBF).

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Category: Energy Storage | **Authors:** Henning Kraudzun, Dr. Angela Kruth, Jens Wartman, Michael Steffen

GREEN AMMONIA IN THE TANK

Campfire – new energy storage systems and ship drives

The research alliance Campfire wants to decarbonize the maritime sector with the production of green ammonia and its application in emission-free drives. With an innovative process, the carbon-free energy source is to be produced from air, water and locally generated renewable energies and used in the future as marine fuel, primarily over medium distances. Routes on the Baltic Sea are ideal for this. In this respect, it was obvious that the alliance of a total of 31 partners from research, industry and policy advice had come together in the coastal region.

The cheers were great when Campfire was selected last April as one of 20 innovation initiatives by the Federal Ministry of Education and Research for the "WIR! – Change through Innovation in the Region". Finally, the practical implementation of the individual projects will receive up to EUR 15 million over the next five years. Good prerequisites for far-reaching innovations. Government investment could pay off in the future: These cutting-edge research projects involve no less than the development of new fields of technology and solutions for sustainable structural change in eastern Germany.

Campfire has presented a clear concept for the North-East model region, which extends from Rostock to Szczecin in Poland. The focus is on the decentralised storage of renewable energies and their utilisation in the transport sector. The production of green ammonia plays a key role here: NH_3 is the perfect hydrogen storage medium and, due to its high hydrogen content of 108 g H_2/l, has a volumetric energy density comparable to methanol [1]. It is also easy to liquefy and can be safely stored, transported and handled according to experience in the chemical industry dating back more than a hundred years. Ammonia is the future – as a cost-effective fuel for emission-free shipping, as a raw material for sustainable fertilizers and for use in stationary energy supply systems.

So far, this recyclable material has only been produced industrially using the Haber-Bosch process. But the major disadvantage of this reaction process, which chemist Fritz Haber and entrepreneur Carl Bosch brought to market as early as 1910, is the enormous use of energy and fossil fuels. Since the bond between the two nitrogen atoms is extremely stable, it has to be broken under high pressure and high temperatures of up to 550 °C. In addition, most of the hydrogen required for synthesis is obtained from the methane contained in natural gas. Five percent of the natural gas produced worldwide and two percent of energy production is consumed to produce ammonia.

SEARCH FOR ALTERNATIVES TO AMMONIA SYNTHESIS At the same time, global demand for ammonia is growing. The largest factor for this development is the increase in global food production: More than 80 percent of the 150 million tonnes of ammonia generated annually are used in fertilizer production. In view of the poor environmental balance of conventional ammonia synthesis, scientists in Asia, North America and Europe have long been researching energy-saving and clean alternatives. For example, new catalysts for the Haber-Bosch process are being tested, which has so far worked well on a laboratory scale. For industrial applications, however, many technical questions still remain unanswered.

In this context, Campfire relies on several research strands – the development of electro-ceramic membranes for energy technology, new technologies for the synthesis of green ammonia, systems for H_2 generation from ammonia and for the direct use of ammonia as a fuel.

By integrating innovative components with high efficiency and low cost, ammonia synthesis would undergo a major technical update. In detail, that means: Novel oxide ion, proton and mixed conducting ceramic membranes optimise solid-state electrolysis processes that synthesize hydrogen from water vapour and nitrogen from air to ammonia in one or more process steps (Solid Oxide Electrolysis – SOEC, Oxygen Separation Membrane – OSM and Solid State Ammonia Synthesis – SSAS). Wind turbines or solar fields supply the necessary energy. In this way, ammonia can be produced on a small scale and decentralised from air, water and renewable energies – which represents a decarbonised alternative to the Haber-Bosch process and enables the storage of fluctuating renewable energy.

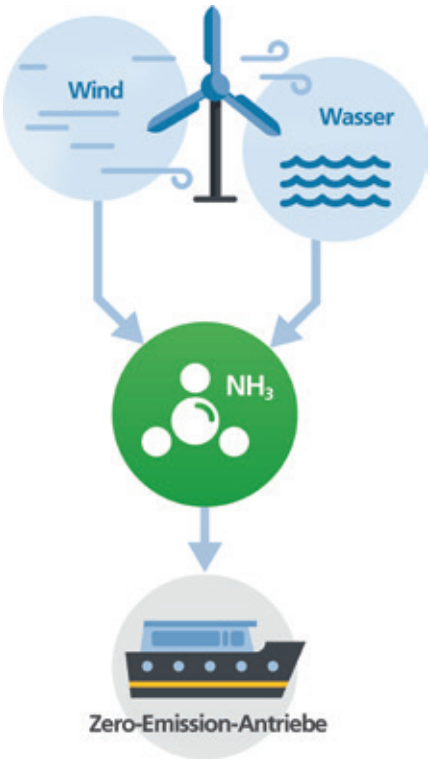

Fig. 1: Campfire vision

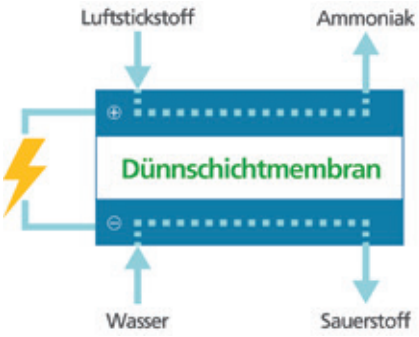

Fig. 2: Functionality Membrane/SSAS

THIN FILM MEMBRANES AS COMPONENTS At the heart of these new energy technologies are electro-ceramic thin-film membranes with perovskite structures. The Campfire researchers want to further develop the

Fig. 3: Ammonia cracker module [Source: ZBT GmbH]

ceramics on the nanoscale in such a way that they are highly efficient and have a long service life – and their production consumes few resources. They are also mechanically resilient, heat-resistant and can conduct oxygen ions, protons and electrons. Perovskites are already established as electrode material in solid-state fuel cells (SOFC), but also have great potential as electrolyte material, for example for SSAS.

The ZBT contributes the technological basis for the construction of high-performance fuel cells and the development of innovative processes for hydrogen and ammonia production to the alliance. The Duisburg research institute was one of the pioneers in Germany to make NH_3 attractive for the energy industry. In the generation of electricity, heat and cooling, this resource can be used on a large scale if fuel cell systems, gas turbines and combustion engines are adapted accordingly. Numerous application-oriented projects have been successfully completed at the ZBT, a non-profit limited liability company.

DEVELOPMENT OF NEW CRACKER MODULES Another field of research in this context is the development of ammonia cracker modules in which NH_3 is converted back into hydrogen. In the field of crackers, the Centre for Fuel Cell Technology has developed new prototypes that combine process technology components such as burners, reactors and heat exchangers and also feature optimised heat management. The integration of an alkaline 4 kW fuel cell is possible without any problems. The corresponding system is prepared for CE certification so that safe operation can be guaranteed.
In addition, a highly efficient system for off-grid power generation was developed within the framework of the European Alkammonia project with the participation of the ZBT, which brings significant cost savings compared to conventional diesel generators and even the established PEM fuel cells. Two technologies were combined: alkaline fuel cells and a novel ammonia cracker. The proof-of-concept system has not only been developed, but has also been extensively tested and thoroughly evaluated.

The cracker prototype will also be further improved – for example as part of the current EU project NH3toH2. Together with its partners, the ZBT is developing an innovative starting process with ammonia supply so that liquefied gas no longer has to be used when the system is started up. In addition, a supply system with liquid ammonia is being developed to enable use even in extreme frost and to increase efficiency. The objective is also to reduce the reaction temperature in order to reduce the load on the catalyst and material and significantly increase service life.

The fields of application of these cracker modules are manifold: In addition to hydrogen generation and highly efficient combined heat and power systems as well as refrigeration and steam generation, gas turbines and engines in particular can be operated with an ammonia-hydrogen mixture – this is where the maritime industry comes full circle.

If, in future, these environmentally friendly and resource-saving fuels were used in at least part of the global fleet, i.e. around 6,500 passenger ships, this would make an important contribution to saving the climate. At the same time, a promising industry and qualified jobs could emerge in the structurally weak north-east. ||

Literature:

[1] Michael Steffen, Non-electroelectrical heated ammonia cracker-module for fuel cell systems, NH3 event 2018.

→ www.wir-campfire.de

→ www.ammoniaenergy.org

The alliance is driven by leading regional research institutions and companies from shipbuilding, shipping, energy technology and fertilizer production and coordinated by Greifswald's Leibniz Institute for Plasma Research and Technology (INP).
Among others, the Institute for Climate Protection, Energy and Mobility, the Stralsund University of Applied Sciences, Sunfire AG, Motoren- und Energietechnik GmbH, Yara GmbH & Co. KG, Enertrag AG, HanseYachts AG, Neptun Ship Design GmbH and Weiße Flotte Stralsund GmbH & Co KG participated in the project. In addition, supra-regional partners such as the Centre for Fuel Cell Technology (ZBT), the Institute for Competence in Automobility (IKAM) and the Fraunhofer Institute for Ceramic Technologies and Systems (IKTS) support the project as external research partners and provide important impetus for the development of green ammonia as an energy source for sector coupling.

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Category: Electromobility | **Author:** Viktoria Scheidler, Theresa Pfaff

HYDROGEN IN THE NEIGHBOURHOOD

Study on the perception and acceptance of H_2 stations

The transport turnaround requires new mobility concepts and alternative propulsion technologies, for which a new infrastructure will be necessary. Seventy hydrogen filling stations have already been built in Germany. Even though some of these are located in metropolitan areas, the small number of fuel cell cars means that there are hardly any points of contact between the technology and the population. The filling station infrastructure offers a present interface between hydrogen and society. Acceptance research can build on this and examine perception and reaction to existing offers.

In connection with H_2 filling stations for fuel cell vehicles, the chicken and egg problem is often stressed. Hydrogen-powered cars can only assert themselves in the commercial market if there are enough possibilities to refuel with H_2 gas. Again, an expansion of the H_2 infrastructure is only worthwhile if there are enough vehicles to ensure adequate capacity utilisation. Verbund H2 Mobility was founded in 2015 to address this dilemma. Supported by shareholders such as Air Liquide, Daimler, Shell and Total, the company intends to set up one hundred filling stations throughout Germany by the end of 2019 and thus give the hoped-for vehicle ramp-up the infrastructural link.

Up to now, vehicles have hardly provided any points of contact for the general public to come into contact with the topic of hydrogen and the associated technologies. However, H_2 filling stations are now a tangible reality. They enable acceptance research to investigate at the local level how the visibility and perception of hydrogen are shaped in an everyday context.

Acceptance is an important prerequisite for the implementation of energy policy projects. In acceptance research one can take up different dimensions of acceptance as focal point [1], [5]. The dimension of *community acceptance* plays an important role for the acceptance of H_2 stations [5]. The aim here is to find out how the local population assesses technical systems of this kind in their surroundings.

In order to investigate the community acceptance of technologies in connection with hydrogen, an empirical study with residents of hydrogen filling stations in Berlin was conceived within the framework of the BMBF-funded Copernicus Project P2X. In this context, the Social Science Research Centre Berlin (WZB) conducted moderated group discussions (focus groups) on the visibility and perception of hydrogen filling stations. The following key questions formed the basis for the discussion:

- What exactly do hydrogen technologies mean in the _energy turnaround?
- How is hydrogen perceived and accepted by the public?
- How is the "hydrogen" tank option perceived?
- What future scenarios for everyday life with hydrogen can the population imagine?
- What role does safety play in relation to hydrogen (filling stations)?

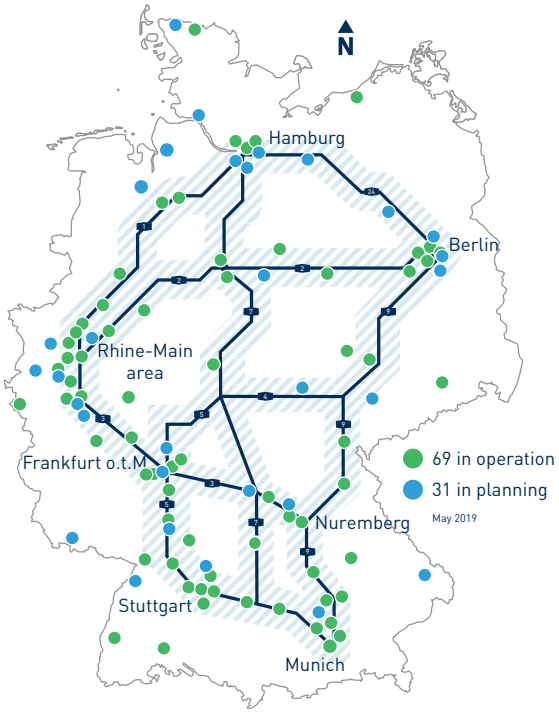

Fig. 1: Current hydrogen filling station infrastructure [Source: H2 Mobility]

METHODICAL APPROACH The focus group method is a thematically guided group discussion in which participants are selected on the basis of predefined criteria [1], [2]. The connection between the group discussion and a thematic information input is particularly characteristic [1].

The BMVBS project HyTrust [4] has already investigated a similar subject with a quantitative approach. People were interviewed at H_2 filling stations about their use and perception. The results generated there can be extended by the qualitative focus group results, enabling a deeper analysis. Focus groups make it possible to discuss a relatively unknown topic intensively with the actors actually affected. Thus focus groups can also be used as a participation format in the development of this infrastructure.

In addition, the level of group dynamics in focus groups can be analysed in greater depth. Participants act together, question each other, and the influence of group dynamics on the formation of opinion becomes observable.

RESULTS OF THE FOCUS GROUPN In November 2018, two focus groups with seven residents* each of two hydrogen filling stations in Berlin (Sachsendamm and Heerstraße/ Jafféstraße) were conducted. Gender balance was taken into account in the selection of participants. The following topics can be summarised as the results of the two and a half hour discussion rounds:

1. Residents are interested and demand more visibility of hydrogen

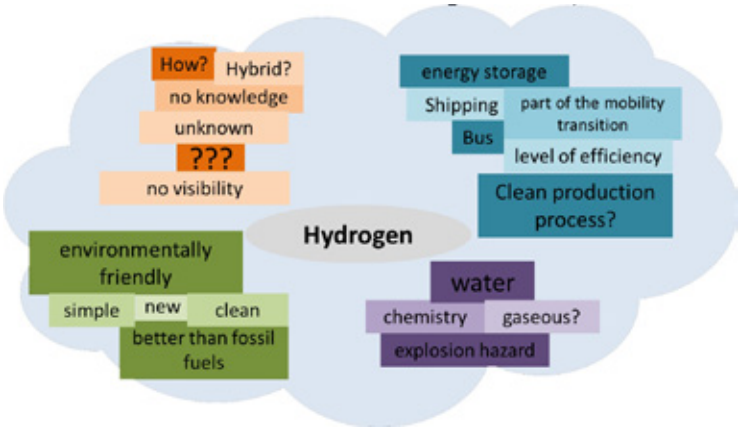

Fig. 2: Associations of the focus group participants with hydrogen, [Source: WZB]

Both groups showed that hydrogen and fuel cells were not common terms for most of them. This became apparent, for example, when writing attribute cards, some of which remained empty (see Fig. 2). While in the second group hydrogen was often associated with "environmental friendliness", the answers in the first group were very different (from "explosion hazard" to "chemistry" or "water"). This covers the results from the HyTrust study, in which 28 percent of respondents could not name any associations with hydrogen [4]. Basically there were many unanswered questions.

