

THE E-JOURNAL ON HYDROGEN
AND FUEL CELLS

H₂international



→ THE COMMERCIAL VEHICLE
INDUSTRY DISCOVERS HYDROGEN

→ POLITICS PUSHES HYDROGEN AS
AN ENERGY STORAGE MEDIUM



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[Source: Nikola]

MORE TOGETHERNESS

The negative image of PtX

Dear Readers!

Despite the current wave of enthusiasm about the potential of hydrogen, there is much discussion and much uncertainty about the role of synthetic fuels. If you follow the current debate, you sometimes get the impression that e-fuels are either another saviour or a spawn of evil.

In short, it is a question of using green electricity and water by electrolysis to produce so-called “green” hydrogen in a sustainable way. If this is processed, for example by turning it into methane with the carbon dioxide from biogas plants, this is referred to as methanisation. It can also be used to produce other gaseous or liquid hydrocarbon-containing substances, such as methanol or synthetic fuel (power-to-liquid, PtL), which can then be used in internal combustion engines as before.

This is where the problem lies: Some stakeholders fear that the Power-to-X process will be used to misuse the positive image of green hydrogen so that inefficient combustion engines can continue to be used in the mobility sector for as long as possible. The advantages would be that these fuels would indeed be cleaner and more sustainable than petrol and diesel. This would also prevent additional CO₂ from being released into the air, but would only use the carbon dioxide that was already in the atmosphere anyway.

The disadvantages, however, would be that a comparatively inefficient technology would continue to be used and the switch to electric drives would be delayed. In addition, the large corporations from the automotive and mineral oil industry would continue to remain “in power”. And private transport could also continue to grow unabated.

It is now clear that a complete electrification, the All-Electric-World, will not come because there are industries that will continue to depend on a material energy source. For example, batteries can only be used to a limited extent in commercial vehicles because their weight limits their payload. Wherever large amounts of energy are required for long distances or large vehicles, pure electricity storage systems are at a disadvantage. As a result, only hydrogen and synthetic fuels can be considered for the maritime and aviation sectors, as well as for commercial vehicles and buses, in the context of advancing decarbonisation.

But even with hydrogen there is hot controversy as to whether grey and blue or only green H₂ should be used for a transitional period. Grey hydrogen is produced from natural gas – blue hydrogen, too, but with subsequent sequestration of CO₂ (Carbon Capture and Storage, CCS) – green hydrogen using renewable energies.

It is not always easy to understand why individual stakeholders have in the meantime opted for one way or the other. The fact is, however, that the Union-led Federal Ministries are open to hydrogen and PtL, while the SPD-led Federal Ministry for the Environment tends to focus on electrification. The liberals are similarly open as the conservatives, while the Greens present themselves as the great sceptics who actually support hydrogen, but, but, but ...

For some, the mere fact that the German Mineral Oil Industry Association (MWV, see H2-international issue Oct.

2019) is in favour of e-fuels alone seems to be sufficient to oppose this technology. Of course, the mineral oil industry would continue to benefit from this. “The proven German infrastructure with refineries, pipelines, fuel depots and filling stations can be fully maintained with climate-friendly power and fuel cells.” This is how it is to be read in the fuel mirror, the magazine of the UNITI Federal association of medium-size mineral oil enterprises, in November 2019.

But is it really advisable to vote against something just because others like it?

It is likely that – as is so often the case – it will amount to both good and bad. We will not be able to avoid e-fuels on our way to a more sustainable energy future, at least not for commercial vehicles, ships, trains and aircraft. Whether this also applies to blue hydrogen remains to be seen, as it is currently not foreseeable that this technology will meet with public acceptance in Germany. Here it could actually make sense to jump directly from the current grey hydrogen to the green hydrogen.

Actually, it's quite simple: Wherever possible, electricity from renewable sources should be used directly (e.g. short distances, delivery services). For more powerful and heavier vehicles (larger than SUVs) hydrogen makes more sense. It remains to be clarified whether the H₂ molecules will then be used in their pure form or as synthetic fuels. First of all, it is important that we now rapidly expand renewable energies and promptly ramp up electrolyser production.

Here in Germany we will only be able to generate a limited part of the huge amount of energy needed in industry, chemistry, mobility and heat supply. As in the past, we will have to import a large part, in whatever form and from wherever.

How all this will be implemented in concrete terms, however, remains to be seen in the coming months.

Sincerely



Sven Geitmann
H2-international editor



KERSTIN ANDREA HEADS BDEW



Since the beginning of November 2019, Kerstin Andreae has been the new Managing Director of the Bundesverband der Energie- und Wasserwirtschaft e. V. (Federal Association of Energy and Water Management). (BDEW). The economist had previously been economic policy spokeswoman for

the Green parliamentary group for many years, but resigned her seat in the Bundestag in October 2019. She takes over the job from Liberal Stefan Kapferer, who was announced in June last year that he will take over the chairmanship of the Management Board of the transmission grid operator 50Hertz, which then already happened in December 2019.

As a Green member, Andreae is surprisingly positive about hydrogen. She explained: “The energy source hydrogen is currently rightly called the all-round talent of tomorrow’s energy supply: It is ideally suited to promote the flexibilisation of the energy system and the decarbonisation of the transport, heating and industrial sectors.” She considers the provision of sufficient green gas to be a European project that can advance the entire local economy, which is why she expressly wishes to intensify the dialogue with industry in this area. ||

is expected to be completed by mid-2020 (total output: 800 MW) and the H₂ CHP plant will be commissioned shortly.

In Haßfurt, Siemens and 2G have already shown what such a plant can look like in a smaller dimension (120 kWel). The hydrogen combined heat and power plant at the local municipal utilities went into operation at the end of June 2019. The next order for a further plant in Germany has now been placed. Christian Grotholt, CEO and founder of 2G Energy, commented: “We are registering a lively and broad interest in our hydrogen know-how and are therefore optimistic that we will be able to further expand our technological leadership.

According to Frank Grewe, the company’s development manager from Heek (NRW), 1,150 g CO₂ per kilowatt hour are emitted when electricity is generated in a coal-fired power plant without combined heat and power. In contrast, a natural gas CHP plant emits 350 g CO₂ per kilowatt hour – an H₂ CHP plant 0 g CO₂. ||

GROWTH AND STRENGTHENING



Fig. 1: A. Steinau, J. Starr, S. Beck (from left to right)

At the annual meeting of the Clean Energy Partnership (CEP) at the end of 2019, a new management trio came together. Jörg Starr of Audi, who was recently elected Chairman of the Board, was joined by two Co-Chairs: Stefanie Beck from Toyota and André Steinau from GP Joule. In addition, the cross-industry industrial initiative was expanded by two new members: With EWE and GP Joule, both an energy supplier and a service provider joined CEP, which now comprises fifteen institutions. Starr also used the conference to prescribe a fresh cell cure for the company merger so that in future the H₂ and FC topic could be brought into the public eye with a little more momentum and vigour. ||

WRIGHTBUS CONTINUES DRIVING

Northern Ireland bus manufacturer Wrightbus was acquired by Bamford Bus Company (BBC) in October 2019 and is now working under Jo Bamford’s leadership on fuel cell integration and H₂ infrastructure expansion. The new CEO Buta Atwal, who like Bamford comes from the British agricultural machinery manufacturer J.C. Bamford Excavators Limited (JCB), explained: “We are entering an exciting phase with the recent announcement by the government of a new national bus strategy in 2020, in which decarbonisation will play a key role. Wrightbus has the opportunity to point the way with our success story in the production of modern, emission-free hydrogen buses, electric and hybrid models.” ||



Fig. 1: A hydrogen-powered agenitor 406 SG – a comparable model with twelve cylinders now available in Dubai

Hydrogen-powered combustion engines seemed dead after BMW had stopped development work on H₂ reciprocating piston engines years ago. This still applies to passenger cars, but not to commercial vehicles or stationary plants. In the sector of large combined heat and power plants, 2G Energy AG has long been working on making its gas engines compatible with hydrogen. How far this development has progressed in the meantime is demonstrated in Hassfurt, where Siemens AG received the order in July 2019 to build such a combined heat and power (CHP) plant in Dubai.

As part of a pilot project on the Arabian Peninsula, solar energy from one of the world’s largest solar parks is to be temporarily stored in the form of hydrogen. The electrolyser for H₂ production is provided by Siemens. 2G has already shipped its agenitor 412 (280 kWel), so that it can re-convert the green hydrogen upon demand. The project aims to demonstrate how solar energy can be generated, stored and used for other applications on a large scale. The solar park

FLEXIBLE, STRETCHABLE BIO-FUEL CELL

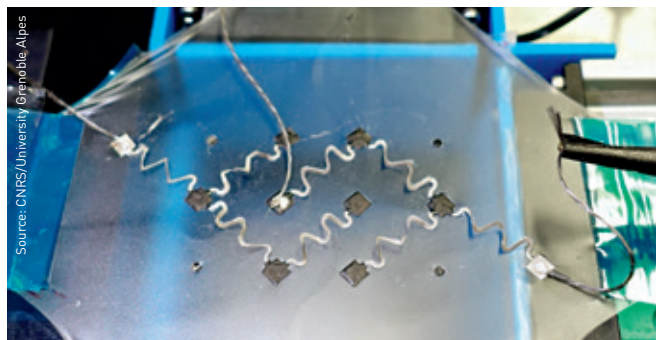


Fig. 1: Energy supply of a diode on the forearm via welding

In an international collaboration, scientists have developed a kind of “bio-fuel cell” that can be worn directly on the body and supplied with energy by sweat alone. At the end of September 2019, French researchers from the Département de Chimie Moléculaire (DCM), a research unit comprising CNRS (National Center De La Recherche Scientifique) and the Université Grenoble Alpes, together with US colleagues from the UC (University of California) San Diego, presented a new flexible and stretchable construction that could, for example, supply portable electrical devices with electricity.

As reported in the journal *Advanced Functional Materials*, the first experiments involved laboratory experiments

with carbon nanotubes and tiny biosensors. However, it is conceivable that in the future an energy supply using body fluids (e.g. lactate in sweat) could contribute to the permanent use of small electrical devices for medical purposes or for recording sporting activities. The researchers have already succeeded in ensuring that an LED lamp is permanently lit. Now they are working on increasing the resulting voltage, it was said. ||

LINDE JOINS ITM

In October 2019, gas manufacturer Linde acquired a stake in British electrolyser manufacturer ITM Power. Linde AG acquired a total of 95 million new ITM shares for EUR 45 million. The former German industrial group, which relocated its headquarters to Guildford in the UK after the merger with Praxair, now owns 20 percent of the Sheffield-based plant engineering company. In addition to this participation, there will soon also be a 50-50 joint venture that will provide green hydrogen for industrial projects. Graham Cooley, Managing Director of ITM Power PLC, said: “Linde’s major strategic investment cements a five-year relationship between us and offers ITM Power a leading global partner with extensive engineering, procurement and engineering expertise and a global customer base. The joint venture will enable us to focus on our core competence in the development and sale of electrolyzers and to supply environmentally friendly hydrogen on a large scale with Linde as a partner.” ||

SUJIN WREN, CLEAN ENERGY PROGRAM MANAGER, WOULD LIKE TO INTRODUCE OUR ADVANCED HYDROGEN FUELING STATION.



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F-CELL ATTRACTS NUMEROUS SUPPLIERS

Hahn-Schickard-Institut wins f-cell award for the second time

On September 10 and 11, 2019, the f-cell took place in Stuttgart for the 19th time, and as one could undoubtedly observe, the event has changed fundamentally over the years. After the focus on the trade fair in the meantime, the symposium is now more in the spotlight again. The central function of this autumn event for the international hydrogen and fuel cell industry, however, is networking, which became particularly clear this year.

For years, events such as the f-cell or the Hanover Fair were regarded as so-called navel-gazing, in which science and industry showed what they had developed and then pat each other on the back. This time less of the well-known stakeholders appeared in the House of Economy, but more newcomers. While some faces, which had come to the capital of Baden-Württemberg regularly over many years, were missing, organiser Peter Sauber was able to welcome all the newer faces.

In particular from the supplier sector, companies, some of which were still unknown, travelled to the fair to find out more about hydrogen and fuel cell technology, but also to introduce themselves to the community and offer their products and services (40 exhibitors). The comprehensive range of matchmaking discussions, workshops and topic tables offered a wide variety of opportunities for making contact and initiating business.

The conference, which was attended by around 250 participants on both days, had interesting lectures to offer, especially on the second day. Among others Bill Johnston, the Minister of Mines and Petroleum of Western Australia, reported about H₂ activities in Down Under, and Dr. Afkenel Schipstra about the plans in the Hydrogen Valley in the Netherlands, which has just been chosen by the EU.

Two highlights were added to the supporting programme this year: The day before, Jürgen Pfeiffer had invited to his political talk in the König-Karl-Halle

(see Fig. 2), so that this was well filled in the evening during the recording of the panel discussion – primarily with technically interested gentlemen of mature age. The focus was not only on the political framework conditions, but also on the economic orientation of companies in the automotive industry such as Audi and ElringKlinger.

FIFTH 24-HOUR HYDROGEN CHALLENGE

In keeping with this, a total of four teams set off during the day in a 24-hour race with fuel cell cars (Hydrogen Challenge) in order to drive as many kilometres as possible within one day or to visit as many H₂ stations as possible (in total: refuelling 39 times). Due to the coincidence with other events, unfortunately only a limited number of FC vehicles were available. The fifth car in the race was Tesla from Max Holthausen, who had to try to catch up with the other teams with his team outside the classification as Fuchs. In the meantime, Holthausen



Fig. 1: H₂ race provides for publicity



Fig. 2: Discussion with politics and business

accelerated his Tesla, which had been converted to be hydrogen-powered by hand, to 245 kilometres per hour during the race to catch up.

The HYghlanders were the winners of the classic classification (including kilometres driven). In the Creative category (best entry), Weiter-mit-Wasserstoff won. This team – consisting of members of the H2BZ-Initiative Hessen – also won the overall race in their Toyota Mirai.

All drivers were euphoric and satisfied after the race, as they all had some great experiences to report. Potential targets were spread all over Germany and beyond, from Berlin down to Zagreb and Bratislava. The actual routes, however, were limited to Central and Southern Germany between Koblenz and Munich, and to the north of Switzerland and Austria, where a team on the Himmeljoch drove through snow in minus temperatures in the middle of September.

AWARDS FOR DRIVERS AND DEVELOPERS The evening event once again took place in the Stuttgart Wagenhallen, where both the drivers and the award winners were honoured. The f-cell award in the research and development category went – once again – to the Hahn-Schickard-Institut in Freiburg. The young team had developed a new coating process using nanoparticles and nanofibers, which enables expensive iridium oxide (IrOx), which is required as a catalyst material by electrolyzers, to be saved while maintaining the same performance.

The prize in the Products and Markets category was presented by Franz Untersteller, Baden-Württemberg's Minister of the Environment, to representatives of Alstom for their FC train Coradia iLint.

"We need the fuel cell, and the fuel cell needs us."
 Franz Untersteller,
 Minister of the Environment of Baden-Württemberg

In 2020, f-cell will take place in Stuttgart from 29 to 30 September and will celebrate its twentieth anniversary. ||

HYDROGEN AND WINDENERGY

Where is the best place to demonstrate how hydrogen and wind power technology can grow together in the future? Northern Germany is certainly predestined for this (see p.

15). This is why Hamburg Messe und Congress GmbH with its WindEnergy has now set a clear course for offering both technologies a common platform at the world's leading trade fair for wind power.

From 22 to 25 September 2020, not only will the entire added value chain of wind energy be covered, but storage technology will also be presented as a new focal topic. Previously, the "Storage Tour" was held every two years in the Hanseatic city during the trade fair, during which visitors were guided to exhibitors of storage solutions distributed throughout the halls. Katja Löwe, Project Manager Wind-Energy Hamburg, told H2-international that this concept is now to be supplemented.

However, instead of continuing previous events with H2Expo, the Project Manager 2020 is fully committed to networking and internationalisation. Especially for start-ups, a H2Insights area is to be made available where as many contacts as possible can be made with as little effort as possible. In addition, the Power4Climate stage will offer space for the exchange of ideas with experts on future-proof solutions. With a new strategy, the trade fair company wants to consciously set itself apart from competitors and partners in Hanover or Husum and in this way establish Hamburg as a central location for wind hydrogen. Bernd Aufderheide, Chairman of the Management Board of Hamburg Messe und Congress, explained: "We're connecting the stakeholders in wind power production with the specialists in electrification, the conversion of renewable energy into hydrogen and H₂ applications." ||



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UNKNOWN AND EXPENSIVE

Home owners are insecure



Fig. 1: Coming in spring 2020 – the eLecta 300

After the gas industry, the heating industry is now also increasingly relying on hydrogen. Although the absolute sales figures for fuel cell heaters are still low, a clear growth trend can be observed. In 2019, the number of funding applications rose by 30 percent compared with the same period of the previous year. This at least gives the members of the Fuel Cell Initiative (IBZ) hope that a real market could emerge in the coming years. However, a turnaround in the heating sector cannot be spoken of here for a long time yet.

Once a year, representatives of the IBZ meet to bring each other up-to-date on the latest developments in fuel cell technology. And every year it is stated once again that the absolute sales figures are still low, that public awareness campaigns can be optimised, that the bureaucratic effort required to obtain funding is immensely high and that installers need to be more closely involved.

This was also the case on 29 October 2019, when around 70 industry representatives gathered in Frankfurt am Main and stated that “fuel cell heaters could make it possible for everyone to enter the hydrogen age”. In order for this to actually happen, however, there are still some prerequisites that need to be changed, and this is precisely what is happening at the moment. At IBZ, no one really knows what the best way might be to achieve sales figures in Germany similar to those in Japan.

For more than twenty years now, stationary fuel cell systems have been researched and developed in Germany. And at least thanks to good funding conditions, there is now a market in Germany that is growing – albeit slowly. On average, the installation of a fuel cell unit in Germany is funded with around € 11,000, but the price to be paid by the customer himself is still five times higher than for the purchase of a conventional condensing boiler.

According to Stefan Thiel, Sales Manager for Germany at Buderus Thermo-technik, the luxury segment is where FC heaters definitely pay off. For example, a fuel cell system without a peak load boiler, but connected to a water-operated wood-burning stove in an upscale single-family home, pays for itself comparatively quickly, especially if an electric car is available for recharging. Thiel openly admitted, however, that this was not a mass market.