The neighbouring filling station was perceived differently by the residents. Many had noticed, for example, so far rather the E charging stations, which are located at one of the two filling stations. It became clear that many participants would be in favour of greater visibility of H_2 refuelling possibilities. One group expressed concerns that there was little contact with technology in everyday life.

> "I find it interesting why everyone doesn't talk about it when it's actually such a great thing. I read a lot of newspapers, I get a lot of information, I haven't heard so much about it. (...) I actually think it's a pity that [...] so little advertising is done."
>
> *Participant*

Following the thematic input on H_2 mobility, the expansion of the hydrogen infrastructure in the immediate vicinity was assessed positively. In general, there was a great deal of interest in the topic of transport turnaround and fuel cells. However, the slow progress was criticized by the participants.

Safety concerns were generally less dominant, which is also in line with the results of the HyTrust study [4]. However, this contradicts the opinion of technology experts, who often assume that safety plays an important role for the population [6]. It was only in the first group that this topic became the subject of discussion. This was soon intercepted by one participant's objection that other fuels were no less dangerous and that they (as well as many other technologies around us) had some kind of "primordial technical trust" in them. Other discussions in the respective discussion groups focused on the topics of (in)visibility of technology, political will and costs. One group again addressed the question of why H_2 mobility is not more widespread in public communication:

The other group discussed the question of whether there is any political support at all for hydrogen mobility in Germany, whose strong automotive industry has so far relied on the combustion engine and in particular on diesel technology. The lack of political will was sometimes seen as the biggest obstacle to turning to fuel cells. In addition, fuel cell cars and buses are currently far too expensive. Concerns arose that the high acquisition costs would lead to the development of a technology for higher earners. Moreover, the use of hydrogen would above all make sense if sufficient renewable energies were available.

2. Active participation is not an explosive topic among residents

The desire to participate in the development of an H_2 infrastructure was more dominant in the first group, in which safety also played a major role. One does not want to be involved in all (political) processes, but still have the opportunity to inform oneself objectively and at an early stage about such projects in the immediate vicinity.

3. Group dynamics contribute to different perceptions of safety

The development of group dynamics can also be understood from the topic of safety: While the topic was hardly discussed in the second group, it shaped the conversation in the first group. In this group there were two persons who were attributed a certain expert status by their background. The rest of the group was increasingly guided by their statements. One of these people raised the issue of safety repeatedly. Accordingly, the safety concerns had a high priority This dynamic was present throughout all phases of the focus group – including the individual responses of the participants. In contrast, the discussion of the other group – despite the good level of knowledge of two participants – was more like a discussion among neighbours. The entire group developed more into advocates of hydrogen, who could not understand why it was not made more visible and promoted by politics or industry.

On the one hand, this insight shows how fragile and vulnerable opinions can be, for example through the influence of individuals or fake news. On the other hand, this also points to the importance of science communication and that experts have a great responsibility to classify current scientific developments, to communicate them to the outside world and to promote discourse between science and society.

PROMOTING VISIBILITY AND EXCHANGE Ultimately, H_2 filling stations hardly encounter any obstacles to acceptance. However, the lack of points of contact means that the >>

general population is too seldom able to familiarise itself with these new technologies. The expensive FC vehicles should also be made accessible to ordinary citizens through the distribution of car and ridesharing services such as Clevershuttle. We must not give the impression that we are promoting luxury technology in the passenger car segment. At the same time, the focus groups have also shown that the desire for active participation in projects such as the construction of a hydrogen filling station is not so high. Rather, it is a matter of providing more information on infrastructure expansion. In the focus groups it has also become clear how group dynamics affect the exchange of information and discussions and what role experts are assigned.

The lack of involvement of the local level (in this case the residents and potential users) reduces the visibility of hydrogen technologies and loses an important prerequisite for the further development of these projects. Focus groups provide a good basis for the participation of local actors: On the one hand, citizens gain new knowledge and impressions about a relevant topic for themselves. On the other hand, knowledge and opinions from society can be fed back into scientific projects and integrated into projects. Such a mutual exchange between science and society is indispensable in order to jointly develop new technologies in a direction that benefits society as a whole, especially since the energy and transport turnaround is to be understood as a social project. ||

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BREEZE – MORE THAN JUST A MILD BREEZE

Early fleet introduction of H_2 rail vehicles

Fig. 1: The H_2 Zillertal railway [Source: Zillertal Transport Services]

Fuel cells on rails are not only talked about in the north. Numerous municipalities and regions have meanwhile turned their attention to this promising form of propulsion. The most advanced up to now is Hesse, where Germany's first serious thought had been given to FC trains and 27 H_2 drive units have now been ordered following a successful tender. But something is also happening in Brandenburg and the Zillertal.

As in Schleswig-Holstein, there was also a tender in Hesse last year for the purchase of new trains and their maintenance, with the subtle difference that fuel cell technology prevailed here. The Rhein-Main-Verkehrsverbund (RMV) and the state of Hesse had agreed to test new technologies in the Taunus region. This involves a total of 27 drive units which are to be used from December 2022 for the Taunus Railway, which previously operated diesel locomotives. The hydrogen for this could come from Industriepark Höchst.

In mid-May 2019, fahma GmbH, a subsidiary of Rhein-Main-Verkehrsverbund, signed a corresponding purchase agreement for the entire fleet worth EUR 500 million. Alstom has announced: "In addition to the trains,

"The project has model character for the BMVI. We hope that many more projects in Germany will follow this example."
Enak Ferlemann, BMVI

the contract also includes the supply of hydrogen, maintenance and the provision of reserve capacities for the next 25 years." Enak Ferlemann, Parliamentary State Secretary in the Federal Ministry of Transport and Digital Infrastructure (BMVI), explained: "The Federal Government supports this investment in climate-friendly mobility by assuming 40 percent of the additional vehicle costs incurred in comparison to diesel vehicles, as well as by providing proportional funding for the hydrogen filling station."

Hesse's Transport Minister Tarek Al-Wazir said: "Transport is responsible for one third of greenhouse gas emissions in Hessen. Steam instead of diesel soot is therefore an exciting approach. We will continue to actively support the project and make every effort to ensure that the necessary adaptations to the rail infrastructure around the hydrogen filling station in Höchst progress quickly."

Fig. 2: The Breeze Railway for Great Britain [Source: Alstom]

H_2 NARROW-GAUGE RAILWAY IN THE ZILLERTAL VALLEY In Austria, everything is done correctly. There, the Zillertal Railway will use hydrogen instead of diesel fuel on the 32 km stretch between Mayrhofen and Jenbach. On 15 December 2017, the Supervisory Board of Zillertaler Verkehrsbetriebe AG (ZVB AG) decided to convert the railway to hydrogen-power in accordance with the *Tirol 2050 energy-autonomous* strategy using regional resources. Accordingly, at the beginning of 2018, a call for tenders was issued which was not technologically open.

Stadler Rail was the only participant to be awarded the contract. Verbund AG will provide the electricity for the electrolysis (2 x 2.1 MW) for H_2 production as part of the H_2 Zillertal project with its power plant at Mayrhofen train station. This hydrogen will then drive the five planned fuel cell trains (option for three more), which together are expected to cost 80 million euros. Stadler, which also offers battery and hybrid trains, is using its FLIRT battery model, which made its first run in October 2018 and is now to be equipped with a hydrogen drive (1,400 kW_{max}, 2 PEM systems with 250 kW each). The first specimen could be delivered in 2020.

The project is scientifically supported by the FFG research project HyTrain of the hydrogen initiative showcase region Austria (WIVA).

NOT SO GOOD IN BRANDENBURG Work on the "Heidekrautbahn", on the other hand, is progressing only slowly. The background is that not only the reactivation of the old route of the regional train RB27 (Berlin – Karow) is causing problems, but also its continuation beyond the original terminal station to Berlin-Gesundbrunnen. Irrespective of this, it is still unclear whether the trains used there could then be operated with hydrogen.

Green electricity is abundant in the Uckermark region north of Berlin, but the Niederbarnimer Railway and the Barnimer Energiegesellschaft (BEG) are still waiting for the approval of their NIP grant application (project volume: € 35 million). According to current planning, in the positive case 2023, the first project stage with seven fuel cell-powered trains, six buses and two refuse collection vehicles as well as an electrolyser at the depot could be commissioned. The hydrogen generated for the four envisaged FC trains could be provided by Enertrag and produced by electrolysis using wind turbines, which will no longer be eligible for EEG funding after twenty years.

A similar project, however with an H_2 combustion engine, is running in the Wittenberg region, where a hydrogen train could be used between Dessau and Wörlitz in about two and a half years. In March 2019, the Trains project was awarded the contract within the framework of the "Change through Innovation in the Region – WIR!" programme funded by the Federal Ministry of Education and Research. Trains had won a competition among 107 applications and is now one of 20 projects to be funded (total funding amount: € 200 million).

Dr. Hans-Joachim Krokoszinski, head of the Research and Technology Transfer Centre (FTTZ) at Anhalt University in Köthen, explained to HZwei: "It will comprise twelve individual projects, five technological, three for securing young talent and skilled workers in Anhalt and four for strategy and image development. Technologically, however, we are not focusing on hydrogen fuel cell drives, but on methane-hydrogen combustion engines, which are retrofitted in exchange for the diesel engines of existing trains. These drives open up a new added value chain in the Anhalt region and are more cost-effective and more durable than fuel cells." The kick-off for the first sub-project is to be on 1 July 2019.

BRITISH BREEZE RAILWAY Meanwhile in Great Britain, the company was working on its own train design for the British market. In January 2019, Alstom introduced Eversholt Rail, the Breeze, an upgrade to the existing Class 321 model. According to the French train manufacturer, this type of vehicle is ideally suited for integrating its own hydrogen system (Hydrogen Multiple Unit – HMU).

At the beginning of 2018, Jo Johnson, British Minister of State for Transport, had set the direction by announcing the end of diesel trains in 2040. ||

"The combination of the experience gained from the successful Coradia iLint and Class 321 Renatus programmes will deliver a hydrogen-powered multiple-unit product that meets the expectations of sponsors and railway operators for an early fleet introduction."

Stephen Timothy, Eversholt Rail

Category: Electromobility | **Author:** Sven Geitmann

A FEELING OF FULFILMENT

H24Racing – hydrogen powered racing

Fig. 1: The Force-VIII – an eye-catcher during the Hanover Trade Fair

While Formula E in Germany was held in Berlin on 24 and 25 May 2019 with purely battery-operated racing cars, preparatory measures are currently underway elsewhere to ensure that hydrogen cars can also take part in races in the future. On 28 March 2019, the LMPH2G prototype completed its first laps at Le Mans with driver Emmanuel Collard and prominent co-driver Bertrand Piccard.

After its maiden run in Spa-Francorchamps in the run-up to the European ELMS long-distance race and the demonstration at the Paris Motor Show, this was the third appearance of the H_2 racing car. The trials that now took place on the Bugatti circuit with the adventurer and circumnavigator Piccard took place during the Les Assises de l'Automobile conference organised by the French Automobile Club ACO (Automobile Club de l'Ouest). The LMPH2G prototype has three H_2 tanks and four PEM fuel cells (drive power: 480 kW).

Within the framework of the MissionH24, launched in September 2018, the French-Swiss team of GreenGT is currently working on being able to start its own class for H_2 vehicles at the Le Mans 24-hour race from 2024. To this end, ACO and GreenGT initiated the formation of an H24Racing team at the beginning of February 2019. A corresponding infrastructure with tank facilities and its own boxes is to be completed by the centenary of 2023.

Irrespective of this, there had been rumours in 2018 that Audi wanted to return to the Endurance World Championship – possibly from 2022, possibly with a fuel cell car. From 2024 BMW could then also be present, it was said from well-informed circles. Until then, the LMPH2G will first be tested in an ACO racing series. "We hope and believe that it can be so far this year," GreenGT boss Christophe Ricard told Motorsport-Total.com. Pierre Fillon added: "From 2024 it should be possible to drive completely CO_2 neutral in Le Mans. And that can only be done with certain technologies."

In 2016 the Italian design company Pininfarina had also announced that they would install the GreenGT drive concept in their *H2 Speed* in small series, not for the road, but for the race track (see H2-international Oct. 2016). The plan was to build a double-digit number for well-heeled racing car fans – at a unit price of around US$ 2.5 million. The roadworthy prototype should be ready at the beginning of 2017. In March 2018, the Geneva Motor Show announced that a total of twelve H_2 cars would be built, accelerating from zero to one hundred in 3.4 seconds.

FORZE IS LOOKING FOR A NEW FUEL CELL At the same time, efforts at the Technical University of Delft are continuing in the twelfth year of its development work. Their Forze racing car (FORmula Zero hydrogen Electric) is now in its eighth generation. *Forze VIII*, which like its predecessors has an LMP3 chassis, completed its first race at the Super Sports Car Challenge on 18 and 19 August 2018.

As Segher Brons of TU Delft explained to HZwei, the hydrogen system has remained more or less unchanged compared to the predecessor model. Brons said: "We've replaced the 350-bar H_2 tanks with newer 700-bar containers. Now we can transport six kilograms of hydrogen, which allows us to drive for 60 minutes. We still have the same Ballard fuel cell with the electric motors and the buffer system. A major goal is to implement a new fuel cell next year that will give us more power." The previous FC system has an output of 100 kW. ||

"I am elated and very enthusiastic because this is the future – clean mobility. It already exists – and it works. [...] With electric drive, fuel cell, hydrogen – that's the future, that's how things have to develop."
Bertrand Piccard, Managing Director of Solar Impulse

"A new team promises excitement, enthusiasm, expectation and confidence. I must admit that with the announcement of the arrival of H24Racing I feel a sense of fulfilment. [...] Personally, I'm probably not the only one who doesn't believe in battery-powered systems as the ultimate, comprehensive solution."
ACO President Pierre Fillon

Category: Electromobility | **Author:** Sven Geitmann

BATTERY INSTEAD OF FUEL CELL TRAINS FOR THE NORTH

Alstom is subject in the first instance to a tendering complaint

The success story of fuel cell trains to date is currently undergoing a severe setback: As the Kieler Nachrichten (news) recently reported, electric trains could roll through Schleswig-Holstein from 2022, but they are likely to be equipped with accumulators for energy storage and not with hydrogen. However, this has not yet been decided, as the drive unit manufacturer Alstom is currently still taking legal action against the tender procedure.

The French company Alstom had recently caused a great stir in both the rail and energy worlds by putting a fully functional fuel cell train into operation in a comparatively short time. The Coradia iLint, which was developed with the support of various technology partners and built in Salzgitter (see H2-international Jan. 2018), was successfully sent on a tour across Germany in early 2019.

Previously, a tender had been held in Schleswig-Holstein until the end of 2018, because the northern federal state intends to buy 50 new trains, which are to go into operation from December 2022, for 200 million euros. This open-technology tender procedure was expressly concerned with low-emission drive technologies that can be used as an alternative to diesel or overhead line locomotives.

The background to this is that in Schleswig-Holstein only around 30 percent of the rail network is electrified. However, both the permanent operation of diesel locomotives and the installation of overhead lines are cost-intensive. According to a Norwegian study from 2016, the construction of overhead contact lines is three to four times as expensive as the use of fuel cell trains, which is why the focus is currently on battery, diesel hybrid and FC drives.

At the beginning of this year, however, the Land and Nahverkehrsverbund Schleswig-Holstein GmbH (NAH.SA) announced that only the previous supplier, DB Regio Schleswig-Holstein, had submitted an offer for purely battery electric trains. Alstom therefore did not submit a final binding bid, but instead filed a complaint with the Higher Administrative Court for discrimination against the specifications of the tender procedure. The accusation is that the price of hydrogen fuel was to be guaranteed for thirty years and that the H_2 infrastructure itself was to be set up without these additional services being adequately taken into account.

PROTECTIONISM OR NAIVETY? During the New Energy Days in Husum in March 2019, Dr. Bernd Buchholz, State Minister for Economic Affairs, Transport, Employment, Technology and Tourism (see Fig. p. 5), was astonished that no other tenders – especially from Alstom – had been received. At the same time, however, he expressed his regret and noted that he had been assured in advance that fuel cell technology would be ready for series production and competitive. His political colleague, Energy Turnaround Minister Jan Philipp Albrecht, could not and did not want to say anything about the ongoing court case, but was "interested" in the fact that there would still be a call for tenders taking into account several technologies.

Ingo Dewald, Managing Director of Norddeutsche Eisenbahngesellschaft Niebüll GmbH, criticised the entire procedure in this connection, but in particular that according to the tender, all 50 units are to be equipped with only one technology. In his opinion, it would make more economic and technological sense to select different drive technologies depending on the route and application. GP Joule GmbH also stated that the tender procedure could not really be described as open to technology if only one bidder had applied.

Fig. 1: The entry of the Coradia iLint could be delayed.

Since then, the fuel cell industry has been hoping for a withdrawal of the original invitation to tender or a positive court ruling so that all three drive technologies in question can apply on an equal footing in a second attempt. In the first instance, however, Alstom suffered a defeat, which is why it has now gone to the Schleswig Higher Regional Court. The judgment is expected to be delivered in June 2019.

SETBACK FOR NORTH GERMAN WIND-HYDROGEN-VISION

The interim success story of the Coradia iLint fuel cell train began with the signing of a letter of intent between Alstom Transport and Hydrogenics in May 2015 (see H2-international July 2015 and July 2017). As planned, an routine test followed in 2018 on the Buxtehude – Bremervörde – Bremerhaven – Cuxhaven route (see H2-international Oct. 2016). As a result, Alstom received numerous advance orders from Germany and abroad as well as significantly more applications for FC rail applications than expected from NOW.

It was only at the beginning of May 2019 that the five Minister Presidents of the northern German federal states spoke out in favour of promoting hydrogen and fuel cell technology more intensively, because the north, as an energy-rich region, hopes that this will lead to an economic upturn. Lower Saxony in particular, where the fuel cell trains are to be built, is therefore unlikely to be as enthusiastic about this development as Schleswig-Holstein. The image of a wind-hydrogen showcase region that is only just beginning to emerge could be ruined before it has properly established itself. ||

"So we are not electrifying the line, we are electrifying the traffic."

NAH.SH Managing Director Bernhard Wewers, Lübecker Nachrichten

Category: Electromobility | **Author:** Sven Geitmann

HYDROGEN FOR AVIATION

Fuel cells for drive or as APUs

Fig. 1: In 2018, the Element One project was launched to transport four passengers over distances of 500 to 5,000 km.
Source: HES Energy Systems, Singapore

Fuel cell propulsion systems are not only being developed for unmanned aircraft, hydrogen is also increasingly becoming an topic in passenger transport. The US space agency NASA, for example, together with the engineering school of the University of Illinois, is constructing electric aircraft using liquid hydrogen and fuel cells. On the one hand, the cryogenic fuel can facilitate the cooling of the units, but on the other hand, the insulation of the cryogenic containers still poses a challenge.

In the Netherlands there is the prototype of a two-seater H_2 motor glider, which the student team AeroDelf of TU Delft presented at the beginning of May 2019. Also with this Phoenix project there are space problems, because the insulation of the LH_2 tanks in itself is 20 cm thick.

Henri Werij from the Faculty of Aeronautics and Astronautics at Delft Technical University reported that the principle of laminar boundary layer extraction was used here in order to be able to fly as energy-efficiently as possible. The wings have been fitted with 14 million tiny holes to reduce air resistance by up to 15%. The first test flight of a small prototype is scheduled for 7 September 2019.

China, on the other hand, is more advanced. Commercial Aircraft Corp. announced that its Lingque H (LQ-H2) hydrogen-powered aircraft has now completed ten test flights in Zhengzhou, Henan Province. COMAC developed the new aircraft with a wingspan of six metres together with State Grid, Gree (Shenzhen) and the Institute of Aeronautical Science and Mechanical Engineering at Beihang University.

FUEL CELLS FOR ON-BOARD ENERGY SUPPLY Parallel to such efforts in the field of drive technology, work will continue on fuel cell-powered auxiliary power units in the aviation sector. In the USA, for example, Liebherr Aerospace & Transportation and General Motors (GM) are researching a fuel cell to replace the auxiliary gas turbine (APU) in the next generation of aircraft. The first step of the project is the construction of a demonstrator. Nicolas Bonleux, head of sales at Liebherr Aerospace & Transportation, said Aerobuzz: "*At some airports, it is no longer permitted to use the APU.*" Fuel cells are more efficient here and also have lower emissions than turbines (less noise, less exhaust gases). For this reason, a system demonstrator is currently being developed that is to be integrated into an aircraft, just as the German Aerospace Center (DLR) and Airbus did more than ten years ago (see H2-international July 2008).

At that time, in July 2007, the first flight tests were carried out, with the help of which the function of the fuel cell was tested under aviation-relevant conditions and successfully demonstrated. Following on from this work, Airbus is still active in this field today and was awarded the German Aviation Innovation Prize (IDL) last year. As part of its Hydrogen-to-Torque (H2T) Imponator project, the European aircraft manufacturer developed a demonstrator at the Centre for Applied Aviation Research ZAL in Hamburg that could replace the auxiliary power unit in the tail of aircraft. In future, this drive unit will combine an electric motor with a fuel cell and liquid hydrogen as fuel. ||

REALIGNMENT OF THE IAA

Fig. 1: Toyota and its Mirai will be missing in 2019 at the IAA

The 68th International Motor Show has to get itself re-organised. Two years ago, the organising German Association of the Automotive Industry (VDA) already had to contend with numerous cancellations by automobile manufacturers because quite a few preferred a presence at the Consumer Electronics Show in the USA to an exhibition in Frankfurt (see H2-international Jan. 2018). This year's IAA Cars, which will take place from 12 to 22 September, is not likely to be any different. In April 2018, for example, BMW announced that the Bavarians would focus more strongly on China and CES in Las Vegas and reduce their IAA stand from 11,000 to 3,000 m², as the planned budget for this was reduced from 25 to 6 million Euros. Other vehicle manufacturers such as Fiat, Mazda, Mitsubishi, Nissan, Peugeot, Renault, Toyota or Volvo cancelled completely.
More than ever before, the VDA is therefore advertising the fact that, in addition to the exhibition, it also has three other mainstays to show for itself: Conference, experience course and career – but they are not really new. Nevertheless, according to VDA press spokesman Eckehart Rotter, these "four innovative formats" are intended to help stem the decline in the number of exhibitions and visitors.

The New Mobility World will also take place parallel to the IAA again this year, albeit somewhat earlier (10 to 15 September). At the NMW Expo, companies in particular will be exhibiting promising mobility solutions. The same hall will also host the IAA Career and the IAA Conference (11 to 15 September), which will be held to discuss topics of relevance to the future such as artificial intelligence, infotainment, alternative drives, climate change, smart cities and the sharing economy.

Rotter could not say to what extent H_2 and FC technologies will be visible on site this year. He assured us that "we need all types of propulsion." But he also said that "we don't expect to reach the objectives for 2030 with hydrogen". The fuel cell technology will come, "but not so fast and not so strong". That is why the VDA primarily relies on battery-powered electromobility. Rotter called this "prioritisation on the time axis".

In response to a question from HZwei, the press spokesman wished the politicians would set the framework conditions in such a way that the market could keep pace. In particular, this would require a massive expansion of the charging infrastructure and even better depreciation possibilities. ||

GREAT WALL MOTOR REMAINS IN CHINA

Great Wall Motor (GWM) did not join H2 Mobility as originally planned. At the end of October 2018, a press release stated that the Chinese market leader for off-road vehicles and pickups wanted to invest in the German hydrogen filling station network. Nikolas Iwan, Managing Director of H2 Mobility, told the FAZ that he had contacted GWM at the beginning of 2018. Its owner "is fully behind it", says Iwan. After a Memorandum of Understanding was signed, the Asians withdrew, however, as they currently had no vehicles for the European market, as it was said. As we have heard from well-informed circles, not all shareholders of H2 Mobility are said to have supported the entry of such a large Chinese company. In addition, there were fears that parts of the technology promoted in Germany with taxpayers' money could flow off to Asia. ||

H2.Live/Card [Source: H2 Mobility]

According to Sybille Riepe, Press Officer of H2 Mobility, the old Clean Energy Partnership (CEP) fuel card has no longer been valid since 31 March 2019. It was replaced in February 2019 by the new H2.Live/Card (see photo), which can be downloaded free of charge from www.h2.live and the app H2.LIVE. Since then, the necessary fuelling instruction has been provided via video training. In addition, payment by direct debit is now possible, and all refuelling procedures can be viewed online if interested.

Category: Electromobility | **Author:** Sven Geitmann

CONTINUOUS INFRASTRUCTURE SUPPORT

New BMVI funding call for H_2 stations

Since the number of hydrogen filling stations in Germany is unstoppably approaching the three-digit range, the inauguration celebrations are becoming smaller and the press releases fewer. Most recently, numerous high-ranking industry representatives and politicians appeared at the 50th H_2 station in Potsdam. For the inauguration of the 67th, 68th or 69th location, the number of media representatives was not quite as high as before – probably only for the 100th time. This phenomenon is already known from other sectors (e.g. CNG, LPG) and is a good sign for the H_2 and FC industries, as it shows that hydrogen filling stations are gradually becoming the norm.

H2 Mobility wants to reach the mark of 100 hydrogen filling stations by the end of 2019. The German government has been less ambitious so far and does not expect this figure until 2020. Then, as the official saying goes, further expansion will be based on the number of existing fuel cell vehicles, i.e. existing customers.

Nikolas Iwan, Managing Director of H2 Mobility, said about further planning during the Hanover Fair that the current demand for passenger cars does not currently justify adhering to the original target (400 H_2 filling stations by 2023), which is why this figure is no longer communicated by H2 Mobility. In May 2019, however, the Federal Ministry of Transport and Digital Infrastructure (BMVI) launched a new call for funding to ensure that there is no premature end to infrastructure development after the hundredth H_2 station. Accordingly, the Ministry will continue to cover up to fifty percent of eligible expenses for the construction of new filling stations, but will also support an electrolyser as part of the refuelling infrastructure for the production of green hydrogen with forty percent of the additional investment expenditure in the future. According to the BMVI, the BMVI would like to "continuously promote the further construction of publicly accessible hydrogen filling stations in road traffic". Applications may be submitted until 31 July 2019. Ivan further stated that he sees his company as an enabler. In this sense, the motto for 2020 is to build H_2 filling stations where more than 50 FC cars are available. As of 2021, this will apply to 100 cars or more. With regard to the availability of the 71 stations opened by the end of May 2019, Iwan was reasonably satisfied: For example, the operational capability of the former CEP filling stations was initially only 79 percent, but now it reaches 93 percent. ||


[Source: Shell]

Fig. 1: Lower Saxony's Environmenta Minister Olaf Lies (l.) inaugurated the new H_2 station directly at the exhibition grounds in Laatzen during the Hanover Fair.

"Lower Saxony has been pursuing a consistent H_2 strategy for some time now and is committed to the use of hydrogen as an energy carrier in a wide variety of areas, including mobility. [...] Hydrogen-powered fuel cells have a permanent place alongside battery-powered electric vehicles."
Olaf Lies, Environment Minister of Lower Saxony

Category: Electromobility | **Author:** Sven Geitmann

WITH OCEANWINGS TO THE OLYMPIC GAMES

Energy Observer stops at the Port of Hamburg

Fig. 1: Central location not far from the Elbe Philharmonic Hall

Only slowly, the Energy Observer fought its way up the Elbe to Hamburg against the tidal ebb. The Hanseatic city in which the solar hydrogen ship moored on 28 April 2019 was the 35th station on the six-year circumnavigation of the world. A total of 101 locations in 50 countries are to be visited.

Although this odyssey is not about speed, Captain Victorien Erussard and his crew were visibly pleased to have new technologies on board that will enable faster progress and more comfortable travel. In Amsterdam, the solar catamaran (see H2-international issue Oct. 2017) was fitted with additional photovoltaic panels, a thermal energy store and special Oceanwings® in mid-April.

The new twelve-metre high masts, which resemble vertical wings rather than sails, replace the previously used vertical wind turbines (Darrieus rotors). Instead of generating electricity, the aim of the Oceanwings is to generate propulsion. Its usage is a world premiere: For the first time, the wings designed by VPLP will be used on such a large boat as the Energy Observer. As Erussard explained during his presentation, their efficiency is twice that of conventional sails. In addition to the fully automatic, intelligent control, a major advantage is that they can be used up to an angle of 22° (conventional sails: 45°). Since their installation, the average speed has increased from five to seven knots.