AWARENESS LEVEL MUST BE INCREASED The industry representatives present showed their full understanding for the fact that many middle-income home owners do not purchase fuel cells in view of the significant cost differences that have existed so far. However, no one had any idea how this dilemma could be solved. That’s why everything revolved around the question of how production figures could be increased in order to get costs under control through series production.

After all, at least those companies that currently have FC heaters on offer are endeavouring to provide further training for craftsmen. It turned out, however, that only around 20 percent of installation companies can be described as so-called innovators and try to bring new technologies to their customers out of self-interest. In the unanimous opinion, education and training were still considered to



Fig. 2: Dr. Frank Voßloh

be of elementary importance. However, as this is associated with a relatively high expenditure, which hardly anyone would do, “the craftsmen are currently the bottleneck”, says Dr. Karsten McGovern, head of the Hessian State Energy Agency.

On the part of the house owners, there is also no sudden increase in demand, as there is still a large information deficit. Fuel cells still stand for the technology that has been developed for a long time and that will not come for another ten years. At the same time, very few people know exactly how this technology works. A lot of educational work had to be done here, the IBZ spokespersons Timm Kehler and Andreas Lücke stated once again, but without presenting any concrete measures. Dr. Timm Kehler, Executive Board of the Future of Natural Gas industry initiative, was sobered to note: “FC heaters are simply not well-known enough.” Alexander Dauensteiner, who after 17 years with Vaillant switched to his competitor Viessmann in autumn 2019, also stated that there was simply no appropriate marketing.

Nevertheless, the representatives of the IBZ member companies were absolutely convinced of the advantages of FC technology. It also became clear, however, that a niche still needs to be discussed here, given the total number of 21 million households with heating systems in Germany. The importance that fuel cells have for these companies can therefore continue to be described as small, which inevitably also applies to their significance within the overall energy supply.

Dr. Frank Voßloh, Managing Director of Viessmann Deutschland GmbH, explained that he was a “fan of the fuel cell”. However, this is not enough, as the current uncertainty among consumers is leading to the withdrawal of numerous reservations. The reason for this is the climate package launched by the federal government in autumn 2019, in the framework of which it was announced that measures to reduce CO₂ in buildings could be funded. As a result of this prospect of state subsidies, orders had been cancelled because numerous consumers had postponed their already planned restructuring measures. Helmut Bramann, Managing Director of the ZVSHK (Zentralverband Sanitär Heizung Klima), told the newspaper Welt: “We estimate that the orders taken back by home owners have already reached a three-digit million figure.”

ELECTA 300 FROM REMEHA

The new fuel cell heater from Remeha, a subsidiary of the BDR Thermea Group, is designed for private homes. The Dutch heating engineer relies on a polymer electrolyte membrane fuel cell (PEM) that delivers an electrical output of 750 W and a thermal output of 1,100 W (overall efficiency: 95 percent, see Fig. 1). The eLecta 300 will first be tested in a field test in the German market and will then be available from spring 2020. Jürgen Jahn, Head of Product Management, confirmed: “It’s plug-and-play – a ready-made system. It will be on the price list next year.”

LIMITED OFFER The number of newly installed fuel cell heaters in Germany in 2019 was around 3,400, 30 percent higher than in the previous year. Since the start of the KfW promotional programme 433 “Fuel Cell Subsidy” in the summer of 2016 to September 2019, a total of around 9,000 funding applications were approved. In Japan, 270,000 devices were on the market in 2018 (target for 2020: 1.4 million; see also Fuel Cell Review 2019 P. 58). In view of the fact that only three suppliers – Viessmann, SolidPower and Buderus – have been present on the local market to date, this comparatively low figure may be understandable. However, there is hope, Remeha presented a new Senertec system at the ISH trade fair in spring 2019 (see box), which should have been available from October. The IBZ furthermore announced that Freudenberg (2020) and Sunfire (early 2020), two further players, could be added, even though Freudenberg stated that ‘Elcore’s activities in the field of fuel cell heaters for domestic use had been discontinued’ (see Möhlenkamp interview, p. 40).

Whether and when Vaillant returns to fuel cell technology remains to be seen. Dr. Tillmann von Schroeter, managing director of the Germany division, merely held out the prospect that the trend towards greater performance for FC devices in continuous operation would continue. He is targeting flexible, decentralised solutions, since “not everyone has to provide for themselves”.

H₂ CHP PLANT

As part of the hydrogen village currently being built in Saxony-Anhalt, a hydrogen CHP plant is also being tested in Germany. As part of the HYPOS projects H2-Home and H2-Netz (see H2-international issue July 2019) at the test site of Mitteldeutsche Netzgesellschaft Gas mbH in the Bitterfeld-Wolfen Chemical Park, both its operation and its connection to the gas network are being investigated. Details can be found in the H2-international issue April 2020.

GAS NETWORKS WITH 100 PERCENT HYDROGEN

However, the development in the gas sector is interesting to observe. While today it is assumed that the gas network can absorb ten percent by volume of hydrogen without hesitation, there is currently discussion as to how quickly this proportion can be increased. For example, the next generation of systems could already be designed for 30 percent. And there are voices that say: “All new gas heaters should be ‘ready’ for 100 percent hydrogen by 2023/24.”

Products such as Remeha’s hydrogen-powered boiler (see H2-international issue Oct. 2019), which is currently being tested in a pilot project in the Netherlands, could then be supplied with green gas in the form of isolated solutions via pure H₂ networks that are separated from the natural gas network and guarantee a sustainable energy supply. Eva Hennig of Eurogas reported on experiments in Great Britain in which devices were successfully operated with up to 80 percent hydrogen. She merely admitted: “You just didn’t see the flame.” The field test in Leeds (see H21 project – H2-international issue July 2018) was still in the planning stage, but she was confident that “we will get an H₂ device”.

However, Frank Voßloh pointed out that its development would take at least five years. Tillmann von Schroeter then explained: “We do not have a choice but to provide 100 percent hydrogen grid sections, and we’ll be standing by as Vaillant.” If Leeds wants to have 3.7 million devices for pure hydrogen in 15 years, “we must deliver”, he promised. Timm Kehler said: “Fuel cell heaters thus have the potential to become the game changer of the heating turnaround. It will enable everyone to enter the hydrogen age.” ||

GREEN HYDROGEN ECONOMY UNTIL 2035

The federal states, the federal government and the EU – suddenly all are demanding H₂ strategies

A process of rethinking took place at the political level last year. Even though the energy turnaround has still not progressed noticeably, there is now at least a vision of what a future energy supply could look like. It is becoming increasingly clear that hydrogen will play an important role in this. However, after years in which there was no concept at all for the introduction of H₂ technology, several federal states and regions announced their own hydrogen strategies in 2019. Thorsten Herbert of NOW therefore felt compelled during the f-cell in September 2019 to emphasise that “by the end of the year a strategy will have been developed to bundle the regional activities and NOW will be involved in their conception”.

The five federal states Bremen, Hamburg, Mecklenburg-West Pomerania, Lower Saxony and Schleswig-Holstein have probably done most of the preparatory work for the concept so far. Since November 2018, they have been working on the North German Hydrogen Strategy on behalf of the respective ministers and senators for economics and transport, which was presented at the conference of the ministers for coastal affairs, economics and transport in Lübeck on 7 November 2019.

This is based on a key issues paper, in the preparation of which several working groups with more than 200 institutions from different countries took part in questionnaires and workshops. The strategy envisages building up at least 500 megawatts of electrolysis capacity in northern Germany by 2025 and at least five gigawatts by 2030. To achieve this goal, concrete measures are planned, such as a joint “Hydrogen Week” in the summer of 2020 throughout northern Germany. In addition, H₂ hubs are to be initiated, which are to gradually enable a regional and later also a supra-regional basic supply of green hydrogen.

In line with this, Schleswig-Holstein presented a study on the potential of the H₂ economy in the district of Nordfriesland at the beginning of October 2019. Project manager Jürgen Meereis explained: “For example, all waste collection vehicles in Schleswig-Holstein could be operated with electrolysis hydrogen from the electricity of about one third of the wind turbines that will no longer be under the EEG funding in 2020.” The study recommends, for example, that local authorities and the Federal Armed Forces vehicle fleet should seek funding for hydrogen-powered trucks or waste collection vehicles (see pp. 28 to 33) in order to demonstrate the practical suitability of the vehicles. In mid-November, the topic also made it to the state parliament, where the coalition factions called on the federal state government to tackle the development of a hydrogen economy based on renewable energies in concrete terms.

The five northern states also started a cooperation with the North-Netherlands region at the end of August 2019. A cooperation agreement to this effect was signed in Groningen between the Hamburg Renewable Energy Cluster

“In northern Germany, a green hydrogen economy will be established by 2035 in order to enable a near-complete supply of all consumers interested in green hydrogen.”

North German Hydrogen Strategy

“With hydrogen, we can get much more value added in the North.”

*Daniel Günther,
Minister President of Schleswig-Holstein*

“Together we now want to start the process of building a hydrogen economy. The necessary backing must be provided by the federal government. This is why we are going to approach the Federal Government promptly with this strategy paper, clarify our determination here in Northern Germany and call on the Federal Government to quickly set the course for the future – towards hydrogen”

*Michael Westhagemann,
Senator for Economics and Transport, Hamburg*

“Our goal of supplying all interested customers with sufficient green hydrogen by 2035 is ambitious. It is important that the federal government now creates the right framework conditions.”

*Dr. Bernd Althusmann,
Minister of Economics and Transport, Lower Saxony*

(EEHH) and the New Energy Coalition Groningen. The aim of the cooperation is to establish a cross-border H₂ corridor between the regions. EEHH Managing Director Jan Rispen said: “The development of a hydrogen economy is not a solo effort in Germany, but is taking place at full speed in a number of EU countries”.

HAMBURG AS H₂ METROPOLIS OF EUROPE Hamburg also made a clear statement in this context, announcing its intention to build one of the world’s largest electrolyzers. Michael Westhagemann, the Hanseatic City’s Senator for Economic Affairs (see Fig. 1), explained that he was committed to the construction of an H₂ production plant with a capacity of 100 megawatts in the Port of Hamburg. The city would make the space available for this. The money for this mammoth project, which is expected to cost a three-digit million sum, will come from industry, the federal government and the EU.

Shortly after this plan became known, the steel constructor ArcelorMittal announced that it intended to invest a total of € 65 million at its Hamburg site in order to reduce the iron ore there to sponge iron with the aid of hydrogen in an almost climate-neutral manner over the next few years. Managing director Uwe Braun explained to the Handelsblatt: “By 2050, ArcelorMittal intends to produce climate neutrally in

Europe.” He went on to say: “For the use of green hydrogen, it is especially important that we get enough renewable energy at affordable prices.” In Hamburg alone, the steelmaker would need around 3,100 gigawatt hours of green electricity annually for H₂ production, equivalent to 175 wind turbines with five megawatts each.

The great importance Hamburg attaches to this topic was also made clear during the International Hydrogen Symposium, to which the Chamber of Industry and Commerce together with the Hamburg Hydrogen Society had invited on 23 and 24 October 2019. With more than 700 participants, more than twice as many interested people came as originally planned, which means that the Hanseatic city has once again taken a step forward on the way to living up to the title “Hydrogen Metropolis of Europe” that it claimed years ago (see also p. 7).

NEW H₂ SCIENTIFIC ALLIANCE IN LOWER SAXONY One person who has long been driving this idea of an H₂ economy forward is Lower Saxony’s Environment Minister Olaf Lies. In July 2019, he announced that his ministry would invest around € 40 million in 2020. In September 2019 his colleague, State Minister of Science Björn Thümler, announced the launch of a new H₂ initiative. However, this commitment is surprising in that the north-western federal state already had numerous activities in the H₂ and FC sector several years ago, but these were discontinued in 2015. In 2004, a Lower Saxony fuel cell state initiative was initially founded, which was expanded in 2009 to include the topic of batteries and in 2010 to include electro mobility (Lower Saxony Fuel Cell & Electromobility State Initiative). However, the work of the resulting state initiative energy storage and systems in Lower Saxony expired at the end of 2015, even though some tasks were taken over by the Klimaschutz- und Energieagentur Niedersachsen GmbH.

Against this background, it is quite astonishing that a Lower Saxony hydrogen technology scientific alliance is

“The aim of the new scientific alliance is to expand the EFZN as a central research, networking and communication platform in order to be able to take up and shape current developments in the field of hydrogen as quickly as possible.”

Ministry of Science and Culture Lower Saxony

“We want to make Lower Saxony the hub and centre of the future hydrogen economy.”

Olaf Lies, Environment Minister of Lower Saxony

“A high-performance hydrogen economy would be an important energy policy component alongside electro-mobility, wind power and the like. It could pave the way to a carbon-free economy. [...] Hydrogen can and must become a central element of an effective climate protection strategy, because hydrogen has many possible uses. [...] Hydrogen could, for example, make steel production cleaner, and there is also great potential for use in the chemical industry. [...] The federal government and the EU must change their funding policies. If the EU takes its “decarbonisation agenda” seriously, European state aid law must be adapted.”

Stephan Weil,

Minister President of Lower Saxony, Handelsblatt

now to be set up in Goslar at the Energy Research Centre of Lower Saxony (EFZN) founded in 2008, after a fuel cell initiative had already existed in Göttingen for more than ten years. After all, what this alliance is supposed to do – bundling the expertise of hydrogen research in Lower Saxony – is almost identical to what the aforementioned state initiative started 15 years ago. Now the State Ministry of Economics intends to make a total of € 6.5 million available for new innovation laboratories.

GREEN GAS FOR BREMERHAVEN On 12 November 2019, the Bremen Senate decided to set up an electrolysis test field on the site of the former Luneort airfield. As part of the “Hydrogen – Green Gas for Bremerhaven” project, Fraunhofer IWES (Fraunhofer Institute for Wind Energy Systems) is to use the existing 8 MW wind turbine to generate green hydrogen that can be used in both industry and the mobility sector. Starting in January 2020, around € 20 million is to be made available from EU and state funds for an initial period of two years. Dr. Claudia Schilling, Senator for Science and Ports, explained: “We want to turn Bremerhaven into a competence centre for hydrogen. With this project in the southern fishing port we are also promoting the development of the sustainable LuneDelta business park and the establishment of the green economy in Bremerhaven”.

BAVARIA FOUNDS H2.B CENTRE But it’s not only in the far north that things are happening. The South of the Republic has also recognised hydrogen as a prestigious topic. On 5 September 2019, for example, a Hydrogen Centre Bavaria (H2.B) was founded in Franconia. The Bavarian minister president Dr. Markus Söder himself appeared together with the Minister of Economic Affairs Hubert Aiwanger and the Minister of Science Bernd Sibler at the Energy Campus Nuremberg (EnCN), where the centre is to be located. Also present were representatives of the Bavarian Hydrogen Alliance (Audi, Bayernwerk, BayWa, BMW, Bosch, Erlanger Stadtwerke, H2 Mobility, Helmholtz-Institut Erlangen-Nürnberg, Hydrogenious, Linde, MAN, Schaeffler, Siemens and others), which the Bavarian State Government had set up on this occasion. The H2.B is headed by Prof. Veronika Grimm and Prof. Peter Wasserscheid and is to develop and implement a Bavarian hydrogen strategy.



Söder explained: “In the coalition agreement, we agreed on an H₂ strategy, and here at the Nuremberg Energy Campus we are creating the nexus of H₂ research with the Hydrogen Centre. We’re investing a double-digit million amount in this. Sibler added that the scientific environment in the Nuremberg region has a very high level of expertise, which should be further expanded “so that we are number one in research and application in Bavaria”.

Wasserscheid, holder of the chair of chemical reaction engineering at the Friedrich-Alexander-University Erlangen-Nuremberg, said: “Research and framework conditions have developed dynamically in recent years, so that we can now say with a high degree of cer- >>

tainty that hydrogen technologies will play a key role in a successful energy turnaround in Germany and worldwide. Furthermore, what matters now is to combine the intensive research and development work that continues to be necessary with a greatly accelerated implementation in practical applications.”

In order to make rapid progress in this area, the Bavarian Energy Minister Hubert Aiwanger also agreed a cooperation agreement with Lower Saxony in mid-October 2019. Aiwanger explained: “The wind farm state Lower Saxony will develop its strengths as a producer of green hydrogen, Bavaria has technologies in the field of H₂ logistics which will be very important in the future.”

THURINGIA WANTS TO TAKE THE LEAD Thuringia is also making rapid progress in this direction. In autumn, Environment Minister Anja Siegesmund presented a six-point plan for the strategic development of the hydrogen economy for the energy turnaround. The basis of this plan is a short study by the Bauhaus University of Weimar, which points out possible ways to a hydrogen-based energy supply. Accordingly, a state innovation centre for hydrogen is to be established, in which research and industry will jointly develop marketable products and in particular start-ups will be specially promoted. Siegesmund complained in Erfurt for the East German federal state: “We want to be at the top here with Thuringia.”

North Rhine-Westphalia, which has been regarded as an energy state for a number of years, not least because of its history with coal, contributed its strategic ideas with the presentation of a fourteen-page discussion paper entitled “Hy-

drogen as the key to a successful energy turnaround”. This was published by the Hydrogen Working Group of IN4climate.NRW, an initiative of the federal state government, in order to inform the federal government of the measures that the institutions in it consider necessary.

In Brandenburg, the new Kenyan coalition announced that it would use an investment fund of one billion euros to buy, among other things, hydrogen-powered buses. The Minister of Economic Affairs Jörg Steinbach told the Potsdam newspaper “Neueste Nachrichten” about the latest news: “Also due to my scientific background I see a huge potential and have the vision of making Brandenburg a showcase area within ten years. In any case, we are going to have a hydrogen strategy sooner than the federal government. And our path will be much more sustainable than what is currently happening at the federal level.”