The aim of this multi-year gymnastics event – in addition to the 2020 Olympic Games in Japan – is to test various technologies. For example, the organisers said goodbye to their kite because it was too complicated to handle. System engineer Hugo Devedeux was not quite as happy with the compressor, which already had to have twelve diaphragms replaced. Otherwise, however, the energy system on board, designed by CEA-Liten, seems to run reliably. ||

PROMOTIONAL TOUR

The visit of several specialist journalists on board the Energy Observer was initiated by the Toyota car group, which is the official media partner of Victorien Erussard's circumnavigation of the world. The Japanese company used the stop in Hamburg to give media representatives the opportunity to steer hydrogen vehicles from Cologne to the Hanseatic city as part of a road show, so that they can gain their own experience with this technology and inform themselves about H_2 technology on water and on the road.

Fig. 2: Hugo Devedeux, systems engineer on board the Energy Observer

Category: Electromobility | **Author:** Sven Geitmann

QUIET AVIATION

Fuel cells enable inconspicuous monitoring

Fig. 1: The Hycopter [Source: HES Energy Systems, Singapore]

Fuel cell systems are also of great interest for use in drones due to their higher range compared to pure battery systems. For several years, research and development has been carried out in this field of aeronautical engineering, whereby the focus is not always on playful activities.

The first products of Horizon Fuel Cells, founded in 2003, were used in drones at NASA in 2006. Under the leadership of Taras Wankewycz, Horizon developed into HES (2009) in the following years, which was transferred to the H3 Dynamics Group in 2015. In this way, Horizon, long known for its teaching and demonstration materials as well as its model cars, became more and more a company for drones and remote-controlled robots with its own product line.

The Singapore-based company HES Energy Systems showed more than ten years ago that drones with fuel cells are far more flexible than those with accumulators. Asians put the weight advantage at a factor of ten, which makes it possible to produce ultra-light aircraft with a long range and a long operating time.

According to H3 Dynamics, the industry leader for energy storage, advanced robotics and real-time analytics, it is no longer only active in unmanned aviation, but also in manned aviation (see also p. 32). The expansion of this work led to the launch in France in autumn 2018 of a new programme for hydrogen-powered passenger aircraft and also for the development of a corresponding infrastructure. The objective is to establish long-haul aircraft powered by zero-emission fuel.

H3, which is financed by the Toyota Mirai Creation Fund Japan, among others, opened its European headquarters in Paris in 2018 and started cooperation with the French companies Delair, a manufacturer of unmanned aerial vehicles, and Ergosup, a manufacturer of zinc-based H_2 production facilities. The origins of these partnerships can be traced back to a French support programme for the implementation of hydrogen technologies at Toulouse Airport.

IT ALL STARTED WITH MODEL CARSN The idea of using several tank cartridges to operate flying objects is ultimately based on the 2010 MiniPak, a charger for mobile phones that was supplied with hydrogen generated by electrolysis via a HydroStick (H2-international Oct. 2011). The concept was the same then as it is today – only today it is bigger and intended for airplanes instead of mobile phones. The former HydroSticks are now being replaced by so-called Aeropak modules for energy storage. Taras Wankewycz, Managing Director of HES and H3 Dynamics, explained: "Starting with smaller aircraft, it's easier to realise larger visions faster." Its objective is to establish a continental network of H_2 filling stations for various autonomous long-range electric aircraft (see cover). "This is an important step with an exciting objective: emission-free mobility in aviation," says Wankewycz.

According to HES, lithium-ion batteries are suitable for a flight time of up to 30 minutes. The Hycopter, which the company presented in November 2018, is expected to last up to 3.5 hours. In January 2019 Dubai Police presented the Hycopter at the International Trade Fair for Protection and Security Intersec in Dubai.

TAXPAYERS' MONEY FOR MILITARY APPLICATIONSN Horizon and HES 2014 had come under fire when the newspaper Blick reported that taxpayers' money intended for poverty reduction and growth promotion in emerging countries had been used to develop drone technology. According to the Swiss newspaper, the development bank SIFEM invested eight mil-

Fig. 2: Taras Wankewycz [Source: HES Energy Systems, Singapore]

"The parent company Horizon Fuel Cell began its journey by selling tiny 'micro' fuel cell products that were initially sold as science kits for children and miniaturised, real-world hydrogen cars and solar hydrogen refuelling systems. The same company has since expanded and 15 years later is selling multi-kilowatt fuel cells to manufacturers of genuine electric cars, trucks and buses in the huge electric vehicle market in China (about 50% of all electric vehicles and 99% of all electric buses worldwide are in China)."

Taras Wankewycz, H3 Dynamics

Fig. 3: In 2007, DLR presented the HyFish, equipped with a Horizon stack, which had recently completed a successful test flight in Bern, at the Hannover Messe. [Source: DLR]

lion dollars in a cleantech fund in 2009, which also benefited the Horizon Group. Company representatives and the SIFEM Fund, which is supervised by the State Secretariat for Economic Affairs (SECO), had played down the importance of drone technology by telling the editors that they were "very far removed from a mass-produced product" or "prototypes". Corresponding products are said to have been used, for example, in the Horn of Africa. In concrete terms, for example, it dealt with so-called Boomerang drones from Horizon (H2-international Oct. 2009), which were purchased by the Ethiopian army in 2011 (see box).

Horizon is said to have played a key role in their development, as the company provided the know-how for the Boomerang drive. According to the manufacturer, the Boomerang model is particularly suitable for "reconnaissance, monitoring and target acquisition in open fields and urban war scenarios". According to Blick research, the SIFEM fund intervened in 2012 and announced that Horizon had spun off the armaments division. HUS Unmanned Systems was founded in 2015. In addition, military content had been removed from the most important company websites following the editors' request.

THE BLACK SHARK WITH THE DRONES Bshark is also active in this area. In September 2018 , the hydrogen-powered drone research company from the British Virgin Islands announced that it had entered into a partnership with MicroMultiCopter (MMC), a Chinese drone manufacturer. MMC UAV manufactures the HyDrone 1550, which successfully completed test flights at an altitude of over 4,000 metres in the mountains of Yunnan Province in China in spring 2017. Based on this technology, Bshark, whose name stands for black shark, launched the hydrogen-powered Narwhal 2 drone. The suitable hydrogen filling station for it is called Orca (killer whale; price: US$ 180,000).

Fig. 4: The Narwhal 2 [Source: Bshark]

SURVEILLANCE TASKS

BlueBird Aero Systems introduced an unmanned aircraft in 2009 that could stay in the air for nine hours with the help of a FC drive (H2-international Oct. 2009). The flight duration of the Boomerang drone, which weighs nine kilograms, with a company-owned first-generation fuel cell lasted five hours in the test flight. For the next model generation, Ronen Nadir, Managing Director of the Israeli company BlueBird Aero Systems, opted for the fuel cell system from Singapore based Horizon Fuel Cell Technologies, which is now available under the name Aeropak.

In August 2010, Horizon announced that the UAV manufacturer Israel Aerospace Industries (IAI) had also signalled interest in its Aeropak system and would equip the Bird Eye 650-LE mini drone with FC drive (H2-international Oct. 2010). The 200 W system should allow the drone a long endurance of up to six hours. Gareth Tang, Managing Director of Horizon: "Aeropak reduces the number of launches while increasing the operating radius." It was said that the comparatively long flight duration of drones made them particularly attractive for surveillance tasks (e.g. border and environmental protection). In addition, they are difficult to find because they are quiet and the thermal signature is extremely low due to the efficient and economical fuel cell propulsion. The latter is only two degrees Celsius above the ambient temperature, so that the drone can hardly be detected with infrared sensors.

The Caribbean manufacturer built about 100 Narwhal 1s before launching its successor, an H_2 quad-copter with 120 minutes flight duration, LTE module and 30 km video transmission range. Narwhal 2 has a lightweight aluminium frame, a 3.5-litre type 4 tank and a metallic PEM fuel cell (800 W) and is rain, dust and fire resistant according to the manufacturer. It is said to be available for $24,000 to $30,000.

Boeing or its subsidiary, the drone manufacturer Insitu, is also active in this field. Together with the former Ballard subsidiary Protonex Technology Corp., which was taken over by Revision at the end of 2018, the Americans developed the ScanEagle with fuel cell propulsion, which was successfully tested for the first time in 2017. ||

Category: Electromobility | **Author:** Rajko Rothe, Max Lakkonen

HYDROGEN VEHICLES IN CASE OF FIRE

Safety research accompanies introduction of modern drive technology

Fig. 1: Fire fighting needs to be practiced [Source: IFAB]

Against the background of climate change, the reduction of greenhouse gases in the transport sector is increasingly coming to the fore. At present, electrically operated and in particular battery-powered vehicles (BEV) are of great importance. Although cars with fuel cells (FCEV) do not yet have a significant market share, this could change soon in view of the imminent problems of battery-powered vehicles. New vehicles with H_2 drive are used both in passenger cars and in local public transport. The latter covers the entire range of vehicle types with city buses, passenger trains and trams. But what about their safety?

Fires in vehicles happen every day, even if it is currently only the BEVs that "make it" to the headlines. The fact that the fire behaviour of a lithium-ion battery differs from that of petrol or diesel is just as obvious as the fact that the hydrogen used to power a fuel cell poses completely different risks. In particular, the high operating pressure at which hydrogen is carried in vehicles and which, depending on the application, is 350 bar or 700 bar, harbours the danger of a fire event unknown to conventional vehicle engines: jet fire.

A jet fire occurs when combustible gas escapes from a container through a small opening and is ignited on contact with ambient air. Depending on the pressure inside the container and the size of the opening, jet flames with a length of several metres can occur for a short time. An additional risk is posed by an urban environment: Underground facilities, such as tunnels, multi-storey car parks, bus and train stations, generally require special conditions for fighting fires and ensuring the safe escape of people. Like the new drive technologies, these are part of a modern infrastructure, so that safety issues should be taken into account when planning new and upgrading existing infrastructure as well as when designing vehicles.

RESEARCH PROJECT SUVEREN Can the same safety regulations continue to apply in the City Tunnel in the future if most hydrogen-powered vehicles pass through it? Since mid-2017, the SUVEREN project, funded by the Federal Ministry of Education and Research (safety in underground urban transport sector using new energy sources), has been dedicated to answering these and other questions. In this project, Fogtec Brandschutz GmbH & Co. KG, the study company for tunnels and traffic facilities e.V. (STUVA) and the Federal Institute for Materials Research and Testing (BAM) are to investigate the effects of fires with new energy sources when the vehicles are in underground facilities.

In the event of a fire, underground facilities pose a challenge both for escaping the fire and for the fire brigade to fight the fire. The aim is to be able to better assess the potential hazards and, if necessary, to develop measures with which precautions can be taken on the facility side. The focus here is on the early detection of (imminent) fires and other damage events as well as stationary fire fighting to support the self-rescue of persons and to contain the dangers for the arriving rescue forces.

FIRE TESTS IN THE SERVICE OF SCIENCE The focus of the investigations is on real-scale fire tests and fire simulations. In the latter, the effects of damage events, which are described by representative so-called "design fires" developed in the project, are investigated in concrete plants. By calculating the spread of smoke as a result of a fire, in combination with knowledge of the design of escape routes, it is possible to simulate the evacuation of an underground car park or an underground bus station, for example. The fire tests provide realistic data on the course of a damage event, and suitable simulation tools make it possible to calculate its effects and transfer them to a traffic facility.

In the SUVEREN research project, Ingenieure für angewandte Brandschutzforschung GmbH (IFAB) is responsible for carrying out fire tests focusing on the behaviour of lithium-ion batteries, as the safety of electric vehicles requires short-term responses due to the market situation. The damage event under investigation is the so-called thermal runaway, in which the battery heats up through chemical reactions and the energy released is locally sufficient to damage neighbouring cells in the same way. This can lead to a chain reaction that is difficult or impossible to interrupt, with the result that the battery becomes the ignition source for the entire vehicle. In addition, some toxic, health-endangering and corrosive substances are released during the chemical reactions, which are quantified in the fire tests and compared with conventional vehicle drives. On this basis, the dispersion of the gases can be simulated so that the results can be used to assess the evacuation situation.

In addition, the effects of jet fires are another central object of investigation in the fire tests. A jet fire can be triggered by a temperature-controlled pressure relief valve on a gas tank in the event of a fire on the vehicle or in its vicinity, if the gas tank has been heated too much. Approved tanks must have a protective function designed to release the contents of the container into the open in the event of an accident, thereby preventing the container from bursting and exploding.

Fig. 2: Fires in underground garages can be tricky [Source: shutterstock]

In the fire tests planned for the coming year, jet fires with methane as fuel will first be investigated. Methane in the form of CNG (compressed natural gas) is already established in the vehicle sector and is normally used at tank pressures of up to 200 bar. The fire tests should enable a description of the basic flow conditions during a jet fire and the associated validation of corresponding simulations. In addition, the interaction of a jet fire with its surroundings will be investigated, including the reaction to common methods of stationary fire-fighting. Especially through the use of simulations, many central questions of CNG can be transferred to hydrogen-powered vehicles and the processes to be expected here can be described.

In H_2 jet fires, the energy released does not necessarily play the decisive role, as it is lower in today's (planned) tank designs than in comparable conventional vehicles. However, a jet fire has the potential to accelerate the spread of the fire to adjacent objects or vehicles. With the help of the data from the experiments, fire simulations are to be carried out with which such situations can be predicted and, if necessary, measures can be recommended with which the fire can be sufficiently controlled until the arrival of the fire brigade.

OUTLOOK According to the wishes of the Ministry of Education and Research, the results should directly improve safety in urban city facilities. Summarised in the form of a guideline for the planning of fire protection measures and systems in underground facilities, this enables installers, operators, experts and authorities to evaluate each individual object individually and optimally on the basis of the design scenarios described. The guideline will contain a documentation of the special features of the energy sources relevant in the vehicle sector as well as recommendations and requirements for active fire-fighting measures in structural fire protection. In addition, recommendations and information for rescue forces are to be derived so that, for example, fire fighting tactics and the necessary equipment can be adapted to the fires in electric, fuel cell and hybrid cars. ||

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Category: Development | **Author:** Dr. Ken Wackermann

EFFECT OF HYDROGEN ON MATERIALS

Fraunhofer IWM receives new hydrogen laboratory

Atomic hydrogen partly diffuses into materials during production and operation. If this results in degradation of the material properties, the term hydrogen embrittlement is used. The Fraunhofer IWM has set itself the task of better understanding and mastering such chemical processes and their consequences. For this purpose, a new laboratory for material qualification for hydrogen applications has now been set up.