COALITION CONSIDERS TAX EXEMPTION A change of mood also seems to have taken place within the federal parties, so that more and more players are showing themselves open to H₂ and FC technology. Bernd Westphal, the SPD’s economic and energy policy spokesman, explained, for example, according to WirtschaftsWoche: “Hydrogen from renewable electricity is urgently needed because we do not see many of the problems that there are with electric mobility or with the transport of electricity. The prerequisite for the breakthrough of this technology, however, is that we now fully develop renewables, especially wind power. [...] I could imagine, for example, that electricity from renewable energies for hydrogen production could be exempted from taxes, levies and duties for a limited period of ten years, thus

NORTHERN GERMANY – THE HYDROGEN REGION

- Michael Westhagemann

Senator for Economics, Transport and Innovation
Hamburg

- Daniel Günther

Minister-President of Schleswig-Holstein

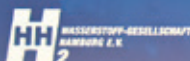


Fig. 1: Günther (L.) and Westhagemann during the H₂ Symposium in Hamburg

"Besides the battery, the fuel cell will play an important role. Our initiative to found the H2.B has also created a new dynamic."

*Hubert Aiwanger,
Bavarian Minister of Economic Affairs*

"The centre is to bring together industry, science and politics in order to advance the 'hydrogen economy' and in particular hydrogen in mobility in Bavaria as quickly as possible and to achieve the use of hydrogen in a wide range of practical applications."

H2.B

"The Bavarian State Government and the allies involved see the enormous potential of hydrogen as the energy sources of the future. They are convinced that hydrogen technologies will make an important contribution to the success of Germany's turnaround in energy and mobility"

Hydrogen Alliance Bavaria

stimulating the ramp-up. This would help the steel, copper, chemical and aluminium industries, for example, as well as the economies of scale for electrolysis equipment that we finally need to succeed with the technology."

Previously, Federal Economics Minister Peter Altmaier had put it on record: "We are going to build a modern system. This system cannot do without sector coupling. And this system – if we want to store renewable electricity – will never work simply by installing many thousands of lithium-ion batteries. Because if we want to make electricity available in winter, which is produced mostly in summer and used less, then it is best to use clean gas: hydrogen, which is produced by electrolysis, which works with renewable electricity. And then we have to ask ourselves how many pipelines we still need, how many pipelines we can fill with them, and above all after these have been acceptance. Many citizens say that we do not want four times, three times or twice as many wind turbines as today. That is why the energy turnaround is far from over, and we have to discuss it."

He explained further: "It is being considered that we have wind turbines in the North Sea that produce electricity that is not transported ashore, but immediately produces hydrogen from this electricity, and then you can bring the hydrogen ashore in tankers. You can then use it in gas-fired power plants, which are thus supplied with renewable energies. You can use it in the transport sector. You can do this with Power-to-Liquid. We have now published a call for tenders to make so-called real laboratories where we want to test all this hydrogen technology in four large real laboratories to see how this is possible on an industrial scale and whether a business case can be achieved" (see also p. 22)

THE GREEN PARTY WANT GREEN HYDROGEN Meanwhile, six members of the Green parliamentary group have published a position paper on the topic of "Green Hydrogen". The surprising thing is that the Ecoparty has so far been very cautious about this actually green topic. Dr. Ingrid Nestle, the spokeswoman for the energy industry of the Parliamentary Group "Bündnis 90/Die Grünen", told H2-international that she had "already been committed to the production of hydrogen during my time in Schleswig-Holstein and also in the Bundestag". And made clear, "We have never been against hydrogen. We just said we wouldn't want to use hydrogen in



Fig. 3: Dr. Ingrid Nestle

passenger transport." In general, however, it can be said that the Greens have not yet succeeded in integrating hydrogen and fuel cell technology into their political work and in making this clear in public or to the media.

As we have heard from various quarters, some representatives of the Greens have so far shied away from hydrogen because, among other things, nuclear energy could have been used as an "environmentally friendly" and inexpensive energy supply for electrolyzers. It is feared that a targeted H₂ economic system could thus have been used as an argument to be able to continue operating nuclear power plants. However, now that the political decisions have been taken to phase out nuclear energy definitively by 2022, there is actually no longer any reason for such concerns.

A further credo of the environmental party is the reduction of individual traffic, which is why hydrogen is rejected as a fuel for passenger cars. According to the Green politician, fuel cell cars would also be ineffective because they required three times more energy than battery cars. Nestle told H2-international that this had always been articulated in the same way. On the other hand, they are open to the introduction of hydrogen as a fuel for commercial and rail vehicles.

Nikolas Iwan, managing director of H2 Mobility, criticised however a too strong fixation on efficiencies in large parts of the Ecoparty. At the f-cell he accused in particular the group leader Anton Hofreiter of being too insistent that green electricity should not be converted into hydrogen due to the associated energy losses. In this context, Iwan called for more openness to technology and also more willingness to be open to new ideas.

In her position paper, however, Nestle, together with her colleagues Oliver Krischer, Lisa Badum, Matthias Gastel, Stephan Kühn and Julia Verlinden, now demands that crash barriers be created "to ensure system serviceability and thus prevent the production of hydrogen from triggering additional redispatch requirements". At the same time, however, she questioned the economic viability of setting up a second infrastructure – in addition to the many new charging stations for battery cars. Robert Habeck, the federal chairman of Bündnis 90/Die Grünen, had also expressed similar concerns towards H2-international.

Furthermore, the green veteran Hans-Josef Fell gave a clear vote against blue hydrogen in mid-October 2019. In a letter to his supporters, published by various media, he explained: "Blue hydrogen is produced from climate-damaging fossil natural gas. In order to give it an ecological coating, the carbon dioxide resulting from the production of hydrogen from natural gas is then to be separated and 'safely' disposed of in mines or in old natural gas reservoirs." In his opinion, however, the CCS technology used here is "inadequate, unsafe and far too expensive".

Fell describes the introduction of this new term as a new "deception by the climate-damaging natural gas industry" and notes: "It is necessary to clearly mark the dividing line between climate-friendly green hydrogen >>

and climate-damaging blue hydrogen wherever hydrogen is discussed.” Meanwhile, completely different sounds can be heard from the gas industry. Blue hydrogen is regarded here as an important element for a future energy supply.

FDP SUPPORTS HYDROGEN In everyday life, the approach of numerous FDP politicians, on the other hand, seems much more pragmatic. Again and again it can be heard from rural districts that concrete H₂ projects are supported much more constructively by liberal community representatives. At the end of October 2019, for example, Dr. Hans-Ulrich Rülke, chairman of the FDP state parliamentary group in Baden-Württemberg and member of the federal executive board, pointed out at a specially convened federal state press conference that “the future of climate-neutral mobility in Baden-Württemberg lies in synthetic fuels and hydrogen mobility”. He called for “an end to the absurd battery fetishism in the current mobility policy in the state, the federal government and in Europe” and presented a matching thirteen-page paper entitled “Battery mobility is astray”. The goal he formulated in this: “Baden-Württemberg must become the leading location in the development and production of hydrogen-based drive systems.”

compared to 1990 (ten percent more than before). € 100 billion is to be made available for this purpose over the next few years via a fund. Even some environmental associations praise this increase in targets.

“Hydrogen offers an opportunity to achieve climate protection targets while maintaining industrial added value in Germany and the EU. Hydrogen can secure the future of energy-intensive sectors such as the steel and chemical industries in Germany and support sustainable transformation in the transport and heating sectors. At the same time, hydrogen technologies open up new export opportunities for German industry.”

BDI

“An ambitious hydrogen strategy is an opportunity for climate protection and industry at the same time. [...] Global climate protection is not possible without hydrogen and chemical energy sources produced from it; not least because Germany, as an energy importer, is also dependent on supplies of ‘green’ energy from abroad.”

VDMA

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Fig. 4: Excerpt from the strategy paper of the FDP

INDUSTRY ASSOCIATIONS CALL FOR TECHNOLOGY RAMP-UP But not only German politicians, but also large business associations are now speaking out loudly and clearly in favour of hydrogen. In an “Industrial Roadmap for the Use of Climate-friendly Gases”, the BDI presented concrete measures which, from the point of view of German industry, are necessary to support a technology ramp-up. The long-term goal of the BDI is to create a liquid hydrogen market both in Europe and globally to meet the needs of the industrial, transport and, in future, heating sectors.

The German Engineering Federation (Verband Deutscher Maschinen- und Anlagenbau e.V.) (VDMA) takes a similar view and called on the German government to “finally provide its announced hydrogen strategy with concrete measures for a market ramp-up of this technology”. The association sees great opportunities in using hydrogen. Medium-sized companies in particular could benefit considerably from an international market ramp-up and strengthen their competitive position. In concrete terms, a seven-page list of demands states that the ambitious implementation of the European Renewable Energies Directive (RED II) into national law is now necessary to enable market entry. Together with other associations, the VDMA is calling for a 20 percent share of renewable energy in transport by 2030 for RED II.

GREEN DEAL BY URSULA VON DER LEYEN At the European level, politicians have so far held back – until 12 December 2019, when the new EU Commission head Ursula von der Leyen announced the “Green Deal”. According to the plan, Europe should become climate neutral by 2050 and CO₂ emissions should be reduced by 50 to 55 percent by 2030

In addition, the EU Commission also wants to establish an H₂ strategy. Vice President Frans Timmermans, who has already been described as a new champion of hydrogen, said: “I see a central role for hydrogen because clean hydrogen is an area where Europe is still a leader.”

At the same time, the European hydrogen association Hydrogen Europe (HE) is also working to boost the electrolysis industry in the EU in order to achieve the climate targets. It is currently being examined whether the hydrogen topic can be classified as an important project of common European interest (IPCEI). Should this be the case, significantly higher sums can be invested nationally without the EU preventing these as illegal subsidies. The conditions for granting IPCEI status could be met if there is market failure (supply and demand do not arise because costs are too high).

HE President Jorgo Chatzimarkakis also announced the signing of an agreement to build 40 GW of electrolysis capacity in Northern Europe and a further 40 GW in North Africa and Ukraine. ||

“Hydrogen is increasingly assuming a key position for the turnaround in energy and mobility. In Germany today, the chemical and petrochemical industries alone produce around two million metric tons of carbon dioxide, all from fossil fuels. In the future we are going to need green hydrogen and much larger volumes. To this end, we need a nationwide agenda with the right framework conditions for the development of a hydrogen economy.”

*Reimund Neugebauer,
President of the Fraunhofer-Gesellschaft, Free Press*



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CDU/CSU MINISTERS COMMIT THEMSELVES TO HYDROGEN

Major stakeholder conference in Berlin



Fig. 1: Peter Altmaier, Minister for Economic Affairs, who was still slightly suffering from his fall at the Digital Summit



Fig. 2: Dr. Gerd Müller

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Hardly anyone had expected such a rush. 300 participants were expected. But then 600 registered, and finally 700 came to the stakeholder conference for the National Hydrogen Strategy (NSW) on 5 November 2019 in Berlin. However, the great interest is not really surprising, as a total of four federal ministries sent out invitations. The hope of the many high-ranking representatives from industry, business, research and development was correspondingly high to learn something new about the contents of the announced strategy. But although this hope was disappointed, it was a successful event with a clear commitment to hydrogen on the part of the Federal Government.

The invitation was issued by the German Energy Agency (dena) on behalf of the Federal Ministries of Economics, Transport, Research and Development (BMW, BMVI, BMBF, BMZ) under the motto "Hydrogen and Energy Turnaround". Apart from the Federal Minister of Education and Research, Anja Karliczek, who represented Chancellor Angela Merkel in China, the three CDU/CSU ministers attended the Westhafen Event & Convention Center. In a detailed panel discussion, all representatives made clear statements about the significance and potential of hydrogen.

EMERGENCE OF AN H₂ ECONOMY Peter Altmaier, Minister of Economy and Energy, was the first to start in his slightly whimsical manner and explained: "Gas is sexy." Hydrogen has been the "Cinderella" until now, but now you can see: "Hydrogen is super-sexy." At the moment, there would be "a historic opportunity", said the Minister of Economic Affairs. He said: "We want to produce hydrogen on an industrial scale. This will help to bring about an energy turnaround." Altmaier noted in his remarks that, among other things, "consideration is being given to an own H₂ infrastructure

with pipelines" because hydrogen is "far too good for mixing". At the same time, he held out the prospect "We will see the emergence of a hydrogen economy worldwide."

His cabinet colleague for transport and digital infrastructure, Andreas Scheuer, announced in his opening speech the "next success story of the German economy" and predicted that "hydrogen made in Germany has a future". With regard to the transport sector, he criticised: "Made in Germany needs to get better at getting cars on the road." And he admitted: "This is a technology that may have left us a little behind. [...] For me, the development times to market access are too long."

Dr. Gerd Müller, the Federal Minister for Economic Cooperation and Development, outlined a future in which hydrogen will be used for methanol production in sunny regions. Methanol is tomorrow's fuel in his opinion. According to Müller, methanol is "the refinement of hydrogen" because no new infrastructure is needed. However, this way "only makes sense if we have green methanol from the African sun". Then, according to the Development Minister, a price of 2 cents per kilowatt hour would be feasible and "methanol would become competitive". Müller went on to say: "The methanol of the future will replace oil from Saudi Arabia." Specifically, he announced an industrial consortium with Morocco for the development of methanol production, which would create added value and local jobs.

Dr. Michael Meister, Parliamentary State Secretary at the BMBF, was present as the representative for education and research. He explained "What oil is today will be hydrogen in the future." Karliczek let us know in after the event: "Hydrogen is a core component of the Federal Government's National Hydrogen Strategy. As a transmission belt it brings renewable energies into all areas of life. [...] It is undisputed that Germany must import large quan-

tities of green energy. This is the only way to achieve the climate targets by 2030 and beyond. Green hydrogen is a key option.”

She further explained in the “Handelsblatt”: “Africa is predestined to take the first step into the hydrogen future. With green hydrogen, the geographical advantages of renewable energies could become the development engine for local societies. With H₂ partnerships for production and transport, we are opening the way to global energy markets and greater prosperity for Africa’s states. In this way, we not only



Fig. 3: Andreas Scheuer

create the basis for German technology exports, but also guarantee a climate-friendly energy supply.”

MINISTER FOR THE ENVIRONMENT WAS NOT INVITED The question of what the SPD-led Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), which was not present, plans, remained unanswered. Minister of Economic Affairs Peter Altmaier outlined how “the coffee party has expanded” after announcing the National Hydrogen Strategy: His colleague Scheuer then said that he was already doing a lot, and that the BMBF and BMZ had also joined him. He continued while looking at the Minister of the Environment Svenja Schulze: “We’re not shutting anyone out.” Minister of Transport Scheuer stressed that the “NSW is from the Federal Government”, i.e. also from the BMU.

“PtX will thus be part of the transformation of selected sectors. However, since the conversion of electricity into hydrogen and subsequent PtX products is associated with conversion losses, direct use of electricity is always preferable wherever technically possible. If the direct use of electricity is not technically possible (e.g. in steel production), the use of hydrogen should be preferred to other PtX products due to energy efficiency. It is important that the scarce resource of renewable electricity is used as efficiently as possible in order to achieve climate and environmental goals (e.g. area, resource, acceptance).”

Action Programme Federal Ministry for the Environment

A BMU spokesman told H2-international in mid-December 2019 when asked: “The Federal Ministry for the Environ-

ment is very interested in actively and constructively participating in the National Hydrogen Strategy. However, we have not yet received a draft of the National Hydrogen Strategy; we are therefore not aware of the planned contents. Therefore, no statements can be made about possible differences of opinion within the Federal Government. Federal Ministry for the Environment Schulze was not invited to the stakeholder conference of the BMWi, BMVI, BMBF and BMZ on 5 November 2019.”

At the World Climate Conference in Madrid, Schulze repeated her announcement of July 2019 to initiate an international Power-to-X platform with an office in Berlin and a competence centre in the Lausitz energy region as part of its own action programme (see H2-international issue Oct. 2019).

ACTIVE EXCHANGE OF VIEWS During the stakeholder conference, the statements from the ministries were followed by the workshop part. The many industry representatives present were able to comment on various theses independently. Even though the number of participants was large, there was not only an informative exchange of ideas, but also a process of opinion formation. And the organisers of the event stated that the questions and feedback from the auditorium would be included in the development of the National Hydrogen Strategy. The question of whether this is actually the case or whether the entire conference was more of an alibi function was doubted in a small group, but not clarified.

One of the points of controversy in the workshop discussion was how to deal with blue hydrogen. This is hydrogen produced from natural gas, whereby the resulting CO₂ is then captured underground using the Carbon Capture Storage Process (CCS). Minister of Economic Affairs Altmaier could well imagine using this procedure in Norway, Great Britain or the Netherlands. Before that, however, a broader acceptance would have to be created and the public would have to be informed. In any case, CCS is only worthwhile from a CO₂ price of € 35 per tonne. Currently the price is € 25 per tonne of CO₂.

Although this was a professionally organised event that brought many decision-makers together in one central location and that almost unanimously spoke out in favour of a hydrogen economy, the big question remained at the end of the day as to how all the noble goals are to be implemented. Whether the cabinet decision at the end of 2019 will provide information about this is more than questionable.

Ultimately, the National Hydrogen Strategy will show whether Peter Altmaier will achieve his goal, which he has repeated several times since the summer of 2019 – that Germany will become the number one in the world for hydrogen technologies. ||

The draft of the National Hydrogen Strategy should be discussed and presented in the cabinet on 18 December 2019. Due to differences of opinion between the Social Democratic environment ministries and the four CDU/CSU-led federal ministries listed above as well as the associated delays, the cabinet decision will most likely only be taken in the new year.

PERHAPS THE MOST INTERESTING ENERGY SOURCE

German Federal Council votes for hydrogen economy

Hydrogen has now reached the highest political level: Even before the summer break, Chancellor Angela Merkel had already spoken out in favour of an H₂ strategy for Germany. It was therefore she who set the course for the energy turnaround, even before Federal Economics Minister Peter Altmeier publicly announced the presentation of a corresponding concept at the end of the year. The German Federal Council has also been dealing with this topic for several months now. Several country representatives are trying to adapt the current legislation, after years of little progress.



Fig. 1: Thomas Bareiß

Hydrogen was on the agenda of the German Federal Council on 11 October. Lower Saxony promoted the set-up of an H₂ economy and the corresponding implementation of the Renewable Energy Directive (RED II) into German law. It also called for a reform of taxes and levies in the energy sector to make green hydrogen competitive. Thomas Bareiß, Parliamentary State Secretary at the Federal Ministry of Economics and Energy, also agreed: "I believe that hydrogen will be a very, very important building block for the energy turnaround, for climate protection. We need to move faster here. We need more courage, more money, more initiatives. I believe that the hydrogen strategy will be a very, very important building block here too, together with the federal government and state governments."

Then, on 8 November, the proposal submitted by Brandenburg for the ambitious implementation of the European Renewable Energies Directive RED II was adopted by a large majority. This was accompanied by a call to the Federal Government to go well beyond the target set out in RED II with the implementation, namely that by 2030 fuel must contain 14 percent renewable energies. The old and new Economics and Energy Minister of Brandenburg, Jörg Steinbach, proposed "at least 20 percent". On this he said: "Only in this way can it become an initial spark for Power-to-X technologies.

RESOLUTION OF THE GERMAN FEDERAL COUNCIL FOR THE COMPREHENSIVE DEVELOPMENT OF A HYDROGEN ECONOMY BASED ON RENEWABLE ENERGIES

The German Federal Council emphasised that the development of a hydrogen economy based on renewable energies also offers many opportunities for the economic and industrial location. "Green" hydrogen not only plays an important role in the supply of energy and fuels, but is also indispensable for the transformation of energy-intensive basic industries such as the chemical, steel, paper and glass industries towards climate neutrality. In the view of the German Federal Council, "green" hydrogen is therefore a key raw material for an industry geared to growth and climate protection.

However, it was expressly pointed out that green hydrogen does not necessarily have to come from domestic production, but can also be imported if a corresponding EU-wide methodology and certification system is established.

The competitiveness of "green" hydrogen must be strengthened in a targeted and effective way by reforming taxes and levies in the energy sector. This requires a legally binding investment framework at least for the period of depreciation of the plants and also the provision of funding in order to achieve economies of scale in the production and use of electrolysis plants.

The regulatory obstacles arising from emissions trading for the production of synthetic gases or liquid fuels (such as methane or methanol) from "green" hydrogen and CO₂ must be removed, for example by offsetting or crediting certificates under the ETS.

For refineries, the prerequisites must be created as soon as possible to enable the inclusion of "green" hydrogen in the production process and to use the scope resulting from the Renewable Energies Directive (RED II) for the development of a hydrogen economy.

A market incentive programme for the development of a hydrogen economy [e.g. for investments in fuel cells and electrolyzers] should be developed.

The German Federal Council asks the Federal Government to provide in particular for the exemption of electricity from the EEG levy which is used for the production of "green" hydrogen for use in rail transport.

The German Federal Council asks the Federal Government to place a central energy policy focus of the German EU Council Presidency, which begins in July 2020, on the need for action in the sector of "green hydrogen".

Excerpts from printed matter 450/19B, Nov. 2019

And only in this way will electrolysis capacities be created for the conversion of renewable electricity into hydrogen." He also announced that he would also exert "pressure at Euro-

pean level” to ensure that the remaining legislative acts were “adopted swiftly”. His goal is that the Lusatia region remains an energy and industrial region.

BACK AND FORTH Earlier, in the spring of 2019, the topic of hydrogen had caused a stir in the German Federal Council, when shortly before the meeting at the beginning of April it was leaked that the Federal Ministry of Economics wanted to introduce a change in the law, which would have led to a worse position for hydrogen production. The change could no longer be prevented due to the short time available. But almost overnight, the representatives of the federal state of Schleswig-Holstein campaigned for a protocol declaration stating that this process should be reversed as soon as possible. As a result, the planned change in the law first came into force on 13 May 2019, but was reversed in September 2019.

The Energy Industry Act § 118 of 7 July 2005, paragraph 6, sentence 7 now reads as follows: “Sentences 2 and 3 shall not apply to plants in which hydrogen is produced by water electrolysis or in which gas or biogas is produced by hydrogen produced by water electrolysis followed by methanisation. The explanatory memorandum states: “Sentence 7 in section 118(6) EnWG shall be worded as it applied until the entry into force of the amendment by the Act to Accelerate the Expansion of Energy Transmission Lines passed by the German Federal Council on 4 April 2019. This will make it possible, after consultation with stakeholders, to make a proposal as to how the overall framework conditions for the use of ‘Power-to-X’ can be designed.”



Fig. 2: Prof. Jörg Steinach

VOTE OF THE FEDERAL CHANCELLOR In autumn 2019, German Chancellor Angela Merkel declared that hydrogen is “perhaps the most interesting energy source”. She sees great potential for industry in particular: “Industrial value added chains will change completely here, because one day we will need emission-free steel production.” ||

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HYSTARTER IS STARTED

Where will Germany's H₂ shop windows be built?



Fig. 1: All the happy HyExperts and HyPerformer winner

At the beginning of July 2019, the HyStarter tender was decided. Nine regions have been awarded the contract and will receive support for their entry into hydrogen and fuel cell technology as part of the HyLands overarching funding project. In the future, their concepts will also serve as a blueprint to inspire other regions.

138 expressions of interest were received after the first call by project manager Nadine Hölzinger, managing director of Spilett new technologies GmbH. Hölzinger, Anke Schmidt and Julia Epp of New Urban Transport Solutions (Nuts One GmbH, a spin-off of the mobility service provider Choice) judged each individual submission on the basis of six criteria specified by the National Organisation for Hydrogen and Fuel Cell Technology (NOW). In order to enable an even more detailed differentiation, NOW introduced further criteria which also took into account the starting level of the respective region, i.e. whether experience had already been gained with H₂ and FC technology.

The final decision was taken by representatives of the Federal Ministry of Transport and Digital Infrastructure (BMVI), the programme company NOW GmbH and the project executing agency Jülich. Due to the high number of applications, nine regions were finally selected instead of the original six, and each region is now advised on the organisation and content of the programme for a period of twelve months. Their distribution shows that attempts have been made to consider different regions and also different subject areas – from North to South, from wind power to lignite, from small and medium-sized enterprises to Europe-wide networking. NOW and the project partners were particularly pleased about the great interest and the large number of very good applications.

REGIONS WORKSHOP SERIES The rejections to the unselected applicants were sent out as soon as possible, with the indication that it was still possible to apply to HyExperts, the second round within the HyLand project. In addition, further information events are to be offered as a follow-up to this application procedure so that the preparatory work was not in vain. There will be a series of regional workshops in 2020. NOW spokesman Tilman Wilhelm told H2-international: “With this, we want to give regions that have not had a chance at HyStarter or HyExperts due to the very high demand a tangible opportunity to stay on the ball when it comes to the topic of hydrogen. The workshops will take place on site at the host community. In addition, we are continuing our webinars, which also give local authorities the opportunity to obtain further information on specific topics

The newly selected HyStarters will now be divided into two groups, of which five will receive support in the first year, followed by four regions to explore the role hydrogen can play as a building block in regional energy and traffic turnaround activities. In this way a mutual fertilisation with ideas is to be made possible. Spilett and his partners Becker Büttner Held Consulting, Choice, Energy Engineers and Reiner Lemoine Institute will help to raise awareness for the topic and to initialise the organisation in the selected regions. Among other things, it is about concept work, network building, but also about media-effective public relations work. The aim is to develop implementation-oriented concepts so that the HyStarter regions can translate their ideas into projects. To this end, strategy workshops are initiated on a monthly basis.

HYEXPERTS AND HYPERFORMER For those regions that already have extensive experience in handling hydrogen, the HyLand sub-programmes HyExperts and HyPerformer

HYSTARTER WINNERS

Rügen-Stralsund – Coastal land/Wind energy – 1st year
 Lausitz – structural change/energy – 1st year
 Kiel – Metropolitan Region/Mobility – 1st year
 Neustadt a.d. Waldnaab – Border Region/European
 Networking – 1st year
 District Schaumburg – medium-sized region – 1st year
 (East) Allgaeu – medium-sized region – 2nd year
 Weimar – Education/knowledge transfer – 2nd year
 Marburg – Education/knowledge transfer – 2nd year
 Reutlingen – Industry/Automotive – 2nd year

HyStarter: Networks of actors – development of first ideas

HyExperts: Regional concepts – preparation of in-depth analyses

HyPerformer: Implementation – procurement of actual applications

are available (see H2-international issue Jan. and Jul. 2019). For these, a competitive procedure was planned, at the end of which there were 13 winning regions at HyExperts, each receiving a subsidy of up to € 300,000. Originally, only five HyExperts were planned. HyPerformer concerned the granting of investment grants of € 20 million. This sum should actually only be awarded to one winner. On the recommendation of NOW, however, the BMVI significantly increased the funding budget and selected three winners.

For those regions that have been active in this sector for years, this would mean a tremendous financial boost and image gain. The efforts of some actors are correspondingly great. For example, the federal state government of Baden-Württemberg had already promised considerable additional funding of its own in advance if its application was accepted. From Bavaria, which has only recently awoken

from a long H₂ hibernation, one could also hear that in the event of a contract being awarded, a separate H₂ filling station infrastructure with several dozen locations would be set up there, but primarily financed from industrial funds.

A total of 28 applications were submitted for the regional concepts and six for their implementation. On the part of the Federal Ministry of Transport and Digital Infrastructure it was said: “The high number of applications received confirms the pronounced interest throughout Germany in rethinking the energy supply of the regions and orienting it towards the future.

The winners were announced at the Federal Ministry of Transport on 12 December 2019.

HyExperts: City Brake, District Emsland, City Essen, City Frankfurt am Main, City Fulda, City Ingolstadt, District Lippe, District Oberallgäu, District Osterholz, District Recklinghausen, Federal State Saarland, City Ulm, District Wunsiedel im Fichtelgebirge

HyPerformer: Landshut Region (with the districts of Munich and Ebersberg), Northwest Metropolitan Region (Oldenburg and surrounding area), Rhine-Neckar Metropolitan Region (around Mannheim and Heidelberg) ||

“Investment grants – i.e. procurement subsidies – are to be used to establish regional, integrated added value chains with a focus on mobility”.

*Steffen Bilger,
Parliamentary State Secretary at the BMVI*

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NORTH NETHERLANDS BECOMES HYDROGEN VALLEY

At the European level, Baden-Württemberg and its agency e-mobil BW had applied for EU funding for the Hydrogen Valley, but came in second behind Groningen. Now one hopes for the award for HyPerformer (see p. 22), it was said afterwards.

Bart Biebuyck, Managing Director of Fuel Cells and Hydrogen Joint Undertaking (FCH-JU), commented that work is underway to build a Hydrogen Valley in Europe similar to Silicon Valley in the USA. The Big Hit project, which has been under construction in Great Britain for several months now, is already a promising approach, but too small. For this reason, the FCH-JU launched a call for proposals at the beginning of 2019 for a total of more than 90 eligible European H₂ and FC regions. In the end, six applications were received – which Biebuyck was very pleased about – from which HEAVENN emerged as the clear winner.

“It’s all looking very promising.”

Bart Biebuyck, FCH-JU

Behind the project name HEAVENN (H₂ Energy Applications in Valley Environments for Northern Netherlands) are a total of 65 supporters as well as the cities of Groningen, Delfzijl and Emmen. A total of 90 million euros are to be invested in this region over the next six years (of which 20 million euros will be EU funding). ||





Fig. 1: Microgrid – before ...

Category: International | Author: Sven Geitmann

AN ENTREPRENEUR WHO IS DOING SOMETHING

Company portrait: Electrolyser manufacturer Enapter

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Sebastian-Justus Schmidt is not only an unusual name. The man with that name is also an extraordinary person – and he does things that are anything but ordinary. In October 2019 sent out invitations to Thailand so that he could present his idea of a microgrid, a small, self-sufficient energy supply system. Several dozens of interested people from all over the world followed his invitation and were shown the whole range of what hydrogen and fuel cell technology has to offer over a period of several days.

Sebastian-Justus Schmidt is a free-spirited man, a man with visions, who wants to change something in the world – usually in a friendly and good mood. However, the founder and owner of Enapter said that he was never satisfied with himself. Perhaps this is the reason why he does so much – in the truest sense of the word, he is an entrepreneur.

Almost exactly two years ago Schmidt took over what was left of the ACTA S.p.a. company. The Italian electrolyser manufacturer had to file for insolvency at the end of 2014 and was then rescued in 2015 by Heliocentris AG, which itself went bankrupt in October 2016. Odasco then wanted to acquire the assets in which it had just invested a mid-double-digit million amount, but this acquisition was not completed by October 2017 (see H2-international issue Apr. 2018). And that was his calling.

“Our mission is to make the production of green hydrogen cheaper than fossil fuels.”

Sebastian-Justus Schmidt, Enapter

He acquired a majority shareholding from the insolvency administrator and thus gave eleven former ACTA employees at the company headquarters in Pisa a future again. Within two years, it has grown into an internationally active team of

76 mostly young employees with further locations in Berlin, Russia and Thailand. Together they are continuing to optimise the electrolyser and highlight what is special about their technology.

These are neither PEM nor alkaline devices, but so-called AEM electrolyser (Anion Exchange Membrane). As Jan-Justus Schmidt, one of the founder's two sons employed in the company, explained, this is a mixture of both concepts and one “combines the advantages” of both technologies. “This technology enables us to produce small hydrogen generators cost-efficiently because we can do without precious metals such as platinum,” says the junior. One advantage, he explains further, is that compressed hydrogen (35 bar) with high purity comes from the comparatively simple devices. Thanks to their modular design, they can also be tailored to individual customer requirements (0.5 to 20 Nm³/h).

The first AEM system is still located in the Phi Suea House of Sebastian-Justus Schmidt, a building complex in northern Thailand near Chiang Mai. The main house, two guest houses, workhouse, recreation and sports facilities are supplied solely with solar energy – partly stored in hydrogen. “Thailand can be very proud of that,” says Schmidt. Further modules have been sold in recent months to various customers in eleven countries – be it for industrial H₂ generation, back-up systems, seasonal energy storage or drone refuelling. In response to rising demand, Enapter expanded its production capacity in Italy in September 2019. The automation of production not only aims to reduce unit costs by 20 percent, but also to increase productivity by a factor of 8.

The first plant in Germany is located at Arno Tilsner, the publisher of the magazine “na dann...”. The journalist and visionary has lived energy self-sufficient since 2012. In the summer of 2019, Enapter supplied him with his own EL 2.0 electrolyser for storing the solar electricity (500 l_{H₂}/h) he had produced himself – 185 days after the first contact was made.

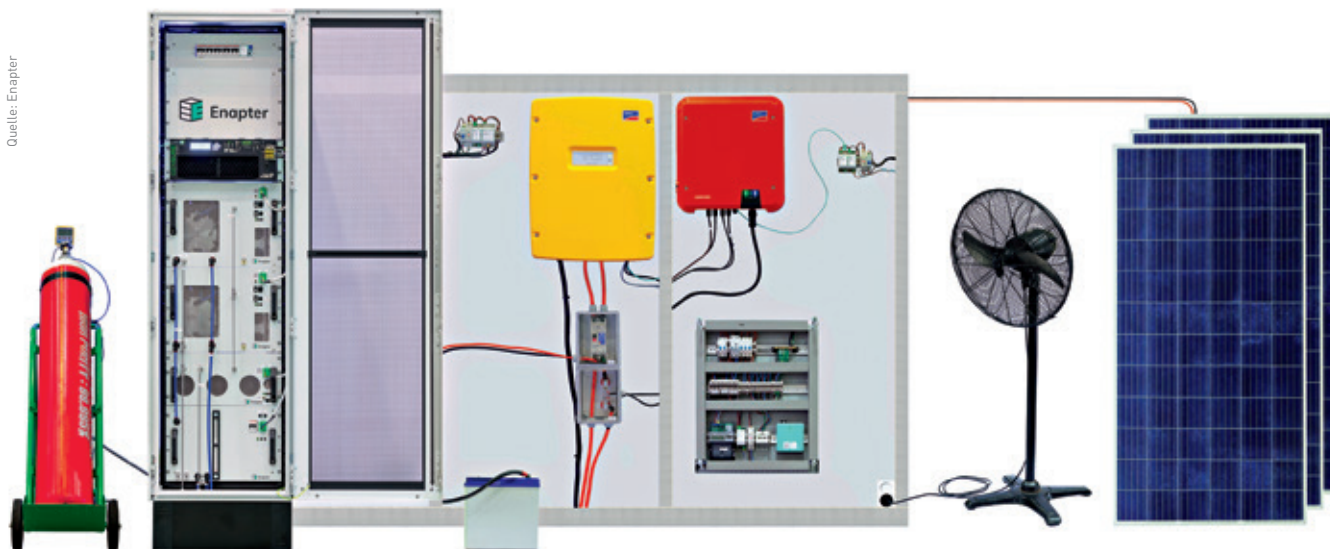


Fig. 2: ... and after assembly

Schmidt explained to H2-international that instead of the previous project work with individual solutions, he was now focusing on series production. He said: “With the launch of our new EL 2.1 system in February 2020, we plan to build at least 50 units per month in our new building. We intend to gradually increase this number even further. The new production unit will make more than 100 systems per month possible in shift operation.” He went on to say: “We started with a rather chaotic assembly at the end of 2017 – now we’ve taken significant steps towards a stable series.”

The company is financed from investor funds, a large part of which comes from the founder, who was CEO of SPB Software in his previous life. Financing now comes now from the income from the first sales.

Enapter is an artificial word from the English terms ENergy (energy) and adAPTING – ER is used for pronunciation. “We have created a word that sounds the same in almost all languages and is easy to pronounce,” says S.-J. Schmidt.

HANDS-ON WORKSHOP IN PATTAYA During the event, which lasted several days, the start-up in Thailand showed how the electrolyzers are structured, how they work, what chemical processes take place inside and how business models can be generated from them. At first, the Schmidt family and the entire team were invited to Pattaya, where the technicians demonstrated how a microgrid can be built without the use of fossil fuels. There was a hands-on workshop where system integrators, installers and planners could work hand in hand with all the individually designed components and assemble them until the system – from the photovoltaic system to the EL 2.0 to the fuel cell – actually worked (see Fig. 1a/b and 2).

The venue for this work assignment was the Nong Nooch Tropical Garden, a 600-hectare botanical tourist attraction with 168 different species of dinosaurs on display, which is visited by 5,000 people every day. The 73-year-old head of the plant, Kampon Tansacha, together with Schmidt Senior, spoke out in favour of more sustainability and emission-free energy supply, so that at the end of the day the hydrogen-powered microgrids were reported on six Thai television channels.