Hydrogen links the various sectors of energy use – heat, electricity, industry and transport – and is therefore an important component of the energy system transformation process. Hydrogen is an important starting product for many chemical products, for example for ammonia production using the Haber-Bosch process. However, hydrogen embrittlement, for example, impedes the use of high-strength steels for lightweight construction in mechanical engineering, as these materials in particular are often severely affected. The Fraunhofer IWM has therefore set itself the goal of investigating the influence of hydrogen on materials and products more closely.

The institute is involved in three ongoing public funding projects aimed at qualifying materials for use in gaseous hydrogen. The funding is part of Hypos, a research programme funded by the German Federal Ministry of Education and Research (BMBF) through Initiative 2020. Based on the measurement results, design specifications and service life predictions are made.

The first project, Hypos-PIMS (Pipeline Integrity Management System), aims to develop a model to evaluate the service life and integrity of long-distance pipelines for the transport of hydrogen-containing gases. The project also includes the qualification of new materials and existing materials, for example by SSRT and crack growth tests.

The second project, Hypos-UGS (underground storage), deals with the storage of hydrogen gas in large underground salt caverns. The potential storage quantities correspond to a supply of energy to Germany for several weeks. The Fraunhofer IWM uses mechanical tests and the model-based description of the static and cyclic breaking loads to qualify the steels and weld seams used in the risers for the injection and withdrawal of hydrogen.

The third project, Hypos-HD (high pressure tank), is developing a pressure tank made of carbon fibre reinforced plastics for up to 1,000 bar for mobile applications. The Fraunhofer IWM tests whether the materials are subject to hydrogen embrittlement. Furthermore, thermal stresses occur during storage processes due to temperature gradients, which lead to material fatigue. The Fraunhofer IWM integrates the thermal stresses into existing models for the service life predictions in order to be able to make a life prediction.

SITE EXPANSION The official opening of the laboratory in Freiburg took place on 10th and 11th April 2019. High-ranking representatives from politics and science inaugurated the new facilities, and a workshop on “Controlling the Effect of Hydrogen on Materials” was held on the occasion.

The expansion of the previous IWM location in Wöhlerstraße was completed in the course of the past two years, so that significantly more analysis possibilities are available from now on. At the heart of the new H_2 laboratory are two gas-tight sealable pressure cylinders (autoclaves) for comprehensive material analysis. The first autoclave with an internal volume of one litre enables the qualification of materials at a pressure of up to 480 bar and test temperatures of up to 330 °C. In these, for example, loading devices can be introduced in order to statically load material samples in a hydrogen atmosphere (e.g. on bending) and thus be able to determine long-term limit breaking loads in situ.

Samples can also be preloaded for subsequent mechanical material qualification. Here it is important to note that the hydrogen introduced can gas out again from the microstructure after loading. In contrast to austenitic steels, ferritic materials (e.g. common structural steels) exhibit very rapid hydrogen diffusion at room temperature. The diffusible hydrogen from components can be completely degassed here within a few hours. In order to investigate the H_2 embrittlement of these materials, such as those used for hydrogen long-distance pipelines, they must be tested with an in-situ hydrogen loading in order to map operating-relevant test conditions.

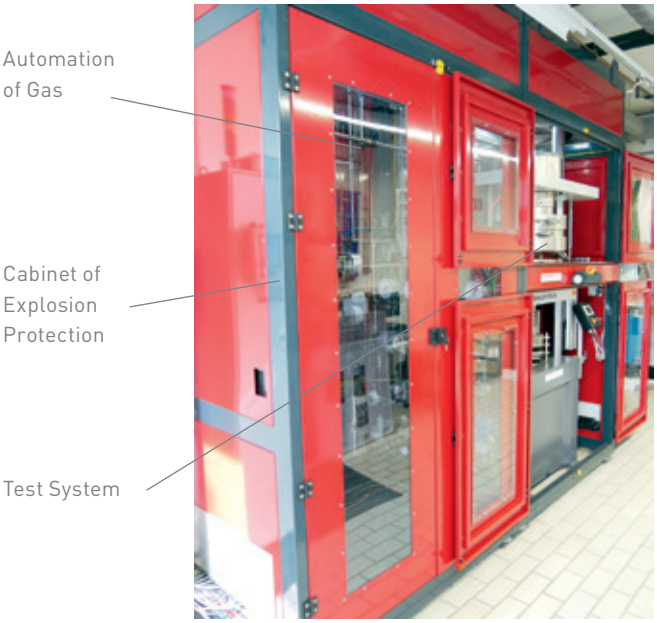


Fig. 1: Complete test bench for in-situ loading

The second autoclave, consisting of a testing machine and gas automation, is particularly suitable for such experiments with in-situ loading. Due to the test gas (H_2), this pressure cylinder is subject to explosion-proof according to ATEX Directive 2014/34/EU. In order to limit the ATEX zone, the entire system is installed in an additional housing in the laboratory (see Fig. 1).

An explosion-proof ventilation unit ensures multiple gas exchanges every hour with discharge into the free atmo-

sphere, with a flow monitor controlling the air flow and initiating an emergency shutdown in the event of a failure. The actual test bench consists of a servo-hydraulic load frame with integrated H_2 pressure cylinder (see Fig. 1), which allows both very slow and very fast tests.

The force is introduced into the samples by a rod, which is guided from the underside into the interior of the autoclave. Special cable bushings allow the connection of extensive measuring instruments such as a strain gauge, a load cell, a potential probe for crack length measurement and other sensors. When closed, the upper side lies like a bell over the inner structure of the pressure cylinder.

With this testing machine, common and standardised tests for material qualification are now also possible under hydrogen pressure. Slow Strain Rupture Test (SSRT) with slow strain rates and test times of one to two days, for example, allow an initial statement to be made about the susceptibility of a material to hydrogen embrittlement. For fracture mechanical evaluations, crack growth tests and measurements of the critical crack length are performed – either based on the critical stress intensity factor K_{IC} or the J-integral.

COST-EFFECTIVE EXAMINATIONN As a cost-effective alternative to autoclaves, test benches for cylindrical hollow samples are also available in the laboratory. Their axially drilled oblong hole is filled with compressed gas from the inside. Internal pressures up to 100 bar and an optional temperature regulation allow strain rupture tests under operating-relevant conditions. Flushing before the start of the test reduces the gas contamination with air to a possible minimum. A constant test pressure is guaranteed by a two-stage pressure control and a permanent gas supply.

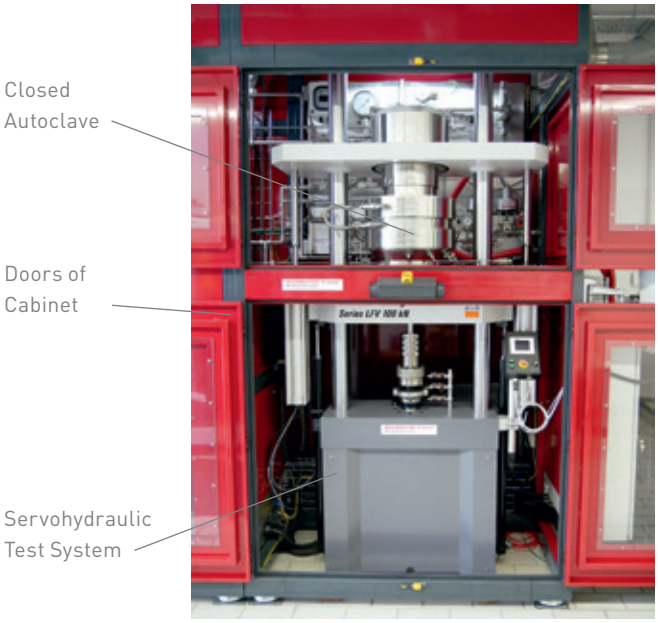


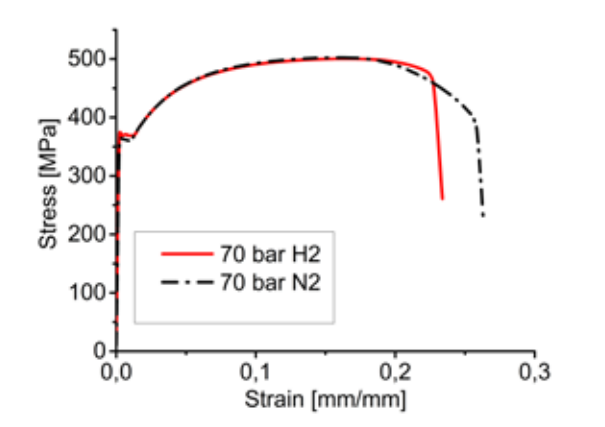
Fig. 2: Hydrogen autoclave in the test bench

This simple test bench makes it possible to examine materials at internal hydrogen pressure at low cost. However, it should be noted that the outside of the sample is not exposed to any hydrogen gas and therefore a gradient of the H_2 concentration is formed in the material.

For the comprehensive qualification of materials with regard to hydrogen embrittlement, supplementary permeation cells for measuring the H_2 diffusion coefficient, hot gas extraction for measuring the total hydrogen in the material and thermal desorption spectroscopy for measuring the trap binding energy of the hydrogen in the material are available.

These test devices can be used to measure important material properties, for example for the optimisation of heat treatments to expel hydrogen. In addition, the measurement results provide important characteristic values that can be included in simulation calculations. With suitable simulation methods, local hydrogen concentrations in a component can be calculated as a function of time, temperature and stress, for example, or service life predictions can be made together with mechanical qualification. ||

Fig. 3: Stress-strain curves of hollow samples filled with hydrogen or nitrogen, with an internal pressure of 70 bar, tested at a draw-off rate of 3.5 µm/min



SSRTs on StE 360 pipeline steel show a clear effect of hydrogen on elongation at break compared to reference tests using nitrogen under pressure, see Fig. 3.

We would like to thank the Federal Ministry of Education and Research and the Ministry of Finance and Economic Affairs of Baden-Württemberg, Department 71, for their financial support for the new laboratory.

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Category: Development | **Author:** Maximilian Möckl, Dr. Maximilian Bernt

IRIDIUM COULD SLOW DOWN ELECTROLYSER RUN-UP

How limited raw materials set limits for the economy

Although hydrogen produced from renewable energies has been under discussion for decades as a possible alternative to fossil fuels, it has so far only played a minor role. Recently, however, there have been signs of change, so that "green" hydrogen could gain momentum in the energy sector: More and more powerful electrolysis systems are available, and the prices for these systems are falling. If, however, PEM electrolysers were to be added on a large scale, iridium could become scarce and thus more expensive and thus stand in the way of a reduction in the already considerable investment costs. At present, iridium-based catalysts are not yet particularly relevant for total costs, but this could change soon. Therefore, in this article we would like to highlight the role of the raw material iridium, which is critical for PEM electrolysis, and show a possible solution against scarcity.

PEM electrolysis with its high dynamics, its outstanding hydrogen quality without complex post-treatment steps, its very high power density and the already high technological maturity represents a particularly promising technology for H_2 production. A major boost is also currently coming from increasingly cheaper renewable electricity generation capacities. Low electricity prices are essential for the competitive electrolytic production of hydrogen. Hydrogen from the classic steam reforming of natural gas currently costs about 2 €/kg including investment, operation and maintenance of the plants [1]. If the H_2 gas were to be produced electrolytically with a system efficiency of 70 percent (Lower Heating Value – LHV), electricity costs of 4 Ct/kWh would already result in 2 €/kg operating costs (neglecting all other costs incurred in purchasing and operating the electrolyser). In order to be on a par with conventional fossil fuel production, the total costs for electrolytic hydrogen must be reduced even further.

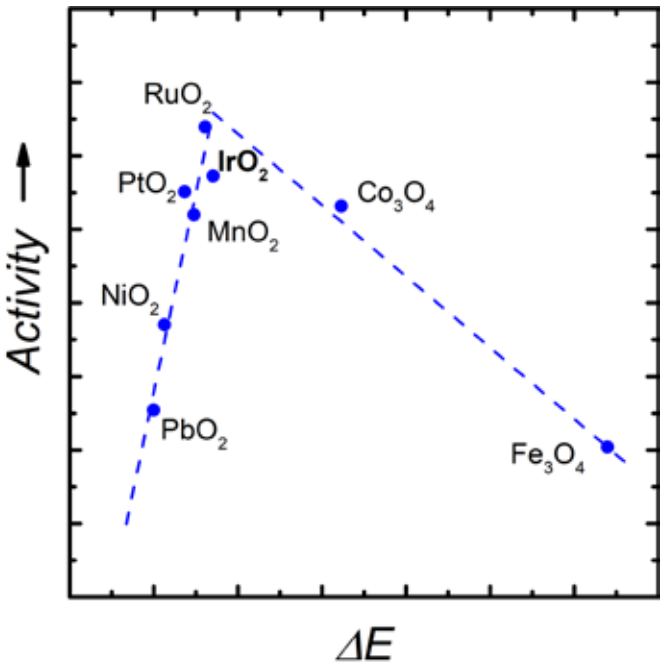

Fig. 1: Vulcano plot of different metal oxides for oxygen evolution, according to [2]

IRIDIUM IN PEM ELECTROLYSIS Water splitting during electrolysis takes place at the anode and is a relatively slow reaction. For each molecule to be cleaved, four electrons must be transferred during this oxygen evolution reaction (OER). Accordingly, a highly active catalyst is important in order to keep overvoltage and thus losses to a minimum.

Abbildung 1 shows in the so-called Vulcano plot the activity of different materials for the OER over the affinity of the products and educts of the reaction to the material surface: Neither should the surface of the catalyst allow the water to adhere poorly (left area), nor should the products O_2 and H^+ only be detached hesitantly (right area). Thus, the materials near the tip of the Vulcano plot in particular are theoretically well suited for use as OER catalysts. In real operation, however, the stability of the materials is another decisive aspect.

At the anode of a PEM electrolyser there are high potentials of more than 1.23 V at a pH value close to zero. This strongly oxidizing environment further restricts the selection of possible materials. Although ruthenium dioxide would be more active as a catalyst than iridium dioxide, it is eliminated for reasons of stability, as are the other materials shown in Figure 1. Therefore, there is currently no sensible alternative to iridium-based catalysts for OER in PEM electrolysers.

In common systems catalyst loads of about 2 mg_{Ir}/cm^2 are used on the anode [3]. With a cell efficiency of 70 percent (LHV) and a corresponding cell voltage of 1.79 V, current densities of about 1.5 A/cm^2 can be achieved in real systems today [4]. This means that the iridium requirement for a 1 MW plant today is around 750 g [5]. Although iridium is more expensive than platinum (24 €/g) or gold (39 €/g) with market prices (as of May 2019) of around 45 €/g, the impact on total costs remains small at present (see Fig. 2).