ABOVE THE ROOFS OF BANGKOK In other workshops held during the Big Thing week proclaimed by Enapter, the young employees in Bangkok provided information about the precise electrochemical processes that make AEM electrolyzers so special. Scientists from all over the world came to Thailand’s capital for this purpose. The same applies to the financial workshop in which Forbes journalist Ken Silverstein discussed the potential of a hydrogen economy for the global financial and energy market with various experts. The unanimous opinion is that there will be a change not only in the energy sector, but also in the investment sector – towards something more disruptive.

Remarkable was how many high-ranking representatives and renowned experts from all over the world (Europe, Japan, Malaysia, Russia, USA etc.) came to learn more about the visions of Sebastian-Justus Schmidt and the capabilities of AEM technology. The fact that the company’s presentation at the SETA trade fair (Smart Energy Transformation Asia), which Deutsche Messe also co-organised, did not attract many visitors was hardly significant.

Apart from the German ambassador to Thailand, Georg Schmidt, more people were clearly impressed by the dedication and the passion with which the entrepreneur Schmidt is pushing ahead his ideas during the final evening reception high up on the 37th floor of the event hotel. ||



Fig. 2: Jan-Justus Schmidt explains the completed Microgrid

In April 2019, Enapter won the international SET Award in the Low CO₂ Power Generation category for the most innovative and effective business models in energy turnaround areas and climate protection.

BATTERIES FOR PASSENGER CARS – FUEL CELLS FOR TRUCKS

Increasing interest in hydrogen from freight forwarders



Source: Hyundai Motor

Fig. 1: The designers of the HDC-6-NEPTUNE Concept were inspired by the Streamliner Railway (1936-1959).

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Two years ago, the interest of German truck manufacturers and freight forwarders in fuel cells was extremely low. It's different today. Almost all logistics companies are now in some way concerned with the question of what fuel their vehicles will be powered by in the future. It is almost inevitable that hydrogen will also be considered in the context of these considerations. What is remarkable here is that this is usually not just a matter of a few thought games, but that numerous serious scenarios are now being designed and concrete projects initiated.

The development of FC technology in the commercial vehicle sector can be particularly well observed using the example of the US-American Nikola Motors Company. The start-up company, which wants to set up the appropriate infrastructure in addition to fuel cell trucks, is currently in the process of delivering a similar story in the truck sector as Tesla is in the passenger car sector. For months, Nikola's managing director Trevor Milton has been the topic of conversation. So, it came as no surprise when truck manufacturer Iveco announced at the beginning of September 2019 that its US parent company CNH Industrial had bought itself in to Nikola with 250 million US dollars as part of the fourth round of financing. A short time later, Bosch and the South Korean group Hanwha followed, each investing more than 100 million dollars.

CNH said that fuel cell technology was the "logical next step after LNG motors (Liquefied Natural Gas)". Gerrit Marx, President of Commercial and Special Vehicles at CNH Industrial, said: "While today LNG delivers significantly lower well-to-wheel emissions, which can be virtually reduced to zero using biogas, fuel cell and BEV technologies [Battery Electric Vehicle] will deliver the ultimate goal of an emission-free truck in the medium to long term."

In addition to money, the CNH subsidiary Iveco and its sister company FPT Industrial will also provide support for the development and production activities of both battery and fuel cell trucks. In November 2018, the engine specialist FPT itself also presented a drive concept based on hydrogen (400 kW, 800 km; see H2-international issue 2018). This know-how will now also flow into the One and Two models designed for the US market, as well as the Tre model (expected by the end of 2022) for Europe, for which Nikola and CNH Industrial are planning to set up a start-up.

CEO Trevor Milton said: "Nikola has the technology but needs a partner with a European network to achieve the goals in time. With CNH Industrial's investment and partnership, we can now bring zero-emission trucks to Europe. [...] By bringing CNH on board, we now have access to production expertise, purchasing power, proven truck components, factory and much more. Hardly anyone will doubt now that we can commercialise trucks."

He went on to explain: "While other OEMs believe that zero-emission solutions are not possible within the time frame set by regulators, Nikola, FPT Industrial and Iveco prove that these time frames are realistic. [...] Instead of going it alone, as many start-ups do, my goal was to build the most powerful network of partners on the planet, and I think we've done good work with CNHI, Bosch, Hanwha and others."

In early December, Iveco and Nikola also presented a design model of what the Nikola Tre could look like. The big N at the front stands for the US-American partner, the base vehicle is an IVECO S-WAY. The official presentation will take place during the IAA Nfz 2020 in Hanover. The first customers are to receive their first battery-operated units in 2021. The fuel cell powered version will be available from 2023.

Concerning the other investors – Hanwha is a globally active green electricity producer, which among other things took over the solar module manufacturer Q-Cells – the Nikola boss said: “Bosch can support us in commercialising very complex vehicle components, and Hanwha can provide us with clean energy at the hydrogen sites where possible”.

Nikola has the largest hydrogen filling station available in the USA at its headquarters in Phoenix, Arizona. It can produce more than 1,000 kilograms of hydrogen per day. “Future Nikola filling stations will produce and supply 8,000 kg of hydrogen per day – making them the largest in the world,” says Milton.

CONVERSION OF OLD TRACTORS The Lower Saxony-based Clean Logistics GmbH takes a completely different approach. The company from Winsen an der Luhe, founded in October 2018, is planning the conversion of conventional tractors together with consortium partners. In the future, a hybrid system together with H_2 pressure vessels will be installed where the diesel aggregate and tank were previously located. The two fuel cells (75 kW each) in the so-called HyBat truck are produced by Proton Motor, the hydrogen technology from Hydac. The H_2 tanks can store up to 45 kg at 350 bar and enable a range of 400 to 500 km.

According to Managing Director Dirk Lehmann, the freight forwarder involved in the project insisted on a battery pack that would guarantee a minimum electrical range of 100 km (400 kWh) so that the vehicles could always reach the nearest filling station safely. Two prototypes are currently in preparation. The first, a VW T5 minibus, was completed in November 2019. The second, for which the bodyshell of the manufacturer DAF was selected, is to be ready for operation in the second half of 2020. In general, however, other makes should also be used.

The conversion is expected to cost around € 250,000, with the purchase of the old vehicle estimated at € 30,000. If everything works out, pre-ordering of the first units could start in spring 2020, says Dirk Graszt, another managing director of Clean Logistics. A pre-series with 30 units could then be delivered in 2021.

TIGHTENING OF LIMIT VALUES FOR COMMERCIAL VEHICLES

In April 2019, the European Parliament in Strasbourg declared its support for a reduction in the emission levels of commercial vehicles by an average of 15 percent by 2025 and 30 percent by 2030. Originally, 35 percent was the goal, but German companies and associations in particular fought against over-regulation. [see H2-international issue Apr. 2019]

IMPROVING THE AERODYNAMICS OF TRUCKS

The design of truck cabs could change significantly in Europe in the near future. Up to now, the freedom of design has been severely restricted by the legislator, which is why box-shaped trucks with vertical front sections are mainly to be found here on the roads and these have extremely high air resistance. In the USA, on the other hand, trucks with much longer muzzles and lower CW values (drag coefficient) are found on the highways there. From 1 September 2020, it should be possible in the EU to allow truck cabs to be up to 90 cm longer, which could reduce energy consumption.

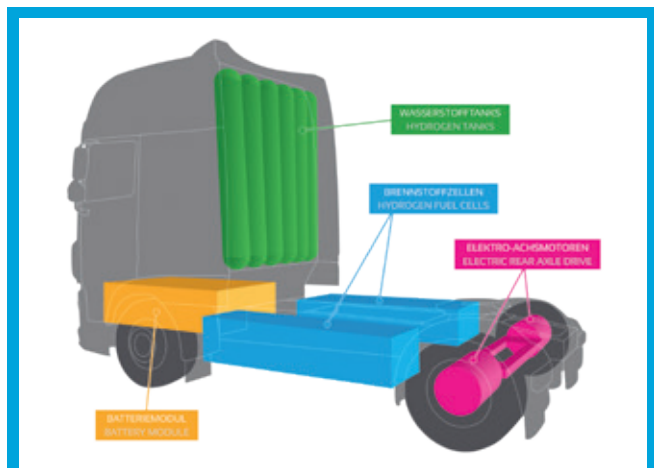


Fig. 2: HyBat-truck, [Source: Clean Logistics]

“We can’t wait for the OEMs, not even for Nikola.”

Dirk Graszt, Clean Logistics

How serious Dirk Lehmann is about these activities is demonstrated by the cooperation he entered into with Re-Fire Technology in mid-November 2019 in his capacity as founder and managing director of eCap. Re-Fire is regarded as one of the leading companies for fuel cell solutions in China. Since its foundation in 2014, it has built nearly 50 FC prototypes with companies such as FAW, Dongfeng, Zhongtong – especially in the commercial vehicles sector. Its systems are to be used in mobility solutions from eCap in the future. Founded in 2015 and, like Clean Logistics, based in Lower Saxony, the company specialises in the development and use of alternative drives. However, it focuses in particular on “individual conversions in passenger cars, machines and commercial vehicles” in industry and commerce as well as for private individuals, as Lehmann explained to H2-international. As a development partner, eCap is also involved in the conversion of the HyBat truck.

The question of where these trucks are to be refuelled in the future is still not decided. H2 Mobility is currently continuing to build up the hydrogen infrastructure, but the primary focus here is on 700-bar filling stations for passenger cars. At most locations the H_2 fuel pumps are integrated into the brand name petrol stations in such a way that FC cars can easily refill H_2 gas there – for larger vehicles, however, the fuel nozzles are often out of reach because either the roof is too low or the swivel radius is too small.

As H2 Mobility confirmed, discussions have been initiated to discuss possible solutions. For example, some shareholders of the consortium of companies are quite open to considering the possibility of refuelling commercial vehicles at future locations. It is already foreseeable today that it is going to be necessary to increase the H_2 capacity at new stations so that several FC buses or trucks can be refuelled in succession. In addition, sufficient locations with easily accessible nozzles and 350-bar connections must be available in the coming years.

ECOLOGICAL REVOLUTION IN SWITZERLAND Meanwhile, H2 Energy and Hyundai continue to work on their hydrogen-powered truck fleet for Switzerland. Rolf Huber, Chairman of the Board of Hyundai Hydrogen Mobility AG (HHM), a newly formed joint venture between Hyundai Motors Company and H2 Energy, stated: “As you >>

know, we are planning nothing less than an ecological revolution in the truck business in Europe by bringing 1,600 fuel cell trucks into service in Switzerland by 2025.”

At first it was said that the partners wanted to bring 1,000 units of these 34-tonne trucks named H2 Xcient onto the Swiss roads. However, as the number of advance orders grew rapidly, production was increased to 1,600 in April 2019. The H2-Xcient trucks are to have a 190 kW fuel cell system on board consisting of two parallel stacks and seven hydrogen tanks with a storage capacity of 35 kilograms (range: over 400 kilometres). Delivery will start in 2020 with 50 units and should be completed by 2025.

In January 2019, the energy suppliers Alpiq and H2 Energy founded Hydrosponder AG in order to be able to supply 100 percent of the required hydrogen from renewable energies. Both companies each hold 45 percent of the shares in the joint venture. A further ten percent is held by the gas company Linde. The first electrolyser (2 MW) should be commissioned at the Gösgen run-of-the-river power plant (Solothurn) before the end of 2019. The first green H₂ gas is to be delivered to customers from the beginning of 2020 via the Swiss Linde subsidiary PanGas.

“I therefore see a high potential for hydrogen and fuel cell technology, especially for public transport and heavy goods traffic by rail, road and river. The fact that many players in the logistics industry share this assessment is demonstrated not least by the extremely positive response to this event.”

Jens Deuschendorf, State Secretary of the Hessian Ministry of Economics at the Fuel Cell Forum Hesse

NEW TRUCK STUDIES AT THE NACV Hyundai Motor Company went one step further at the end of October 2019 when the Asian company presented a study of a FC heavy-duty truck at the North American Commercial Vehicle Show (NACV) in Atlanta, USA (see Fig. 1). The presentation of this vehicle concept was accompanied by a clear commitment on the part of the Koreans that they see great potential for such trucks, especially in the USA. Edward Lee, head of Hyundai Commercial Vehicles, said: “At this exhibition today – with the presentation of HDC-6 Neptune – we are starting to explore the possibilities in the US commercial vehicle market.”

Luc Donckerwolke, head of the design department at Hyundai, explained: “The fuel cell powertrain gave us the

opportunity to redefine the classic typology and architecture of the truck. The Hyundai Commercial Vehicles Design Team started with a white sheet of paper that focused on the newly defined functionality and reset all standards to project commercial vehicles in the future” Due to the increased cooling requirement, the ventilation slots extend along the entire lower front section of the concept vehicle.



Fig. 3: Rolf Huber

Cummins Inc. was also represented in Atlanta with a new fuel cell truck. The US-Americans showed a cabin tug suitable for regional traffic, urban delivery services, port tugs and terminal container handling. It has a PEM fuel cell available from Hydrogenics (90 kW) and also a lithium-ion battery pack (100 kWh). The maximum power of the FC system can be scaled up to 180 kW in 30 kW or 45 kW increments. If necessary, the range can also be extended from 240 to 400 kilometres by increasing the tank storage pressure or installing additional fuel cells.

Vice President Thad Ewald said, “The development of this state-of-the-art H₂ fuel cell truck as a technology demonstrator is an important step to gain valuable insights that are critical for further developing the right solutions for the market and preparation for the next 100 years”.

FC TRUCK UP TO 2039 And what is happening at the German and European vehicle manufacturers? In the fall of 2019, Daimler’s Board of Management announced that a development team would push ahead with the electrification of all five truck subsidiaries (Mercedes, Fuso, Freightliner, Bharat-Benz, Western Star). Martin Daum, the head of the commercial vehicle division, explained: “We’re doing everything we can to ensure that from 2039 we no longer need diesel in Europe.”

The subsidiary Mitsubishi Fuso Truck and Bus Corp. presented a fuel cell truck prototype, the Vision F-Cell, at the Tokyo Motor Show in October 2019 as a kind of outlook for the future. The model presented was the prototype of a 7.5-tonne truck with a maximum output of 135 kW and a range of up to 300 km. This vehicle, which can be equipped with up to four 700-bar pressure vessels, will be used to sound out the extent to which FC technology can be used for various performance classes. However, according to current planning, series production will not start for another ten years.

In concrete terms, Daimler Trucks & Buses plans to include production vehicles with battery electric drive in its vehicle portfolio in Europe, Japan and the USA by 2022 – and hydrogen-powered models by the end of the decade. By 2039, only new vehicles that are CO₂ neutral in operation (Tank-to-Wheel) are to be offered.

The VDL Groep is currently involved in the H2Haul project (Hydrogen Fuel Cell Trucks for Heavy Duty, Zero Emission Logistics), an EU funding project in which various partners are setting up a total of 16 FC trucks with correspondingly large refuelling facilities for commercial vehicles. Among others, the Dutch vehicle manufacturer VDL is working with the FC manufacturer ElringKlinger, which is supplying the PEM stacks so that the trucks can then be tested at the Belgian retail group Colruyt. The



Fig. 4: BZ Truck from Cummins and Hydrogenics

"Local CO₂ neutral trucks and buses won't sell themselves. [...] This is why we need state incentives to make them competitive. Especially necessary: The European Commission has proposed the following measures: conversion and staggering of tolls throughout Europe on the basis of CO₂ values, which would significantly reduce the burden on CO₂ neutral vehicles; a targeted support programme for buses and for a nationwide charging and hydrogen infrastructure; and uniform standards for the transport and refuelling of hydrogen."

Martin Daum, Daimler Trucks & Buses

aim of the H2Haul project is to advance the development of the fuel cell as an alternative drive technology in Europe to market maturity. A total of twelve million Euro in funding from the EU is to be made available over the five-year period.

Energy supplier Alpig is also involved in this project and is to contribute the electricity required for H₂ production. For example, a 2 MW electrolysis plant is planned at Alpig's hydroelectric power station in Gösigen on the Aare Canal, which will be provided by Hydros spider AG (see above). Hydros spider will supply the filling stations exclusively with green hydrogen, explained its boss Rolf Huber to H2-international. The plant is scheduled to go into operation at the beginning of 2020 in order to supply around 50 FC trucks with hydrogen in the future. Other project partners include companies such as Element Energy Limited, FPT Industrial, Hydrogenics, IRU Projects, Iveco and PowerCell.

HORIZON SUPPLIES 1,000 FC SYSTEMS Horizon Fuel Cell Technologies is also planning a similar scale of H₂ commercial vehicles to Hyundai. The Singaporean company announced in July 2019 that it signed a letter of intent to equip 1,000 trucks with Horizon fuel cell systems. The energy supply systems are to provide at least 100 kW and drive heavy commercial vehicles in Chinese ports in the future. The first units were to be delivered in 2019, the remainder within three years.

George Gu, managing director and co-founder of Horizon Fuel Cell Technologies, said: "The worldwide recognition of the harmfulness of diesel engine emissions has accelerated the electrification of heavy vehicles. The resulting improvements in air quality are changing the quality of life of the people most affected by air pollution."



Fig. 5: FC truck prototype Fuso Vision F-Cell

At the end of 2019, Horizon also announced its intention to produce significantly more powerful systems in the future. The company announced that it was already working on the next generation of a high-performance fuel cell (VL-III), which could provide 370 kW with a power density of more than 5 kW/l and 5 kW/kg. These should be available from mid-2020. Orders are already accepted.

It had previously become known that the Asian company was working with Wenger Engineering, among others. The Ulm-based consulting service provider had analysed Horizon's fuel cell system and confirmed its comparatively high energy density. In this context, managing director David Wenger explained: "Customers don't want to compromise. They want the performance levels to which they are accustomed in commercial vehicles without paying exorbitant prices. Horizon is innovative to deliver excellent performance at a sustainable cost, and we see great potential in Europe with this combination. We strongly believe in the mass marketing of hydrogen vehicles and therefore I co-founded a special hydrogen infrastructure company, Hydrogentle GmbH."

H2 ENERGY

It is worth noting how often the name H2 Energy appears when one obtains information on H₂ activities in Switzerland. This small, fine engineering firm, which started as a Swiss subsidiary of Proton OnSite under the name Diamond Lite and organised the distribution of electrolyzers in the Alpine republic, is now the hub of numerous projects in Switzerland. H2 Energy is not only significantly involved in the Hyundai truck deal and responsible at H2Haul for the construction of the filling station infrastructure but is also involved in the foundation of the H2-Mobility Switzerland promotion association. In May 2018, seven companies (Agrola, AVIA, Coop Cooperative, Coop Mineraloel, fenaco, Migrol, Migros) joined forces in the association and commissioned this start-up company to bring Switzerland forward in the topic of hydrogen. The association now has 17 members, some of whom want to take care of the vehicles and others the infrastructure.

"We want to join forces to make hydrogen mobility in Switzerland even better."

Jörg Ackermann, Coop Management and President of H2-Mobility Switzerland

Wenger had already announced during FC Expo 2019 that it intended to set up H₂ filling stations at German autobahn stations especially for trucks and vehicles in adjacent industrial estates (see H2-international issue Apr. 2019). Whether this is actually feasible, however, and whether Horizon trucks could be used for this purpose, remains to be seen. It was said that one was in conversation with various actors.

FUEL CELLS ALSO IN HEAVY-DUTY APPLICATIONS Similar efforts can also be observed in Canada, where FC manufacturer Ballard is also active in the heavy-duty sector. In May 2019, the Vancouver-based company announced it was participating in a pilot project to fuel two 64-ton trucks with fuel cells. As part of the three-year Alberta Zero-Emissions Truck Electrification Collaboration (AZETEC) lighthouse project, the suitability of H₂ systems for use in heavy-duty transport is to be tested. >>

Ballard contributes a total of six FCmove modules, each with an output of 70 kW. The hybrid vehicles are large trucks specially developed for the Alberta region (range of up to 700 km). I want them to transport goods between Edmonton and Calgary. Rob Campbell, Chief Commercial Officer of Ballard: “The semi-trailer towing vehicles used in the AZETEC project are the first FC electric vehicles of this size and capacity to be built and tested in the world”. (See also interview with Ballard boss MacEwen on p. 58).

The competitor Toyota is already one step ahead and announced the next generation of an H₂ truck in April 2019. Together with the US-American truck manufacturer Kenworth, the Japanese designed a new model as part of the Project Portal that has a range of around 482 km on one tank of fuel. At the end of 2019, the new Fuel Cell Electric Trucks (FCETs) should start operating in the ports on the west coast of California. The base vehicle is a Kenworth T680 Class 8 Truck, in which the same FC systems as those installed in the Mirai (0.76 kg_{H₂}/100 km).

With regard to the development of costs, the Scania Pathways study “Fossil-free goods traffic by 2050” reports the fol-

JOINT VENTURE BETWEEN MICHELIN AND FAURECIA
Michelin and Faurecia announced in March 2019 their intention to combine their fuel cell activities in a French 50:50 joint venture. This step was taken at the end of November 2019. In particular, the focus is on Symbio, a subsidiary of Michelin, which has since been operating under the name “Faurecia Michelin Hydrogen Company”. Tyre manufacturer Michelin and automotive supplier Faurecia are to initially invest 140 million euros in the joint venture to accelerate the development of the latest generation of fuel cells, start mass production and expand business in Europe, China and the United States. Its target market includes light commercial vehicles.

lowing: “Since vehicles with fuel cells are more expensive, a substantial increase in this field will probably take place later than with battery electric vehicles. If the cost of this technology falls and renewable hydrogen is available in sufficient quantities, fuel cell technology could make up a significant proportion of any fleet by 2050.” ||

Category: Electro-mobility | Author: Sven Geitmann |

HYDROGEN IS ON EVERYONE'S LIPS

28 *The maritime sector discovers the fuel cell*

While hydrogen in the maritime sector has only ever been treated as an option for the future under “far away” for years, not only the events at which this energy source is the subject of lively debate are currently on the increase, but also the reports on concrete projects. More and more shipping companies are turning to hydrogen because the pressure to say goodbye to fossil solutions is growing from all sides.

Although most players in the maritime industry are probably aware that large tankers and cruise ships will not be using hydrogen tomorrow, the discussion about sustainable propulsion systems has now reached a new dimension. Even though many shipping companies are currently initially

focusing on liquefied natural gas (LNG), the industry is already characterised by the attitude that LNG will be “only a transitional technology” in maritime transport.

“Hydrogen is on everyone's lips.”

Dr. Andreas Schröter, Managing Director of DNV GL Energy

“There are no show stoppers.”

Dr. Felix Weise, Managing Director of DNV GL Oil & Gas

“I'm a big fan of hydrogen.”

Enak Ferlemann, Parliamentary State Secretary BMVI



Fig. 1: Design draft of a future FC ship

It was not without reason that Dr. Andreas Schröter, Managing Director of DNV GL Energy, explained in October 2019 in Berlin: “We live in times of disruptive change. We have crossed a tipping point and believe that hydrogen has a huge potential.” Shortly before, the Hamburg-based consultancy service provider to the maritime industry had presented the DNV GL Energy Transition Outlook 2019 – a study which concludes that “more than ten times as much solar energy and five times as much wind power than today, as well as further technological measures” will be required for the energy turnaround. “This is the only way to limit global warming to well below 2°C and to achieve the Paris Climate Agreement,” the paper says.

One of the resulting measures recommended by DNV GL is “Green Hydrogen for heating buildings and industrial plants and for transporting fuels, as well as using surplus renewable energy in the power grid.” It should be noted that



Fig. 2: Enak Ferlemann

the Norwegian classification society (2013 merger of Det Norske Veritas and Germanischer Lloyd) has so far been primarily active in the gas and oil business, but is now acting as a supporter of sustainable mobility solutions.

FC DRIVE SYSTEM WITH 3.2 MW

New discussion topic in the field of large ship drives. In November 2019, the Swedish fuel cell manufacturer PowerCell announced that it would join forces with the Havyard shipyard to

provide a concept for the propulsion of ferries solely using fuel cells (in total: 3.2 megawatts, see Fig. 1). With the help of several 200 kW modules connected in parallel, existing ships are to be converted to an emission-free propulsion system so that they meet the requirements of the International Maritime Organisation (IMO) for maritime safety. First of all, it is concerning the conception and certification. However, there are still numerous hurdles to be overcome, especially when using liquid hydrogen, which is to be stored on board in Linde cryogenic tanks. Kristian Osnes, head of the FreeCO2ast project at Havyard Group ASA, said: "The regulations for these solutions have not yet been developed."

IMO

In 2018, the United Nations International Maritime Organisation (IMO) announced a strategy to reduce greenhouse gas emissions from ships. The aim is to reduce greenhouse gas emissions by 50 percent by 2050 compared to 2008 and to eliminate all greenhouse gases as soon as possible. The IMO estimates that ships emitted 1.14 billion tonnes of CO₂ in 2008, equivalent to 3.5 percent of total annual global emissions.

Per Wassén, CEO of PowerCell Sweden AB, explained: "This will be a milestone for us and the global efforts to reduce emissions from commercial ships, and the experience we gain from this project will also benefit us in other segments such as stationary power generation". The ships are to be deployed in Norway by the shipping company Havila Kyststruten, which will operate ferries in areas with increased environmental protection requirements.

At the same time as announcing this cooperation, PowerCell presented its new 100 kW FC system designed specifically for maritime applications and special machinery. The new version of the MS-100 is 30 percent more efficient, according to the producer, and is especially designed for reliable operation under harsh conditions.

BALLARD TO BUILD MARINE CENTRE IN DENMARK The Canadian competitor Ballard is also stepping up its efforts in the maritime sector. In spring 2019, the European subsidiary Ballard Power Systems Europe A/S announced its intention to establish a Marine Center of Excellence (Marine CoE) in Hobro, Denmark. From the beginning of this year, high-performance modules based on the new FCgen[®] LCS stack for zero-emission drive units will be developed and manufac-

tured there. The production capacity at the site is to be 15 MW per year.

Jesper Thomsen, President of Ballard Power Systems Europe, said: "We are currently witnessing the first signs of long-term disruptive changes in maritime transport, with dirty diesel engines being replaced by zero-emission fuel cell systems. Our Marine CoE – combined with our extensive experience and knowledge of heavy-duty motive applications such as buses, trucks and trains – will make Ballard the epicentre of this fundamental change in the maritime market. [...] In 2019, we took on a growing number of European maritime projects, which is a sign of the growing interest in zero-emission solutions for the maritime industry." (see interview with Ballard boss MacEwen on p. 58)

Current Canadian activities in this sector include a cooperation with ABB to develop a 3 MW module and the *HySeas III* project to operate an emission-free car and passenger ferry in Scotland (see H2-international issue Jan. 2019). As was announced in October 2019, Ballard will also supply the three 100 kW modules for the drive of the German "Elektra" (see H2-international issue Apr. 2016). As part of this project, which is funded by the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP 2), the BEHALA push boat is to operate between Berlin and Hamburg from the end of 2020. Ballard concluded a further contract with Norled A/S for the supply of two 200 kW modules. In 2021, the modules are to be used in a Norwegian ferry.

The competitor Nedstack Fuel Cell Technology BV is also getting involved. Together with Ulstein Design & Solutions BV, the Italian FC producer presented a design for an assembly ship for offshore wind farms. The ULSTEIN SX190 Zero Emission DP2 should be able to run for four days in emission-free mode – the target is a period of up to two weeks. It will have a total capacity of 7.5 MW available, of which 2 MW will be provided by fuel cells, so that it can also fall back on a conventional diesel-electric system with low-sulphur fuel if required. According to the company, the first unit could be delivered in three years.

FC SYSTEMS FOR ON-BOARD POWER SUPPLY A much more obvious field of application for fuel cells in the maritime sector is currently the on-board power supply of ships. For example, Bloom Energy, a producer of stationary high-temperature fuel cell systems (see p. 50), is active in this field and, together with Samsung Heavy Industries (SHI), presented the concept for a power generator in September 2019 with which the emission of climate-damaging gases is to be reduced by up to 45 percent. The natural gas-powered system is to be installed on board a container ship. The first step towards implementation, the necessary approval from DNV GL, has been obtained, it was said.

SHI is relying here on its concept for liquefied natural gas. "SHI's new Aframax design features a new generator system in combination with conventional generators and new fuel cell technology, both powered by LNG," said Hwa Lyong Lee of DNV GL. KR Sridhar, founder and Managing Director of Bloom Energy, said: "The introduction of this transformative clean technology of the Bloom Energy Server into the maritime industry provides us with an incredibly fascinating opportunity to accelerate the decarbonisation of another important sector of the world economy."

In July 2019, AIDA also announced its intention to continue working on lower-emission solutions for its cruise ships. By 2023, for example, two more LNG-powered ships are to be built after the AIDAnova. In addition, the first >>

H₂ LUXURY YACHT

In the year 2009, there was the idea to also equip yachts with fuel cells. The *SchIBZ sub-project* was also launched as part of the e4ships lighthouse project [see H2-international issue Oct. 2009]. The name stands for “ships with fuel cells” and was intended for the use of molten carbonate fuel cells (MCFC) on ocean-going mega yachts and special ships. Almost exactly ten years later the Dutch yacht builder Sinot presented at the Monaco Yacht Show just how such a ship could be built today. The “Aqua” is a 112 metre long luxury yacht and will be powered by liquid hydrogen stored in two 28t tanks. This concept provides both a PEM fuel cell and a large battery pack for the electricity supply, which should enable a maximum speed of 17 knots and a range of 3,750 nautical miles. However, this is initially only a study that was designed together with Lateral Naval Architects within five months.

practical test of fuel cells on board an AIDA ship is planned for 2021. The first official announcement of this step was made in Warnemünde at the kick-off event of the e4ships lighthouse project in 2009. Currently, the installation of FC power plants on cruise ships is being pursued together with Meyer Werft as part of the PaXel-2 project. (Details can be found in the April issue 2020.)

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LH₂ TRANSPORT ACROSS THE OCEAN Hydrogen is, however, not only targeted as a fuel for the propulsion units or the on-board power supply, but also in order to be able to transport large amounts of energy over long distances. Moss Maritime, Equinor, Wilhelmsen and DNV GL presented the design of an LH₂ bunker ship at the beginning of last year. In view of the fact that in the future not only between Australia and Japan, but in the future probably also worldwide, ever larger quantities of liquid hydrogen (LH₂) are to be transported, the demand for such ships could certainly rise.



Fig. 4: Design draft of an LH₂ tanker, Source: Wilhelmsen

Håkon Lenz of Wilhelmsen Ship Management said: “As soon as the market signals show that there is a need for large-scale liquid hydrogen, we and our partners are ready to take this design to the next level.” The ship will have a storage capacity of 9,000 m³ available.

“Equinor believes that hydrogen could be an attractive energy solution for those sectors that are difficult to decarbonise and currently not covered by renewable solutions such as batteries. “Long-haul maritime transport is one of them.”

Steinar Eikaas, Equinor

Further details on the use of electricity-based fuels in inland waterway transport can be found in the next issue of H2-international in April 2020. ||

Literature:

□ [Energy Transition Outlook Report 2019 – https://eto.dnvgl.com/2019](https://eto.dnvgl.com/2019)



Fig. 3: Concept for the Aqua Luxury Yacht

ECONOMIES OF SCALE ACHIEVABLE QUICKLY

Interview with Claus Möhlenkamp from Freudenberg Sealing

Freudenberg Sealing Technologies (FST) is regarded as one of the pioneers of fuel cell technology, at least in Germany. The globally active seal manufacturer is one of those automotive suppliers who see the far-reaching changes in the mobility sector as an opportunity. With the purchase of battery manufacturer XALT Energy and parts of FC supplier Elcore in 2018, the basis was laid. Claus Möhlenkamp, Chairman of the Management Board, explained to H2-international that this combination brings not only technological but also cost-specific advantages. FST sees great potential above all in maritime transport and buses. The first projects with renowned partners such as Meyer Werft or Flixbus have already started. While intensive consideration is being given to entering the charging infrastructure, Elcore's activities in the FC heater sector have now been shelved.

H2-international: A number of companies have now given up due to the frequent shifts and delays in the fuel cell sector. Why have you remained true to this technology?

Möhlenkamp: Twenty years ago we started with the basic development and production of components. As the market was not yet mature at that time, we initially scaled back our activities considerably. But the know-how was not lost. The knowledge remained in the company. Reactivating this was relatively easy for us.

How do you monitor current market developments?

Electro-mobility and its many facets – not just the battery-electric variant – are bringing back interest in the fuel cell. In addition to passenger cars, commercial vehicle manufacturers or shipbuilders in particular are showing great interest in this technology. The market thus becomes much wider. This is why we are expanding our know-how and are now building complete fuel cell stacks.

At the end of 2017, the takeover of parts of the FC heater manufacturer Elcore (see H2-international issues Jan. and Apr. 2018) caused a sensation. Was this the necessary step towards expanding expertise?

Yes, you could say that. Elcore has built complete systems including reformer equipment. That was very attractive for us. We have acquired over 60 patents with Elcore. For us, this is the technology basis in the sector of fuel cells.

Elcore's expertise was in high-temperature PEM (HT), in mobile applications they rely particularly on low-temperature PEM. How did you manage this technological change?

That was relatively simple, because there are many identical parts and a great similarity, for example in the processes. The biggest difference is that the plastic membranes in the HT-PEM have to withstand higher temperatures.

What depth of added value do you aim to achieve in the stack sector?

This must in any case be economically viable. We wouldn't feel comfortable with 30 percent. In the past, we did very well with a depth of value added of 50 to 60 percent. For batter-

ies it is in the range of two thirds. The fuel cell tends to be slightly higher.

Why is that?

Because here we do almost everything ourselves. The spectrum ranges from the production of the gas diffusion layers and the electrolyte membrane through the MEA to the stack and the finished fuel cell.

To what extent is it a problem that you are now a stack producer yourself and also a supplier to others?

That's not a problem at all. The market will become so large, especially in the commercial vehicle sector, that it will be difficult to fully satisfy demand at all.

Will you remain engaged in the reformer field?

Yes. Areas of application here are stationary applications in the HT-PEM sector. Among the attractive areas of application here are energy supply units on cruise ships. We have discontinued the activities of Elcore in the field of fuel cell heaters for domestic use. This sector was not attractive for us.

Why is that?

The market is too small for us in terms of unit numbers and the achievable margins are too low. In addition, it is extremely dependent on politically motivated funding. We use our expertise and focus on mobile FC products and large stationary units.

Which customers do you address with it?

We deliver a first HT-PEM unit in early 2021 to Meyer Werft as a producer of cruise ships. The fuel cell will take over parts of the on-board power supply. The next step is to increase the output to 5 MW. This power class is also still small in relation to the total on-board power supply of a large cruise ship, because we are talking about total outputs in the 60 MW range. However, the introduction takes time. Initially, evaluation and certification topics are the main focus of the FC systems, as maritime transport has enormously high demands in this respect.

The heavy-duty sector is generally regarded as particularly attractive for the use of fuel cells. Do you agree with this?

In the case of fuel cells, we do not rule out any segment for the time being, but that is precisely our assessment. With the fuel cell we are still a few years behind the battery. Both in penetration and acceptance. The discussions are just beginning. Particularly in the maritime sector and in buses, I see a great need for fuel cells. The truck sector is still somewhat more reserved. But even there the interest is going to grow very quickly. This is likely to be driven less by emission targets and more by potential cost savings, specifically the reduction of TCO. >>



Fig. 1: Claus Möhlenkamp

How do you assess the situation in the passenger car market?

According to our evaluation, this will later become relevant for the fuel cell. Firstly, acceptance is not yet as high as it is today for batteries. Secondly, the infrastructure is still in its infancy. But this is not an obstacle. If you currently look at the international market, you can see that Toyota, Hyundai, General Motors or Honda, for example, are very strongly focusing on the fuel cell.

What are your concrete market expectations for batteries and fuel cells?

We expect sales of 400 million euros in the battery and FC sector from 2025 onwards. We also rely on the combination of a fuel cell for the base load and a battery for the peak load. This is currently the best economic approach, because a combination of the two systems designed for the respective load profile makes absolute sense.

What are the concrete advantages here?

Both systems can be built much smaller. In addition, it makes little sense to cover the base load with the battery. We have prepared the following calculation: If we look at a FC and battery system with a value of 100 each, we can build a combination of 70 each. For us, the optimisation of the two systems on each other is in the foreground.

What percentage does the fuel cell cover in such a hybrid module?