The stack accounts for around 60 percent of system costs. Of this, 51 percent is accounted for by titanium bipolar plates, while the costs of the iridium catalyst at the anode account for only 6 percent of the stack costs and thus only around 4 percent of the total costs of the electrolysis system.

CHANGE IN COST STRUCTURE WITH STRONG EXPANSION OF PEM ELECTROLYSIS SYSTEMS As a rule, it is assumed that economies of scale in production and further development, especially of the bipolar plates and transport layers made of titanium, can significantly reduce the costs for stacks and systems in the future [7]. However, there is a fundamental problem that stands in the way of a simple upscaling: The availability of iridium is very limited.

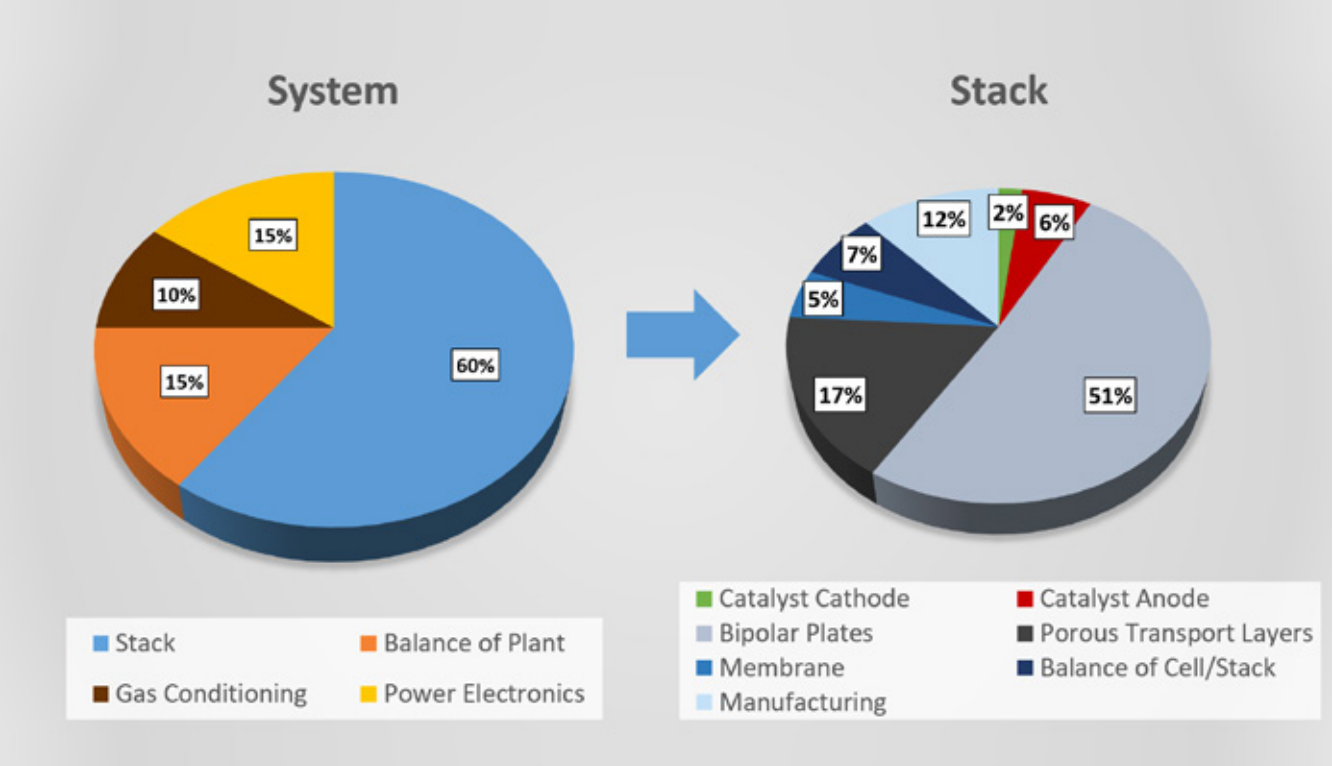

Fig. 2: Cost structure of a PEM electrolysis system, according to [6]

A few years ago the annual supply (mining, recycling) outweighed the demand, but in the last three years both values approached each other due to an increasing demand and at the same time a slightly decreasing availability. However, the current trend points in the opposite direction (increasing availability, decreasing/staggering demand). Accordingly, iridium demand in 2018 was about 6.9 t with a simultaneous availability of 7.1 t [8].

According to experts, the output can be increased under certain boundary conditions, but not by large amounts. If a large part of the annually available amount of iridium were now used for the addition of PEM electrolysers, the prices for this material could rise sharply and in extreme cases the cost structure could dominate with an otherwise largely optimised system (see Fig. 3).

With the already mentioned current output-specific iridium loading of 0,75 g_{Ir}/kW, an addition of 1 GW PEM electrolysis plants per year would require 0.75 tonnes of iridium, 10 GW already 7.5 tonnes and 100 GW 75 tonnes. These figures have a very high effect at the current expansion rates which are only in the MW range. But if global mobility were to be completely converted to hydrogen by the end of the 21st century, conservative estimates would suggest that the gigantic amount of about 150 GW of electrolysis power per year would have to be added [9].

In order to achieve this goal with PEM electrolysers alone, it would be necessary to reduce the power-specific iridium loading to values of 0.01 g_{Ir}/kW (with the same efficiency of 70 percent, LHV). Of course, part of the hydrogen demand could also be met by other technologies (e.g. alkaline >>

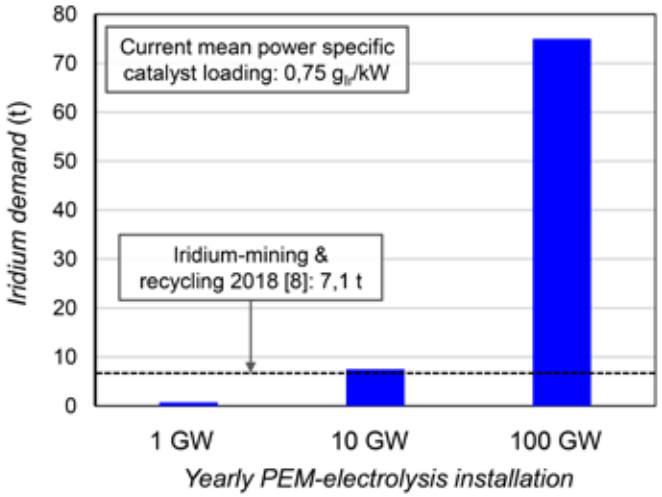

Fig. 3: Iridium demand with different annual additions of PEM electrolysis capacity

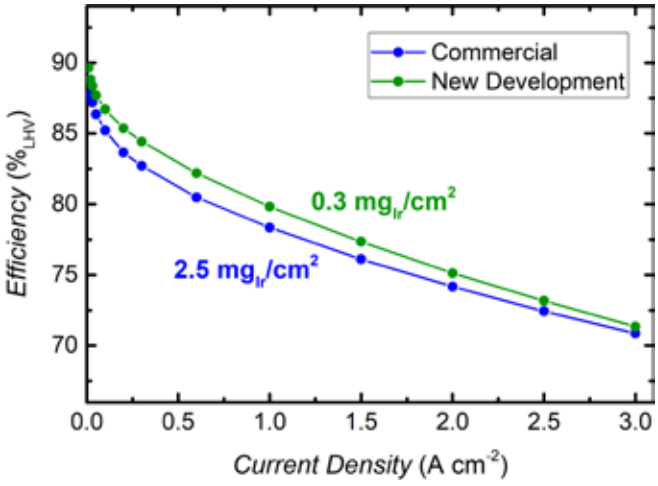

Fig. 4: Comparison of cell efficiency with commercial benchmark and newly developed catalyst

or solid oxide electrolysis). Nevertheless, the example shows that a drastic reduction in iridium consumption will be unavoidable in the future.

NEW CATALYSTS AND IMPROVED PERFORMANCE In order to achieve the required large performance-specific load reduction, two set screws can be turned in parallel: 1) Development of novel catalysts that provide the same or better performance with reduced iridium loading and 2) intensification of power density while maintaining high efficiency.

Both goals are pursued within the framework of the BMBF-funded project Kopernikus P2X in research cluster A1 by a consortium of the Technical University of Munich, Ludwig Maximilian University Munich, Forschungszentrum Jülich, Helmholtz Zentrum Berlin, Helmholtz Zentrum Erlangen-Nürnberg, Bayerisches Zentrum für Angewandte Energieforschung and the companies Linde, Heraeus and Greenerity. Through intensive work over the last two and a half years and the networking of basic, applied and industrial research, it has been possible to take a major step towards the desired goal.

Although the Ir charge of the membrane electrode assemblies (MEAs) was reduced from 2.5 mg_{Ir}/cm^2 in the benchmark system to 0.3 mg_{Ir}/cm^2 , the MEAs developed by Greenerity are more efficient in the entire current density range up to 3 A/cm^2 with the novel catalyst from Heraeus (see Fig. 4). The high current densities can be achieved by using thin membranes, which eliminates most of the ohmic losses in the cell.

With the system shown here, the performance-specific iridium loading at an efficiency of 70 percent (LHV) is reduced from 0.75 g_{Ir}/kW to about 0.5 g_{Ir}/kW with the benchmark catalyst and to 0.06 g_{Ir}/kW with the catalyst layers optimised for the newly developed catalyst by using the thinner membrane. This significant reduction shows that optimised catalysts and membrane electrode assemblies can solve the problem of increasing iridium demand for PEM electrolysis plants on a GW scale. Based on these promising results, securing the long-term stability of the new catalyst system and the more powerful membrane electrode assemblies will now be the central task for the consortium in the further course of the project. ||

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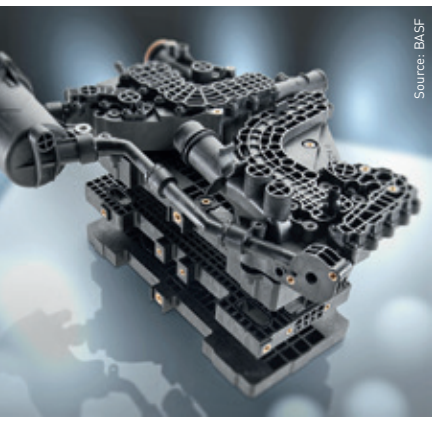
RECOMPRESSION OF HYDROGEN


Source: Mehrer Compression

During this year's Hannover Messe, Mehrer Compression GmbH presented its new, oil-free high-pressure compressor TRx 400 for the first time. This air-cooled piston compressor is designed in particular for a pressure range from 35 to 200 bar and is thus suitable for the post-compression of gases such as hydrogen, nitrogen or oxygen, but also of other process gases and gas mixtures, as well as for the filling of gas cylinders and for synthesis gas storage. The high-pressure compressor can be designed for one or two-stage compression, whether for H_2 recompression of electrolysers or O_2 recompression of gas generators. Toxic and flammable gases can also be used. According to the South German manufacturer, the TRx 400 is considered robust and guarantees high availability. ||

NEW FUEL CELL PLASTIC


Source: BASF

In March 2019, the chemical company BASF presented a new material for the production of fuel cell components: Ultramid®. The automotive supplier developed this technical plastic in cooperation with Joma-Polytec and Mercedes-Benz Fuel Cell. Stefan Milimonka of BASF's Performance Materials company division explained: "Since previous tests with other materials revealed mechanical abnormalities, Daimler had specific requirements for the material. Thanks to our expertise in automotive plastic components, we have identified the right material."

After successful testing of all components, the partners opted for two glass-fibre-reinforced Ultramid® grades, which are now used in series production for anode and cathode end plates in fuel cells. According to the manufacturer, the A3WG10 CR and A3EG7 EQ tailor made grades have good thermal and chemical resistance, dynamic strength, toughness and good continuous service properties. Especially with the FC media distribution plate and the water separator unit, which are exposed to different media with the cooling water, air and hydrogen ducts, this material shows its resistance and at the same time meets the purity requirements. "We have taken a big step in the series development of the fuel cell," said Stefan Heinz, Deputy Development Manager Plastics Technology at Joma-Polytec GmbH, summing up the results.

The Ludwigshafen-based company has not been active in the membrane sector since August 2013, when it divested its subsidiary BASF Fuel Cell Inc. in Somerset, New Jersey (see H2-international Oct. 2013). ||

PRESSURE RELIEF BY MEANS OF BURSTING DISCS

At the Battery Show Europe in May 2019, Bormann & Neupert by BS&B GmbH in Stuttgart presented a bursting disc specially designed for fuel cells and lithium-ion batteries. Bursting discs provide controlled, directed relief at critical overpressures in energy systems and thus protect users and applications, whether in the vehicle sector or with mobile machines.


Source: Bormann & Neupert by BS&B

The maintenance-free eVent bursting discs are compact, ready-to-install predetermined breaking points for the low and medium pressure range and offer pressure relief in the smallest diameters (from 3 mm) and at low response pressures. If necessary, they open the largest possible outlet cross-section with a favourable flow shape in order to quickly relieve the pressure in the event of a rapid rise in pressure (e.g. due to overheating) without damaging the housing.

According to the Düsseldorf manufacturer, the eVent bursting discs guarantee freedom from maintenance and permanent vibration resistance over the entire service life, which gives them advantages over safety valves, for example, especially in the case of small installation spaces. ||

NEW NAFION™ MEMBRANE

In May 2019, the US chemical company Chemours launched a new generation of its Nafion™ membrane to the market. According to the Fayetteville, North Carolina-based company, the NC700 polymer electrolyte membrane has improved chemical resistance and a higher productivity rate. Nafion™ is a per-fluorinated copolymer that was developed in the late 1960s as a modification of Teflon and is considered the industry standard for ion exchange membranes in fuel cells.


Source: Chemours

Mark Vergnano (l.) at the award ceremony in Anting, China

In April 2019, the Chemours Company received the Fuel Cell PEM Special Contribution Award for the development of this membrane during the International New Energy & Intelligent Vehicle Forum in Anting, Shanghai. Mark Vergnano, President and CEO of Chemours, which was spun off from DuPont in 2015, stated: "On behalf of Chemours, I am delighted to receive this prestigious award. The energy market is an important growth area for Chemours and we are committed to partnering with the new energy vehicle industry to continue providing innovative solutions that meet today's needs and tomorrow's challenges". ||

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

CHINA SWITCHES TO FUEL CELLS

Stock analysis by Sven Jösting

The momentum for the fuel cell is constantly improving with increasing dynamics. Recent co-operations such as those between Bosch and PowerCell, but also positive statements on fuel cells from automobile manufacturers such as Audi are attracting attention. Will China be the driver again, as it was when the batteries were introduced and before that in the field of renewable energies? There, new funding guidelines are about to be introduced, which are intended to favour and strongly promote the fuel cell and the hydrogen infrastructure, while the subsidies for purely battery-operated vehicles will, depending on the radius, be abolished in full or to a large extent. The German automotive industry will have to rethink and massively supplement the one-sided approach of battery preference that it has just embarked on with fuel cells. Instead of being a front-runner, Germany will only become a follower. China is setting the pace – and is now focusing on developments in Japan as the future "Hydrogen Society".