That depends on the load profile. The long distance is the FC domain, in urban traffic the battery is more active. By the way, the reduced number of cycles for the fuel cell is not the decisive argument here. This challenge can also be mastered through technical optimisations at the MEA.

With your purchase of XALT Energy in the battery sector and Elcore in fuel cells, you are betting precisely on this combination. Do you expect other suppliers to follow a similar path?

I know of no other company that offers this from a single source today. However, we see not only the synergies between battery and fuel cell, but also between battery system and charging unit. This is because the type of battery charge has a significant influence on the service life of the battery. Here, in particular, the utilisation of the battery's limits and the extension and optimisation of the service life are decisive starting points. That's why we think that we can achieve the highest degree of efficiency in the coordination of these three systems – battery, fuel cell and charging infrastructure – and thus offer the greatest benefit to the customer.

So far, your portfolio has not included the production of charging stations. When are you going to start with this?

We are currently intensively analysing the market environment and are working on concrete implementation. However, the decision as to whether and when we will get involved there will still take a few months. The focus here is not on the pure construction of charging units, for us the technology inside, and in particular the software, is decisive.

How do you coordinate the developments at your American battery subsidiary and your German FC subsidiary?

Our new Battery & Fuel Cell business unit at Freudenberg Sealing Technologies combines the two sectors, which now employ more than 300 people. The activities are closely interlinked. For example, we have set up the FC test stands at our locations in Michigan and Munich and they are identical.

What are your considerations when it comes to costs? How competitive is the fuel cell today?

We are already competitive in the maritime sector. We even have cost and space advantages compared to diesel engines. In the cruise ship sector, it is said that a complete deck can be saved due to the reduced space requirement of the FC system.

And what about trucks, buses and passenger cars?

The goal in terms of costs must be to get where the combustion engines are today. In contrast to the passenger car sector, we see greater planning security for the fuel cell in commercial vehicles and expect to see the first series production models from 2024/25.

The announcement that you wanted to enter the bus business with Flixbus was heard everywhere. What are the reasons for this and what is the current state of product development here?

The high weight of the vehicles and the required range speaks in favour for the FC technology in buses. We can also achieve

THE WAY TO SERIES MATURITY OF THE FC SYSTEM FROM FST

Freudenberg Sealing Technologies' technology road-map aims to develop the low-temperature PEM fuel cell system for series production by 2024. In 2018, the stack design and component selection were determined. In the first half of 2019, the focus was on optimising the operating strategy and in the second on validating the prototype stack and hybridizing it with the battery. At the beginning of September 2019, Flixbus and FST announced that they would jointly bring fuel cell drive coaches onto the road. The expansion of the partnership to include a bus manufacturer is planned. Talks are under way to achieve this.



The year 2020 is dedicated to system validation and calibration of demonstration models. In the years 2021 to 2023, the additional vehicle validations in the targeted heavy-duty applications and the transition to series production will take place.

As technology partner of the Pa-X-ell-2 project promoted by NOW, FST also wants to develop a new generation of fuel cells for use on ocean-going passenger ships together with Meyer Werft. The first practical tests on board the cruise ship AIDAnova are planned for 2021. The project consortium includes the classification society DNV GL, the German Aerospace Centre, AIDA Cruises, represented by Carnival Maritime GmbH, and EPEA GmbH.

The start of series production is scheduled for 2024.

economies of scale more quickly in this sector. If, for example, you are operating a cruise ship of common size completely with fuel cells, then we are talking about an equivalent of 1,000 passenger cars in a single ship. This enables us to quickly achieve economies of scale with which we would also be very competitive in the passenger car segment. Together with Flixbus, Europe's largest supplier of long-distance bus tours, we want to put FC-powered coaches on the road. In partnership with a bus manufacturer. We are in contact concerning this.

To what extent do you benefit from your bus expertise in the USA?

In the USA, we made our first successful experiences with battery-driven buses. Our subsidiary XALT Energy has been supplying batteries to the New Flyer Group for some time, which specialises in the manufacture of buses and coaches and the sale of spare parts. Our XALT batteries are installed in the fully electric city buses of the Xcelsior Charge model, which are on the road in North American cities.

When are we going to see the first Flixbus with Freudenberg-Stack on the road?

That depends on the course of the talks with the bus manufacturers.

When are you going to announce the bus manufacturer with whom you will be working here?

Of course, all well-known producers are invited to participate. We'll discuss that with Flixbus. If it's the end of 2022, that is just fine.

How great is the risk that your market expectations in the battery and fuel cell sector will not be met this time?

There is always an entrepreneurial risk. But I think that the mobility turnaround is no longer reversible. Driven not only by ever stricter emission limits, but above all by new mobility concepts and increasing social acceptance and willingness to change on the part of the end consumer. However, we are still at the very beginning of this new development. ||

130 STATIONS BY 2021



Fig. 1: Nikolas Iwan

The expansion of the H₂ infrastructure continues – albeit much slower than it could be. The declared goal of having 100 hydrogen refuelling sites in Germany is expected to be achieved by mid-2020 – more than a year later than originally planned. By the end of 2021, 10 to 15 new locations are to be added each year.

During the stakeholder conference on the national hydrogen strategy, Federal Transport Minister Andreas Scheuer had reported to the media that the day before he had signed a memorandum of understanding with H2 Mobility to set up 10 to 15 additional H₂ filling stations per year. At the same time, Scheuer announced that by the end of 2021 the capacity in Germany would be sufficient to refuel 60,000 hydrogen-powered passenger cars and 500 trucks.

In 2015 the then Federal Transport Minister Alexander Dobrindt had said: "For the market ramp-up of this technology, we now need a nationwide filling station network for hydrogen. I therefore welcome H2 Mobility's plans to build 400 H₂ filling stations throughout Germany by 2023." Somewhat later (2017), H2 Mobility said – but with one restriction: "100 hydrogen stations by the end of 2018 and even up to 400 hydrogen filling stations by 2023, but depending on the number of vehicles."

With this restriction that filling stations would not be built in any case, but only upon demand, when there were enough FC cars on the road, vehicle manufacturers should be made to comply. Today we know that this has not borne fruit with the German producers and that the unit numbers of H₂ cars are still in the mid-three-digit range. It was therefore questionable whether there would be any further expansion at all. Accordingly, H2 Mobility boss Nikolas Iwan expressed his satisfaction to H2-international that he had received a mandate for further locations, so that he and his staff cannot only take care of the maintenance of the existing stations, but also for further expansion. However, the company will not remain active for longer than 2023 for antitrust reasons.

How things will continue in 2022 remains to be seen and depends to a large extent on the automotive industry. The BMVI declared: "A further expansion can be decided in 2021, depending on the vehicle ramp-up that will take place by then and the plans of the German automobile manufacturers in particular."

At the end of 2019, further H₂ filling stations were inaugurated as part of the infrastructure expansion. Number 77 in Germany was also the first in Lower Bavaria. It is in Passau. Previously, stations in Bad Homburg, Mönchengladbach, Hagenow (Mecklenburg-Western Pomerania) and Schnelldorf (Central Franconia) had also become operational. All these locations were each supported on average by almost 1 million euros in subsidies from the federal government. ||

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LOAD WHEEL WITH H₂ DRIVE



Source: Photograph by Olivier Frajman

Fig. 1: H₂ cartridge exchange

ies; up to 25 kg), but also for shopping by private users.

It has a 250 W drive, which is supplied with energy from two hydrogen cartridges. The H₂ containers, which can be replaced within seconds, come from Aaqius (see interview H2-international issue July 2018) and enable an electric range of 100 km and a maximum speed of 25 km/h. The new concept was presented at the end of October 2019 in Geneva. Aaqius President Stéphane Aver stated that this was a further step towards "truly sustainable mobility that is affordable for everyone". ||

In a joint action, various French stakeholders intend to launch a load tricycle with pedal support in the form of a fuel cell drive on the market in 2020. The bicycle manufacturer Cycleurope has teamed up with Bianchi and STOR-H Technologies for development. The result is the "Sneaker", which can be used for professional applications (material transport, deliveries;

IAA – NEW START LOOKS DIFFERENT

VDA is stuck in old structures and ways of thinking

That's how it is when theory and practice diverge: While the former VDA boss Bernhard Mattes announced a new beginning at the International Automobile Exhibition 2019 (IAA), the exhibition halls were once again full of the same fuel wasters as always. The design of the exhibition stands remained the same, and just as in previous years, visitors were mainly interested in large-engined sports cars. That should be clear: Neither the automobile companies nor the consumers really want to dare anything new at the moment. What was still attractive, although not as well as in the golden years of the car industry.



Abb. 1: BMW i Hydrogen Next

During the opening ceremony of the IAA 2019, which took place from 12 to 22 September in Frankfurt am Main, Mattes talked a lot about the environment, CO₂ and responsibility. ("We represent sustainable and individual mobility.") It was a vain attempt to save Germany's biggest car show. However, so many discussions concerning the IAA and the trade fair venue Frankfurt had already been announced in advance that the words sounded more like crying to oneself in the woods and not at all like a rousing encouragement to tear around an almost already lost game. Although Hessian Minister President Volker Bouffier also gave his best in an almost statesman-like speech to take the wind out of the sails of migration rumours, a quick glance into the halls was enough to see that fundamental changes were needed.

Despite the announcement of Mattes ("An IAA like it never existed before") the appearance was as always – only smaller. Where BMW used to occupy an entire hall alone, Opel and Hyundai also fitted in this year. Worldwide important car manufacturers like Toyota, Renault or Fiat-Chrysler were not there. With them there were also 200 other exhibitors missing who were still there in 2017 (2019: approx. 800 – 2013: approx. 1,100). The exhibition space was also a good 15 percent smaller than two years ago (2019: 168,000 square

metres), several halls were completely empty. There were no really fundamental new developments to be seen, even though the VDA had announced that it wanted to make the event more interesting with a new concept.

"Individual mobility and climate protection are not contradictory. [...] We do what we can, and we can do a lot."

Bernhard Mattes, VDA

"It won't be very easy to roll out a second infrastructure for hydrogen. [...] We'll keep an eye on it. [...] We will present an H₂ strategy."

Angela Merkel, Federal Chancellor

COMBINATION OF CAR AND CONSUMER MARKET Instead, Federal Chancellor Angela Merkel pointed the way – intentionally or unintentionally – in her welcoming speech. She began her statement with a brief historical review of the year 1987, when the first IAA took place in Berlin. With this reference to the German capital, she must have spoken from the souls of all those Frankfurt critics who would like to link the Auto-Show to the IFA in Berlin. With such a change of location, there would be a chance that the "world's leading trade fair for consumer electronics and home appliances" would actually be able to live up to its claim. At a time when modern cars are seen more as smartphones on wheels anyway, mixing the automotive and IT sectors could be attractive – both for exhibitors and visitors. At the CES (Consumer Electronics Show) in Las Vegas, the integration of the automotive industry worked out quite well.

According to the newspaper "Die Welt", the long-standing contract between Messe Frankfurt and the VDA is about to expire. So, 2021 would have to be renegotiated.

In any case, things should not continue as they have done so far. Every two years since 2008, Mattes had announced the launch of electro-mobility, but every time the disappointment grew because the overall picture always remained the same: Alternative drives (including electric cars) have always been on the side-lines because visitors want to see horsepower. So, it is too short-sighted for the environmental activists, who once again called for a stop to CO₂ emissions in 2019, to blame just the car manufacturers. Every car buyer, whether commercial or private, has just as much a share in the failure of alternative drive technologies as the car industry when it comes to vehicle purchase with his choice of model.

Last year, the VDA itself stated that "a classic motor show alone no longer satisfies the demands that exhibitors, visitors and society place on such an event". However, the conclusions were half-hearted. The industry association invited non-governmental organisations and other critics to a citizens' dialogue and was also able to attract prominent speakers on innovative topics to its IAA Conference. However, this remained hidden from the eyes of most visitors, so

that the public image was once again that of an automobile exhibition – without any serious suggestion to fundamentally rethink one's own mobility behaviour.

MÜLLER FOLLOWS MATTES And then came Bernhard Mattes' statement that he would resign as VDA spokesman. During the Executive Board meeting of the Association on the official opening day, he announced his withdrawal at the end of the year under the agenda item "Miscellaneous" – as the Handelsblatt reported – so that it became clear that not only the future of the IAA, but also that of the VDA is open.

It then took until the end of November until the favourite was actually elected president: The VDA board unanimously confirmed Hildegard Müller, former In-nogy Executive Board member, as the new boss. Müller, who was the first female federal chairwoman of the Young Union, has so far worked as Minister of State in the Federal Chancellery and as Chairwoman of the Executive Board of the Federal Association of Energy and Water Management (Bundesverband der Energie- und Wasserwirtschaft e. V.). (BDEW; 2008 to 2016). She will be in charge of the VDA from 1 February 2020. Müller said, "It takes strength for change and courage to innovate for alternative forms of propulsion."

"It's obvious, so let's say it explicitly: The #IAA2019 is a big failure. It is just a sad shadow of what it should be. There won't be any #IAA2021. End of story."

Ex-Opel boss Karl-Thomas Neumann via Twitter

Rapid market penetration of e-vehicles is needed to meet the EU's very ambitious 2030 CO₂ fleet limits. In concrete terms, this means minus 37.5 percent CO₂: In the year 2030 there must be 7 to 10.5 million E-cars on the road in Germany.

VDA press release

BMW COMMITS ITSELF TO FUEL CELLS But there was then a little to see: This year, for example, some companies actually had a few electric cars on the market, which are also going to be launched in the near future. However, producers such as Byton, who presented truly innovative studies, were more of an eye-catcher. For example, the Chinese company showed the M-byte, which has a 48-inch monitor (122 cm screen diagonal, see Fig. 2) as a cockpit.

The H₂ and FC technology was – once again – hardly represented. Only BMW made the headlines by presenting – after years of absolute silence – the headline of a fuel cell car that is to be built for advertising purposes from 2022 in small series (presumably three-digit number of units). The i Hydrogen Next is based on the X5, so it is an SUV, and therefore looks very similar to the GLC F-Cell from Daimler.

More important than the appearance and performance data of the concept vehicle is probably the Bavarian company's commitment to the fuel cell as an option for larger passenger cars. Oliver Zipse, Chairman of the Board of Management of BMW, explained that the company would continue to work on FC cars in addition to battery-operated vehicles.

Mattes had also put it similarly when, in his opening speech for the VDA, he made it clear that concentrating on just one drive technology was not desirable. He



Fig. 2: M-Byte

had thus taken a clear stand against VW boss Herbert Diess, who in spring 2019 had also called on the VDA to abandon the previous technological openness in its development work. In the meantime, however, even Audi representatives, who also belong to the VW Group, have reported that significant numbers of FC cars are to be produced from 2025 onwards. The expressions of the three German car manufacturers Audi, BMW and Daimler are now almost identical. However, this continued to be "very certain", according to "WirtschaftsWoche", that the hydrogen car would not be a relevant option for driving cars in the next ten years because it was unclear where the hydrogen would come from.

Green Party leader Robert Habeck was sceptical towards H₂-international as to whether it would make sense to set up an additional hydrogen supply infrastructure in addition to the many new charging stations. The party leadership thus seems to continue to close its eyes to the ecological potential offered by H₂ technology. ||

35



Fig. 3: Robert Habeck (left) with Jürgen Keller from Hyundai Motor Germany and Jan Burdinski from Hyundai Motor Company (right)

"Hydrogen needs the economic leap."

Robert Habeck, Die Grünen

REMANUFACTURING – THE ULTIMATE RECYCLING ECONOMY

Sustainable added value of PEM fuel cells

According to official statistics, waste management in Germany comprises the entire recycling economy. It differentiates between waste generation, further use and recycling as well as waste disposal. The legal basis is the Recycling Economy Act (KrWG), which is geared towards waste avoidance and recycling with the aim of protecting the environment. The five-level waste hierarchy of the legislator (waste avoidance, preparation for re-use, recycling, other recycling and disposal) makes it clear that function-preserving re-use of products is a desirable option and contributes to sustainable added value.

Product recycling by remanufacturing, which has been known for a long time and has often been very successfully practised, is currently not included in the official statistics of the recycling economy, as this added value can be attributed to the areas of the manufacturing sector by maintaining its value. It is obvious that product recycling can be attributed to waste avoidance and is therefore at the highest level of the waste hierarchy. The allocation of remanufacturing to the manufacturing industry makes it considerably more difficult to assess its significance.

However, the remanufacturing of suitable, often high-quality products is highly lucrative as an ecological and, at the same time, economically sensible alternative to the value-destroying product disposal of the substance-based recycling economy. Accordingly, remanufacturing is a significant sales factor for many industries, such as for automotive or medical technology. [ROS]

REMANUFACTURING OF PEMFC In order to achieve added value through remanufacturing and new marketing of quality-assured products, a number of product-dependent individual processes must be carried out, depending on the product and the objective. This includes the collection of used products – so-called cores –, incoming inspection and dismantling, detailed analysis and inspection and cleaning, remanufacturing (functional and optical/cosmetic), replacement of components if necessary, reassembly, as

well as test/final inspection/warranty. [STE] The pioneer in the successful implementation of corresponding industrial processes and the establishment of lucrative markets is certainly large industry. However, small and medium-sized enterprises in particular, as drivers of innovation, can expect great opportunities in the relevant business fields. The advantages of such a strategy are concrete: Multiple benefits through multiple use [STE] – that means profitable business –, opening up new markets with high customer loyalty and satisfaction as well as sustainable and responsible entrepreneurial action.

Polymer electrolyte fuel cells (PEMFC) are promising climate-friendly, decentralised and mobile energy sources and are being used for the first time for commercial applications in vehicles and as heat and power generators in buildings. PEMFCs are composed of membrane electrode assemblies (MEA) consisting of a thin electrolyte membrane film with an electrode and catalyst applied on both sides. The MEA is comprised of bipolar plates. Together they form a PEM cell. The individual cells are stacked in a row to form a PEM stack.