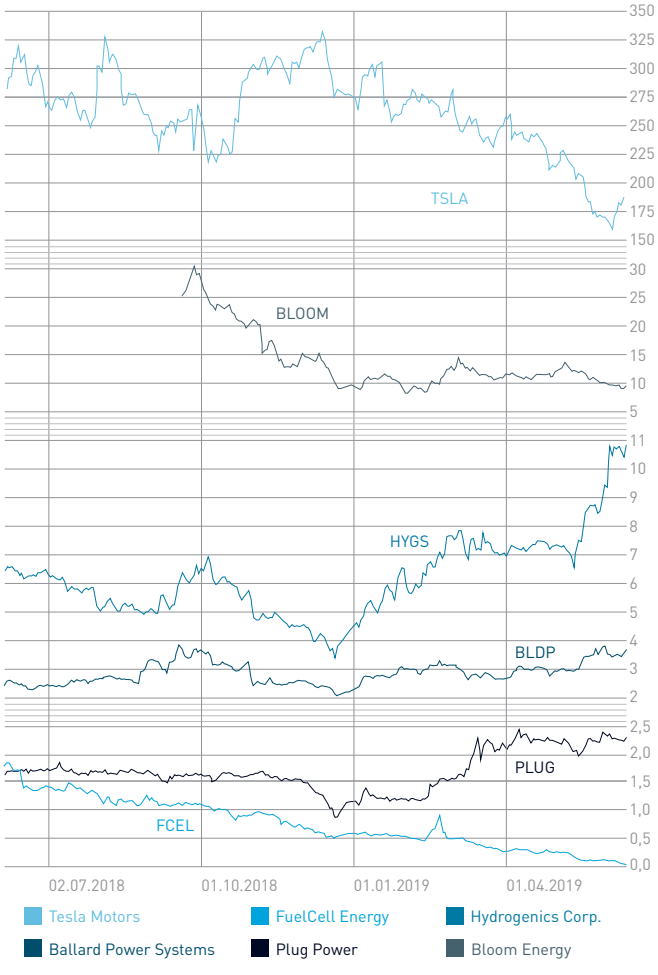


Fig. 1: Share price development of the six discussed companies
Source: www.wallstreet-online.de, Prices from 31 May 2019

BALLARD POWER – "MAJOR NEW CUSTOMERS"

This sentence stuck particularly with me, because Ballard – although already on board with many top partners and large companies in research technology – expects further major new customers, according to CEO Randy MacEwen in the telephone conference on the occasion of the figures for the fourth quarter of 2018. With all this know-how, this is not surprising, since Ballard is technologically ahead of the market. Ballard himself now has to raise money for the production venture with Weishai for LCS-Stracks, because they are setting up a production facility in China in which Ballard holds 49 percent. Although only small quantities are expected for 2019, the breakthrough in terms of volume is likely to take place in 2020.

Investors must be prepared for the fact that the year 2019 will first result in a capital outflow of more than US$ 20 million (investments) and that logical losses will result from this before the harvest (= orders, sales and earnings) from LCS production can accrue after 2020. New major customers, however, are creating course fantasies, as the focus is on research funds/projects, but also on the production of FC stacks. In my opinion, this will result in high-margin new business with good prospects.

So ABB's order for a flagship and a ferry can be seen as an indication of where major orders are waving sooner or later. Even the receipt of an order for twenty FC stacks for buses in London from the Irish company Wrightbus is only a drop in the ocean for the time being. It has just started. Meanwhile, Ballard partner Van Hool plans to produce one FC bus per day soon. Since this would probably require two stacks each, this partner alone could purchase 600 stacks annually.

2020 A DECISIVE YEAR FOR BALLARD Ballard is working on many projects and research partnerships in different product groups around the fuel cell as well as in different markets, so that with the start of production of the LCS stacks important bases for sales, orders and above all sustainable and increasing profits are created. 2020 should finally be the year in which Ballard moves from being an R&D company to becoming a manufacturing one and makes the transition to profitability with a strong upward trend.

CONGRATULATIONS ON THE 40TH COMPANY BIRTHDAY On 22 May 2019, Ballard celebrated its 40th anniversary at its Canadian headquarters in Vancouver. Present was the co-founder of Ballard, Paul Howard, who made a very fitting statement: "It takes time for new technologies to really establish themselves in practice. That's why I tell the doubters: We need the benefits of hydrogen. For humanity to survive, we need hydrogen, which is essentially a limitless source of energy."

Fig. 2: PowerCell stacks at the Hannover Fair 2019

Since its foundation, the company has invested over US$ 1 billion in research and development in order to always be the market leader. It is interesting to note that the founder first focused on the lithium battery, but then realised that the future lay in the PEM fuel cell.

BOSCH JOINS POWERCELL The report was explosive: Bosch enters into a license deal with the Swedish company PowerCell and transfers 50 million euros. For PowerCell, an accolade and, at the same time, a direction set by Bosch, which is now also increasingly focusing on the fuel cell. What does this possibly – pure theory – have to do with Ballard? PowerCell was selected as a partner/supplier by Nikola Motors, which will launch hydrogen-powered hybrid trucks (13,000 pre-orders, 400 H_2 filling stations to be built with Nel Asa) from 2020 onwards. But who does Nikola rely on as a supplier?

Let me just fantasise: It could be Ballard, because representatives of the company were also present at the presentation of Nikola Motors, a statement made during the second quarter conference call. Is Nikola possibly waiting for the use of Ballard's new high-performance LCS stacks? You can be curious.

PowerCell's share price on the stock exchange rose from 3 euros to over 9 euros as part of the reports on Bosch. Today PowerCell has a rating that is not far away from that of Ballards, but the Canadians have the much better positioning (including in China). If Ballard also had top new customers such as Bosch, a short development comparable to that of PowerCell would not be unrealistic. Meanwhile, these are pure mental games of mine – theory.

WEISHAI PLACES STRONG INITIAL ORDER Parallel to the quarterly figures, Ballard was able to book an order worth US$ 44 million from Weishai. That's a good sign. After all, Ballard holds a share of over 70 percent of the approximately 2,700 trucks and buses in China equipped with a fuel cell system – not bad.

Ballard also announced various projects. According to the plan, heavy goods vehicles in Alberta, for example (funding program over C$ 15 million) will be converted to fuel cell propulsion. Also with drones (Ballard Unmanned Systems Inc., formerly Protonex), success was achieved in range, flight duration, weight and tank pressure. In addition, individual orders were won for the construction of ship prototypes (ferry in Norway). All these prototypes and test series are likely to become new high-growth markets for the company in the future. So if you want to bet on the fuel cell, you can't get past Ballard.

FIRST QUARTER FIGURES At around US$ 16.3 million, sales were anything but good, but in line with expectations. The same applies to both the loss and the capital stock, which – despite investments in the Chinese LCS production facility – is still in excess of US$ 160 million. A very healthy cushion. The next quarters one to three will not be overly positive either. However, the naming of new major customers will then have a clear impact on the development of the stock market (see PowerCell). I find the comment from CEO MacEwen particularly important that China is planning to introduce completely new funding guidelines for the use of fuel cells and the H_2 infrastructure, which should be in place by the end of June. On the other hand, depending on the radius, the funding of certain battery-operated vehicles is either stopped altogether or reduced by up to 50 percent. The German automotive industry should take note of this – but also companies like Tesla. If China really puts it foot down – and it looks they are going to do that – then this has serious consequences, which would be good for Ballard.

PLUG POWER – EXPECTATIONS ARE NOT EVERYTHING

Plug Power was not able to meet the rather full-bodied expectations of sales in the first quarter. It was 18.6 million US$, 13.5 million less than expected. The loss per share is US$ 0.15. Plug, however, expects that the figures for the year as a whole will generate sales of between US$ 235 million and US$ 240 million and that EBITDA will be positive. New orders in the range of US$ 55 to 60 million are expected for the second quarter.

There will be various very positive news to be published in the course of the year, according to the CEO in the telephone conference. This applies in particular to the new ProGen stack, which is to be used in various vehicles. Since FedEx is often mentioned, it is possible to deduce the forecast from this that orders will now be received after test series. Plug is still looking for a suitable partner for system integration, because the company is too small in terms of manpower for such a potential major order. One can now hope for the supposedly very good news that the CEO has promised for the current year. From a trading point of view this is a clear buy.

HYDROGENICS – PERFECT FOUNDATIONS FOR 2020 FF

Forget the company's operating figures this year. An important factor is the sharp rise in the order backlog, which has already reached US$ 150 million. Good news everywhere, which will determine the stock market price of the future: Alstom has won orders for a further 27 trains, supplied by Hydrogenics for the FC stacks. In four countries there >>

is already concrete interest in FC trains, and eight other countries are on the verge of investing here as well.

The world's largest electrolyser with a capacity of 20 MW is built for Air Liquide in Canada. In New Zealand, the company received an order for a 1.5 MW project from Halcyon Power. It is interesting to note that they are working with Daimler Freightliner and Siemens on FC stacks in California. We are talking about trucks here.. The share price has performed very well, but the potential should always improve.

BLOOM ENERGY – ON THE RIGHT TRACK

In the first quarter, Bloom was able to generate a good US$ 200 million in sales. The bottom line was a minus of US$ 8.8 million or minus US$ 0.22 per share. Nevertheless, a noticeable improvement compared with the same quarter of the previous year, in which a minus of US$ 22.5 million was reported. This represents growth of around 18.5 percent. The cash position is very healthy, amounting to US$ 327.9 million plus US$ 42 million from Power Purchase Agreements (PPAs).

According to its own statement, the company is working on increasing the internationalisation of its network-independent FC power plants, which are used by companies such as Apple Computer. The proportion of institutional investors with over 40 percent is very healthy. This is why Bloom is also a key FC investment, as large investors primarily focus on companies with higher stock market valuations (liquidity in trading shares). The share should break out of the fluctuation range of US$ 12 to 15 this year. I'm expecting prices of US$ 20 or more.

FUELCELL ENERGY – REVERSAL SPLIT AS TURBO OF THE DOWNWARD TREND

FuelCell had to feel what it means to fall for smart investors (loan sharks?). The preference shares that could be converted into ordinary shares were probably used to push down the price via short selling and to receive more and more shares due to a conversion ratio. Did the analysts who evaluate and recommend FuelCell Energy simply overlook this? Now the capital has been merged. The number of artificially inflated shares via conversion of preference shares has now been significantly reduced. Unfortunately, all this seems to leave the management cold, otherwise they would at least make a press release.

The price, which was calculated at US$ 2.20 before the reversal split, then fell further to almost US$ 1.00. Is this provoking a delisting in order to buy up the company cheaply? I am counting on the fact that it will soon be possible to return to normality and that corporate partners such as Generate Capital will constructively support the refinancing of debts (arising from the purchase of various FC projects) and possibly act as purchasers of shares for stabilisation and participation – without any commitment. Because one thing is for sure: FuelCell Energy has good active know-how and has built many FC systems.

The fact that Exxon (Carbon Capture) takes such an unusually long time to win projects/contracts is logical, because both sides have massively stirred up the media. What is not yet will hopefully come. The further price slump after the reversal split was unfortunately to be expected, but a stabilisation at a higher level should now come. And the Nasdaq listing will be maintained because the share price will again be quoted above US$ 1.00. Unfortunately, it is all a crime thriller in which you don't know why certain players have such a great interest in harming the company.

It is also clear that the current valuation, given the company's know-how, order backlog and own FC power plants, could quickly tempt a large plant manufacturer to swallow the company. The fact that another FC power plant "Bridgeport" has recently been taken over for US$ 35.4 million, I interpret as a positive signal.

TESLA – THE STOCK EXCHANGE PUNISHES THE COMPANY

Firstly, all Tesla shops should be closed, because it would be easier to sell the vehicles via the Internet, then some showrooms should remain, because firstly, Tesla would like to continue to be present in important locations (big cities) and secondly, Tesla would not be able to get out of long-term rental agreements without paying a penalty. Such a report doesn't really belong in public, but Elon Musk is very special.

Then the new SUV model Y was introduced, which will only be delivered sometime in 2020. Analysts from various investment banks have expressed criticism that this new model could compete with the Model 3, since some Model 3 pre-orderers are now switching to the Model Y. After all, there is little difference in price, but the Model Y is even more appealing in terms of features/optics. Unfortunately, there are no exact numbers of how many Model 3 pre-orders are still available.

Fig. 3: By no means a spectacular Tesla stand at Intersolar, but still of great interest

It was well known that Tesla urgently needed new capital, especially as a convertible bond in March reduced cash holdings by over US$ 920 million and almost half of the remaining US$ 2.2 billion was due to advance payments. A good US$ 2.7 billion in fresh capital now flowed into the account: 3.55 million new shares were issued for US$ 243 each, and a new convertible bond (Senior Notes, maturity 2024) in the amount of US$ 1.84 billion with a 2% coupon was purchased. Elon Musk himself used US$ 25 million himself to participate in the capital increase. But be careful: This is a clever manoeuvre to build trust. On the other hand, he pledged 13.4 million shares for personal loans. This is supposed to be an amount of 500 million to 1 billion US dollars – without any commitment – so that the 25 million US dollars are rather symbolic like peanuts.

It is interesting to note that very many media (print and TV) regard this US$ 25 million as a very important positive argument. Musk has reached his goal, chapeau. Meanwhile, Elon Musk's next mistake immediately followed, as he considers the US$ 2.7 billion to be sufficient for only ten months and a savings program will be started.

FIRST QUARTER FIGURES Sales rose to US$ 4.54 billion, an increase of more than 30 percent compared with the prior-year quarter. However, the market had expected sales of US$ 5.3 billion. The loss was in excess of US$ 700 million, which is a loss of US$ 4.10 per share under GAAP. One can now be curious to see how the second quarter will turn out, as many Model 3 are "in transit" to Europe and Asia. However, this could only be a brief positive effect, which is reflected in the April figures, but has little impact on the second quarter as a whole.

ARE YOU KIDDING ABOUT PANASONIC? With Panasonic, Elon Musk now also seems to throw himself overboard, as both sides accuse themselves that there is no sufficient demand for accumulators. For the time being, Panasonic does not plan to use further funds. Instead, a cooperation with Toyota is planned. That doesn't sound good, because I think Panasonic has set up the battery cell production lines at Tesla's Gigafactory in Nevada on the basis of contract guarantees. They want to be busy. But now there are rumours that Panasonic has already incurred losses of over US$ 180 million.

In addition, Tesla plans to develop its own insurance policy. But those who completely dissuade Tesla from doing so are investor legend Warren Buffet in a talk show on CNBC. The man must know, because via Berkshire Buffet is one of the world's largest investors in insurers and holds important participations. It's not that easy to just create an insurance policy, says Buffet.

MUSKS TWEET MANIA At first it was thought that EM's tweet, which referred to the annual production of all models and was subsequently relativized "on an annual basis", would have no effect on the agreement with the SEC – far from it, because the agreement now has to be understood differently: It was not about the content of the tweet, but about the promise that each musk tweet, related to Tesla, would have to be approved in advance by the company itself, i.e. by the supervisory board or management. Musk must have forgotten. Now the court has reached an agreement with the SEC, and Elon Musk escapes a high penalty fee, but from now on must have all tweets approved by Tesla in advance. I wonder if he'll stick to it!

CHINA After Tesla received a loan from Chinese banks of over US$ 0.5 billion, construction is now underway on the second Gigafactory. Rumour has it that Tesla even applied for funds amounting to US$ 2 billion, but that may yet come. Having your own production facility in the important Chinese market is certainly the right step, but it could be very late in the day, because competition is growing strongly and the subsidies for purely battery-powered vehicles are being reduced.

FIATCHRYSLER DEAL FiatChrysler and Tesla have agreed on a deal under which FiatChrysler will acquire certain CO_2 certificates from Tesla because they themselves have not brought enough electric cars onto the market. Tesla probably received around US$ 140 million in the first quarter, which makes the result for the second quarter appear even more negative in arithmetical terms. A further US$ 140 million is expected for the second quarter. A nice gift for Tesla, but not sustainable.

OUTLOOKN The second quarter should also close in the red. The competition is getting closer and closer. Customs duties, as demanded by Trump towards China, do not make it any easier for Tesla. The expected shift in China towards fuel cells may have a more negative impact on Tesla in the medium to long term than one might think. Tesla has no FC or hybrid vehicle on offer. Some buyers of an electric vehicle for long distances may not be able to rely on a purely battery-operated car in China due to a lack of incentives/funding. In addition, evaluations according to which the Tesla autopilot, among other things, represents an important contribution to the company evaluation, are viewed very critically, since autonomous driving is not possible tomorrow.

My target price of US$ 200 has already been reached, and it seems exaggerated to see the shares only at a value of US$ 10, as Morgan Stanley analyst Adam Jonas recently said. It can however reach US$ 100, since I lack arguments, which speak for higher prices. It doesn't help if old rumours are warmed up that (according to hearsay from a fund manager) Apple computers had wanted to take over Tesla in 2014 for US$ 240 per share. At the time, I opposed the idea that it could be Apple that could launch a FC hybrid in two to three years' time if there were H_2 filling stations all over the country in important markets. That would be some kind of super-GAU for Tesla. We will see. ||

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: International | **Author:** Alexandra Huss

HYDROGEN AS AN EXPORT PRODUCT

Australia's number one export product was and is energy

Fig. 1: Up to now Australia has exported mainly liquid natural gas. [Source: Woodside: Woodside Donaldson LNG Tanker]

The city of Perth in southwestern Australia was already one of twelve cities worldwide at the beginning of the 21st century that tested fuel cell buses in local transport. After that, however, the energy-rich country no longer emerged as a major promoter of hydrogen and fuel cell technologies. And why should it? After all, the country has huge reserves of fossil fuels, precious metals and rare earth metals. But is that really reason enough not to look for alternatives?

Australia's main energy source and number one export product has been coal up until now. This huge country is by far the world's largest coal exporter (36.6 percent of all coal exports come from Australia) and the fourth largest coal producer. However, liquid natural gas (LPG) has now become almost even more important for export products, and Australian industry is now making more profits with LPG than with coal. As far as exports of liquefied gas are concerned, Australia is expected to overtake Qatar as world market leader before the end of this year.

South Korea, Japan and China are today the most important buyers of Australian coal and liquefied gas. However, the three countries have announced that in future they will shift their energy supply away from the use of fossil fuels and towards hydrogen. This applies in particular to Japan, which is the main buyer of liquefied gas from Australia. For the coal and gas industry – a powerful economic factor in the country – the signs are not good if fossil energy source sales cannot be offset by other, more climate-friendly products. The change in the energy strategy of the three neighbouring countries may therefore be a major reason why the Australian government under Prime Minister Scott Morrison sees the hydrogen economy as an important business segment for the country's future.

In addition, consumer prices for electricity and gas, which have been rising steadily for years, are among the highest in the world today. At first glance this seems to be a contradiction, because the country has huge fossil energy resources (coal, oil, natural gas) as well as land for the development of renewable energies (wind, solar). The strong expansion of wind and solar energy over the past four years has led the country to exceed its target of a 20% share of renewables in electricity generation by 2020.

THE AUSTRALIAN COAL AND GAS INDUSTRY But similar to Germany, the strong development of renewable energies means that the costs of development and expansion are passed on to consumers. And instead of providing more coal and gas for domestic energy supplies, the mining and oil companies prefer to sell these energy sources abroad with much higher margins. The government has been trying to counter this for some time, especially as it is not entirely innocent of the situation: The government situation in Australia, which has been unstable for years (six new and reorganised governments since 2010), has prevented a viable national energy policy. This in turn has led to the energy industry concentrating primarily on exports rather than on the domestic market.

Nevertheless, Australia has a fundamentally positive attitude towards hydrogen, which goes hand in hand with the government under Liberal Scott Morrison that came into office in the summer of 2018 and was confirmed in office in the recent parliamentary elections. Morrison and his Liberal Party are on the side of the coal and gas industry, which is also the real driver behind the Australian H_2 economy. Industry is under pressure, not only because of its neighbours' energy policies, but also because of international climate protection. Australia ratified the Paris Climate Convention in 2016 and committed itself to reducing greenhouse gas emissions by 26 to 28 percent by 2030 compared with 2005. This share corresponds approximately to the GHG share that is generated today by the generation of electricity from coal in Australia. Although GHG emissions from electricity generation have decreased due to the expansion of renewable energies and the shutdown of obsolete coal-fired power plants, they have risen sharply due to the expansion of LNG production. This has the effect that Australia lags far behind its climate targets.

H_2 TECHNOLOGY IS STILL IN ITS INFANCY Against this background, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the government agency responsible for scientific research in Australia, announced a National Hydrogen Roadmap in summer 2018. This announcement was accompanied by the publication of the Hydrogen for Australia's Future report by the Hydrogen Strategy Group of the COAG Energy Council of the Australian Government. This group is composed of representatives of the Australian energy industry, relevant associations and scientists. In the same period, the Australian Renewable

Energy Agency (ARENA) published a study on the export potential of hydrogen for Australia.

Australia has so far had little know-how of its own about hydrogen and hardly any added value of its own. The current state support programmes at the national, state and territorial levels serve above all to catch up in international comparison. With the participation of domestic industry and science, research, development and pilot projects for the production, transport and provision as well as for applications of hydrogen were initiated within a short period of time, which will be implemented in the coming years. This is how Australia's commitment to the international innovation mission, which emerged from the COP21 climate conference in Paris, is to be understood.

23 countries and the EU are working to strengthen and promote clean energy innovation worldwide as part of this non-binding initiative by participating governments. Together with Germany and the European Union, Australia is leading Mission Innovation 8 on renewable and clean hydrogen, launched in May 2018. Its aim is to accelerate the development of a global H_2 market by identifying and eliminating barriers to key technologies in the production, distribution, storage and use of hydrogen in the gigawatt range.

H_2 DEMONSTRATION PROJECTS In 2018, the South Australian government announced a first clean hydrogen plant near Port Lincoln. It is being developed by the joint venture Hydrogen Utility (H2U), in which ThyssenKrupp also holds a stake. The plant, worth 117.5 million (Australian) dollars, produces hydrogen using a 15 MW alkaline electrolyser. The plant also includes a 10 MW hydrogen turbine, a decentralised ammonia plant and a 5 MW fuel cell that provides control power for the power grid. Ammonia is an important raw material for the Australian chemical industry, which is to be produced with renewable hydrogen in the future. At the same time, ammonia is also seen as a potential source of H_2 energy source for export. The plant will also support two new solar farms and a nearby micro power grid used by local fish farms. The involved universities intend to use the plant for research on the establishment of H_2 value chains.

The Australian and Japanese governments are also promoting a joint H_2 project with industrial partners. The core of this project is the establishment of a fully integrated value chain in which hydrogen is produced and shipped as liquid hydrogen from the Australian Latrobe Valley in the state of Victoria to Kobe in Japan. The hydrogen is produced in several steps via lignite gasification and transported to Port Hastings, where it is liquefied, pumped into a specially built liquid hydrogen tanker and shipped to Japan. The project also serves to demonstrate how large quantities of hydrogen can be transported across the oceans.

The project consortium is led by Kawasaki Heavy Industries (see H2-international issue July 2017), which also includes Electric Power Development Company, Iwatani Corporation, Marubeni Corporation and the Australian utility AGL. The first hydrogen deliveries are planned for 2020/2021. Should the plant be commercialised after the pilot phase, the government's CarbonNet project in Victoria plans to integrate an additional carbon capture and storage (CCS) solution to reduce the CO_2 emissions associated with lignite gasification.

In addition, the government is promoting the addition of hydrogen to the natural gas grid as part of various power-to-gas projects. Examples are the projects H2Go and HyP SA. H2Go is the five-year project of the gas network operator Jemena in New South Wales. Hydrogen is produced from wind and solar power in a 500 kW electrolyser near Sydney and fed into the natural gas grid to supply up to 250 households.

In the Hydrogen Park SA (HyP SA) project, the Australian Gas Infrastructure Group (AGIG) in South Australia is investing $11.4 million in a PtG plant based on a 1.25 MW PEM electrolyser. The hydrogen produced with renewable electricity is fed into the local natural gas grid of the Tonsley Innovation District of Adelaide to supply households and businesses with low-carbon natural gas. ||

Fig. 2: ... and coal – in the future also hydrogen! [Source: BHP Billiton: Coal transport Australia Rail]

BUSINESS DIRECTORY

COMPRESSORS

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Sauer Compressors

J.P. Sauer & Sohn Maschinenbau GmbH, Brauner Berg 15, 24159 Kiel, Germany, Phone +49-(0)431-3940-0, sales@sauercompressors.de, *www.sauercompressors.com*

CONSULTING

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DISTRIBUTION

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

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

Reuther STC GmbH, Fabrikstr. 8, 15517 Fuerstenwalde, Germany, Phone +49-(0)3361-694-0, Fax -852, *www.reuther-stc.com*

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

ELECTROLYZERS

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

Diamond Lite S.A., Rheineckerstr. 12, PO Box 9, 9425 Thal, Switzerland, Phone +41-(0)71-880020-0, Fax -1, *diamondlite@diamondlite.com, www.diamondlite.com*

Enapter srl, Pisa, Berlin, Chiang Mai, Via di lavoria 56G, 56040 Crespina Lorenzana (PI), Italy, Phone +39-5064-4281, www.enapter.com

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

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

H-Tec Systems GmbH, PEM electrolyzers for industry application, Maria-Goeppert-Str. 9a, 23562 Luebeck, Germany, Phone +49-(0)451-39941-0, Fax -799, *info@h-tec-systems.com, www.h-tec.com*

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Eugen Seitz AG, Leading H_2-solenoid valve technology from 10 to 1,000 bar, Spitalstrasse 204, 8623 Wetzikon, Switzerland, Phone +41-44-9318190, *h2info@seitz.ch, www.seitz.ch*

Nova Werke AG, H_2 High Pressure Solenoid Valves, Vogelsangstr. 24, 8307 Effretikon, Switzerland, Phone +41-52-3541616, *www.novaswiss.com*

OMB Saleri SpA, Via Rose di Sotto 38/c – 25126 Brescia, Italy, *hydrogen@omb-saleri.it, www.omb-saleri.it*

PTEC – Pressure Technology GmbH, pipelines, screw connections, filters, valves, regulators, TPRD, Linde 11, 51399 Burscheid, Germany, Phone +49-2174-748-722, *mail@ptec.eu, www.ptec.eu*

FUEL-RECIRCULATION AND AIR-SUPPLY

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sera ComPress GmbH, sera-Str. 1, 34369 Immenhausen, Germany, Phone +49-5673-999-04, Fax-05, *info-compress@sera-web.com, www.sera-web.com*

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)

MeliCon GmbH, Metallic Lightweight Construction, Porschestr. 6, 41836 Hückelhoven, Germany, Phone +49-(0)2433-44674-0, Fax -22, *www.melicon.de*

SGL Carbon GmbH, Werner-von-Siemens-Str. 18, 86405 Meitingen, Germany, Phone +48-(0)8271-83-3360, Fax -103360, *fuelcellcomponents@sglgroup.com, www.sglgroup.com*

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ORGANIZATIONS

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ORGANIZERS (EVENTS)

Hydrogen + Fuel Cells ASIA, October 23–26, Hydrogen + Fuel Cells Europe, Hannover Messe 2020, April 20–24 Tobias Renz FAIR, *tobias@h2fc-fair.com, www.h2fc-fair.com*

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

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

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

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

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

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

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TEST STANDS

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

DATES

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

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

September 23 to 27, 2019
Joint European Summer School Introductory – week 1
near Athens, Greece
www.jess-summerschool.eu

September 16 to 20, 2019
Joint European Summer School Advanced – week 2
near Athens, Greece
www.jess-summerschool.eu

September 24 to 26, 2019
International Conference on Hydrogen Safety ICHS 8 in Adelaide, Australia
www.hysafe.info/ichs2019/

October 8 to 10, 2019,
Energy Storage World Forum, organized by Dufresne in Rome, Italy
www.energystorageforum.com

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

October 23 to 26, 2019
Hydrogen + Fuel Cells Asia
Part of CeMAT Asia
in Shanghai, China
www.h2fc-fair.com/asia

November 26 to 28, 2019
gat + wat
DVGW Congress in Cologne, Germany
www.gat-wat.de

DISCOUNTS + TICKETS

October 15 to 17, 2019
eMove360° Europe, in Munich, Germany
Free Tickets – Promotion-Code: EM19-AD97VS96,
www.emove360.com

November 21 to 22, 2019
Forum Neue Energiewelt, in Berlin, Germany
10 % Discount – Promotion-Code: HZwei_19_20
www.forum-neue-energiewelt.de