With its stack design, the PEMFC offers ideal conditions for disassembly and reassembly (see Fig. 1). With regard to the number of returned PEMFCs available for remanufacturing, the assumption is made that this should be in the order of about 100,000 units per year for automotive applications, similar to the number achieved for marketable replacement parts in automotive technology. [STE], [ROS]

The described stack design of the fuel cells allows the construction of an efficient, three-stage remanufacturing process. First, the stack is dismantled, cleaned, inspected and sorted. Sorting is carried out according to the classification of the individual parts (MEA, seals, etc.), on the basis of their condition, a decision is made on further use. The work steps of the following two process steps are analogous to those of the PEM stack, but each with remanufacturing of processable PEM cells and components. In the three process stages, the refurbished elements are finally subjected to an initial inspection, reassembled step by step and high-quality PEMFC stacks are produced. Parts not re-used in the overall process must be treated in accordance with the KrWG (see Fig. 1, left).

GOLDMINE REMANUFACTURING – BOTTLENECK PLATINUM The analysis of the production costs of a PEM stack shows that about 80 percent of the production costs are for the individual cells, which includes only the catalyst, the bipolar plates and the electrolyte membrane. The economic focus of the remanufacturing process is therefore on these parts (see, right).

Assuming an average service life of a PEM stack of about 5,000 operating hours and calculation with the cost structures of the replacement parts production of the automotive industry according to [STE], costs of refurbished PEM stacks at a level of about 65 percent of the new production can be expected.

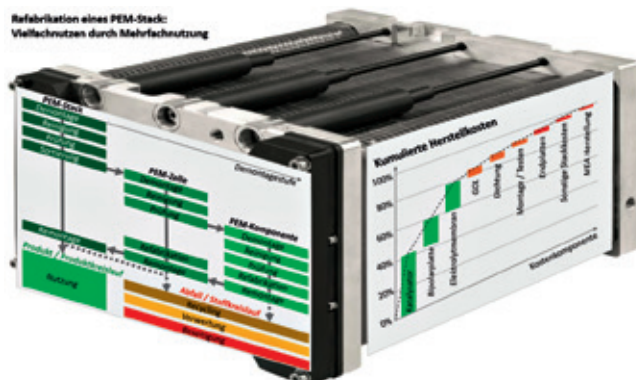


Fig. 1: Remanufacturing process of a PEM stack and its manufacturing cost structure

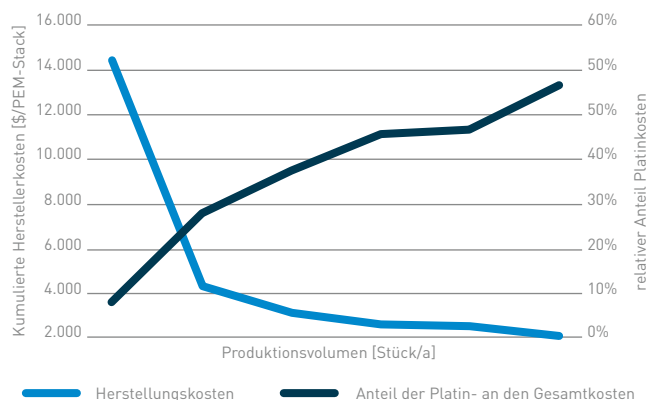


Fig. 2: Cumulative Manufacturing Costs of PEM Stack and Relative Proportions of Platinum Costs, [Source: JÖR]

In the PEM cell, or rather in the MEA, the raw material platinum used as catalyst – which is currently regarded as the raw material with the best properties for application in PEMFC [BAL] – dominates the costs with a share of currently more than 30 % [BRU]. Forecasts for the production of the PEM stacks assume that precisely this cost share will increase significantly due to the worldwide increase in the demand for platinum and the increased PEMFC production volume (see Fig. 2) [JÖR].

Platinum is used in an almost unmanageable number of areas (jewellery, automotive catalysts, electronics, etc.) with the demand growing. Surveys assume that, compared with 2006, the already high demand will continue to rise by a factor of 1.65 by 2030. To satisfy this demand, in addition to the use of primary platinum – an estimated range of only 28 years or 69,000 tonnes of platinum from 2012 – only about 17% is currently recycled using hydro metallurgical and wet-chemical processes due to the high cost and effort involved.

Taken together, the remanufacturing of PEMFC is likely to become much more lucrative, making it a gold mine.

OPTIMISATION OF ECONOMIC EFFICIENCY In addition to the actual remanufacturing process, a coordinated return concept makes a decisive contribution to the economic efficiency of PEMFC remanufacturing, whereby three basic concepts are conceivable:

- Return of cores to collection points and remanufacturing by specialised companies
- Recirculation and remanufacturing by PEMFC producers
- Recirculation and remanufacturing by automobile manufacturers

The three basic concepts were evaluated and compared with the help of expert knowledge from the Chair of Environmental Production Engineering. Four criteria (quantitative, qualitative, scheduled, technological) and their overall influence on the remanufacturing process were weighted (quantitative with a relative share of 35 %, qualitative 25 %, scheduled 10 %, technological 25 %). Each individual criterion per basic concept was evaluated with points, one point being defined as “minimum suitability” and ten points as “maximum suitability”. Multiplied by the total influence, the following results were obtained (see Fig. 3):

The sum of all individual criteria per basic concept (collection points 7.05 points; PEMFC producers 7.10 points; automobile manufacturers 6.50 points) shows that remanufacturing by PEMFC producers is the most suitable variant. This is due on the one hand to the process specialisation and on the other hand to the available production capacities and the associated flexibility of the PEMFC producers.

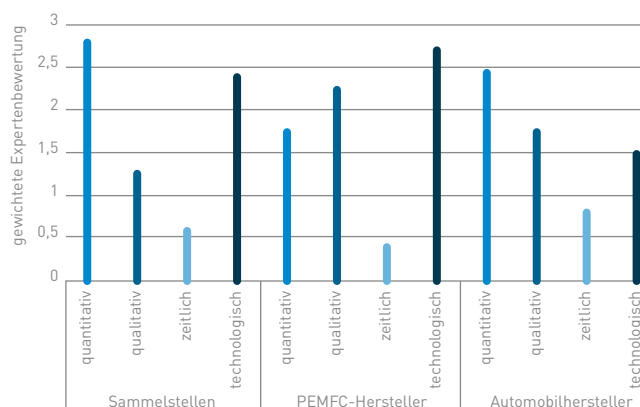


Fig. 3: Comparison of return concepts with weighted expert evaluation

SUMMARY Remanufacturing offers great opportunities, especially for the PEMFC in its stack design. With an expected cost level of 35 % below that of new production, it holds relative economic potential, which is likely to intensify in the future. Decisive for the economic establishment of PEMFC remanufacturing is its return, which leads most sensibly to the remanufacturing of used PEMFCs by the producers themselves. Despite the high potential of PEMFC remanufacturing, the search for platinum alternatives seems advisable, whereby the recovery from PEMFC itself should be a good source of additional income for PEMFC processors. ||

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STRALSUND HAS WRITTEN H₂ HISTORY

Prof. Jochen Lehmann and his complex laboratory

It all started almost forty years ago. At that time his interest in energy brought him to hydrogen. Since then Prof. Jochen Lehmann, a veteran of the German H₂ industry, has achieved a lot: He initiated the installation of the complex laboratory Alternative Energy at the University of Applied Sciences Stralsund with the world's first hydrogen storage power plant, he was co-founder of the German Hydrogen and Fuel Cell Association (Deutscher Wasserstoff- und Brennstoffzellen-Verband e. V.) and, with his own curiosity and enthusiasm, he introduced hundreds of students to the fascination of hydrogen.

trigger for corrosion of high-strength steel" – i.e. H₂ embrittlement. "That's when I learned that hydrogen is easy to store in metals."

When the first industrially manufactured wind power plant (220 kW) for East Germany was erected in Wustrow on Fischland on 10 October 1989, a friend said: "Now we have our own electricity on our Fischland, so all we need is a brewery, we could open a breach and make the Fischland an island again." To Lehmann's question: "And when there is no wind?" But the friend would always have two crates of beer in the cellar. That was the idea: Storage! "Volatile electrici-



Fig. 1: Prof. Jochen Lehmann with his first FC system from Warsitz, Sunnyvale, from 1994

Looking back, he notes with a smile: "I have been driven to energy in my development." At the age of six, his mother explained to him the enormous amount of energy in an atomic bomb. This had made a lasting impression on him, so that he later went to Leipzig to study physics. There he personally experienced Werner Heisenberg, Gustav Hertz & Co. as professors, as he describes it in a slightly amusing but also very respectful way. Heisenberg had been appointed to the chair of theoretical physics at the University of Copenhagen in 1927 when he was 25 years old.

There Lehmann also had the opportunity to listen to Linus Pauling, the US chemist and two-time Nobel Prize winner (Chemistry and Peace) in a lecture. The largest auditorium available would have been "packed," he remembers.

After completing his vocational training, he went into industry, but "it wasn't that exciting for me," he continues. Therefore, he went to the former University of Maritime Navigation Warnemünde/Wustrow and entered the hydrogen sector in 1981. His topic was: "Hydrogen as a



Fig. 2: In the complex laboratory various investigations can be carried out, e.g. the analysis of the proportion of carbon after intermediate storage in LOHC

ty without storage is not possible, but with hydrogen," says Lehmann. So, the idea of a wind-hydrogen system was born – almost exactly 30 years ago.

With its opening in 1991, Lehmann came to Stralsund University and founded the complex laboratory Alternative Energy in 1992. To this end, he initiated the construction of a wind energy plant (100 kW), various PV installations, an alkaline 20 kW electrolyser with pressure storage tank and a CHP plant, which was planned to operate with a natural gas/hydrogen mixture, for re-generation of electricity. Even though he was employed as a physics professor. Thanks to tireless drive and favourable conditions, the "world's first hydrogen storage power plant" was created in this way.

After the fall of communism, Lehmann came to Stralsund University in 1991 and founded the Alternative Energies complex laboratory there in 1992. Among other things, he initiated the construction of a wind power plant (100 kW), various photovoltaic plants, an alkaline 20 kW electrolyser

and stationery H₂ pressure storage tank, although he was actually employed as a physics professor. With his tireless drive he built “the world’s first wind hydrogen power plant”, as he affectionately called it.

Since 1993 he has also been in charge of the energy symposium “Use of regenerative energy sources and hydrogen technology”, which was held last year for the 26th time. This is probably the first conference to address the issue of electricity storage using hydrogen. “Thematically we were always a bit ahead”, he reports mischievously and proudly.

The death of his assistant of many years, Dr. Frank Menzel, was a sad turning point. After years of successful work in Stralsund, he finally accepted a professorship in Wismar in 2004, but had an accident shortly before while driving there by car. I, the author of this text, was allowed to get to know him myself as an extremely competent and patient scientist in the Stralsund laboratories. Therefore, he is still unforgettable in the Hanseatic city and well beyond.

In 2006, Thomas Luschtinetz took over the complex laboratory as Professor of Electronic Components and headed it until 2019. He founded the “ThaiGer” tradition (see below) with the intention of increasing public awareness of green hydrogen. His successor is now Prof. Johannes Gulden, who has already been active in Stralsund since 2012, until now as project manager. He has now been specifically appointed to a professor for renewable energies at the university. Since Prof. Lehmann still has an office in the university despite his retirement and is on site on a weekly basis, the students live in the comfortable situation of having three proven energy experts as trainers.

These good learning conditions lead, among other things, to around 600 students from Germany and abroad applying to the university every year, although only 40 can be accepted.

“Prof. Lehmann started something here where there was a great deal of belief.”

Prof. Johannes Gulden

“That was certainly right from the start!”

Prof. Jochen Lehmann (laughing)

THAIGER-H2 IS THREE-TIME EUROPEAN CHAMPION The fact that the students in Stralsund are no less committed than the professors is proven by the fact that the ThaiGer-H2 university team became European Champion at the Shell Eco Marathon in 2019 for the third time in a row. In 2017 the ThaiGer VI had driven the equivalent of 880 kilometres (see H2-international issue Oct. 2017) and had won in the H₂ prototype category.

In 2018 and 2019, the Hanseatic League again competed in London with this model, although a newly designed version is supposed to be launched every year, but due to problems with lamination, ThaiGer VII was not yet ready for launch. However, the competitors were “extremely satisfied” with the fuel cell stack used by the Centre for Solar Energy and Hydrogen Research Baden-Württemberg, as the student Lukas Hopfer assured H2-international. Last summer they reached a range record of 1,083 km/m³ H₂.

In 2020, the 30-strong team, which also includes some freshmen, wants to compete with the seventh generation of vehicles. At the same time, an urban concept model is to be launched. ||

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ACCEPTANCE OF P2X TECHNOLOGIES BY YOUNG PEOPLE

Invisible Kids – Results of an on-line survey

As part of the social science study “Invisible Kids” in the Copernicus Project P2X, the Social Science Research Centre Berlin (WZB), the WWF and DECHEMA examined the acceptance of P2X technologies among young people and adults in comparison. In the Copernicus project P2X: The research, validation and implementation of “Power-to-X” will investigate how Power-to-X technologies can be brought to market and implemented. A large-scale implementation of P2X technologies, however, is only predicted for the next few years. Accordingly, today’s children and young people will be those who will be sustainably affected by the developments of the energy turnaround and in particular by the use of P2X technologies.

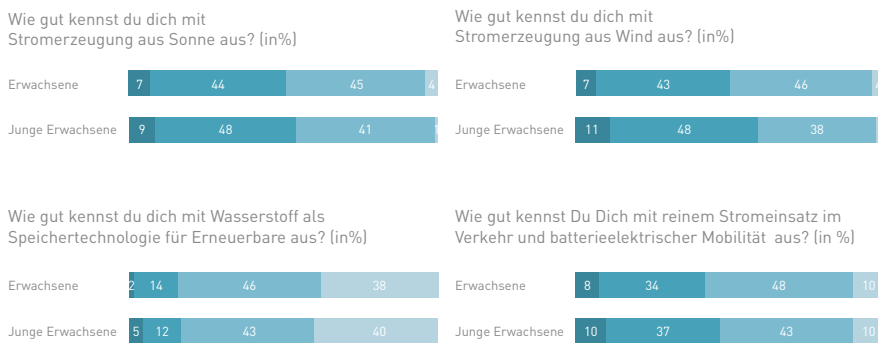


Fig. 1: Knowledge of power generation, hydrogen as a storage medium and battery electric mobility (n = 510/1.036)

The aim of the research work was both to enter into a discourse with a group of actors – young people – that has so far been little represented in studies, and to ascertain their attitudes and perceptions towards a complex and innovative technology in the energy turnaround. In the explorative research design of the “Invisible Kids” study, the methods complemented each other to the extent that, firstly, the technical material was prepared for the young people (expert interviews, design thinking workshop). In the second step, the perception of young people was surveyed and compared with another age group (adults) (on-line survey).

Thirdly, the results of the on-line survey were discussed in depth with the young people in workshops (qualitative survey). Methodologically, the research work posed a challenge. The technically complex material had to be prepared in such a way that it could be grasped quickly by the young people.

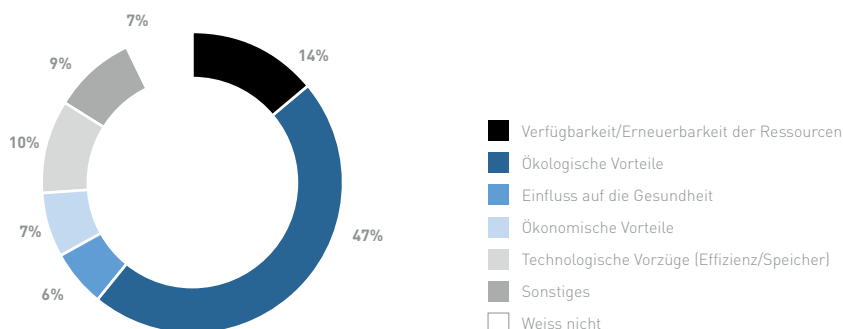


Fig. 2:

The central element of the study was an on-line survey: For this purpose, an opinion research institute was commissioned to provide the necessary sample for the (one-off) survey from its existing pool. The field phase of the survey took place from February to March 2018. Of the 1,546 people surveyed, 1,036 were aged between 16 and 25. These are referred to as “youths” in the further version. Both age groups were surveyed with regard to cross-quotation of age and gender in a representative manner for the population (representative quota sample).

The survey consisted of two phases: In the first phase, the state of knowledge of young people on the topics of energy and traffic turnaround and P2X technologies was surveyed. Then explanatory elements were incorporated into the survey, which were developed in cooperation with WWF education officers to explain the role of P2X technologies in the energy turnaround. In the second phase, the acceptance and perception of P2X technologies was asked.

RESULTS: KNOWLEDGE, ADVANTAGES, CHALLENGES The on-line survey as a core element of the research work shows that knowledge about electricity generation from wind and sun is significantly greater than knowledge about energy storage using hydrogen (see Fig. 1). There does not seem to be any significant differences between the two age groups or between the renewable energy sources wind and solar energy. As older acceptance studies have also shown, the state of knowledge on hydrogen technology is low: Over 80 percent of the young people and adults surveyed stated that they had no or only an approximate idea of the technology. In addition, only just under half of the respondents stated that they were familiar with the use of electricity in traffic and battery electric mobility.

The respondents clearly see the main advantage of P2X technologies in ecology (see Fig. 2). However, the renewable nature of the resources

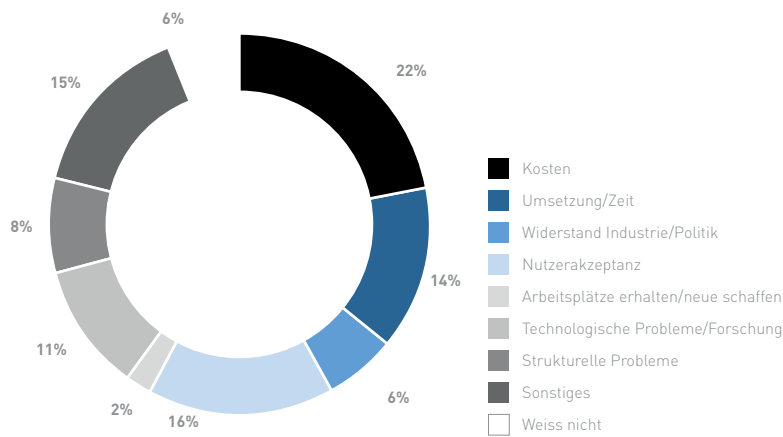


Fig. 3: Further development of P2X technologies (n = 510/1.036)

used, the availability of raw materials and technical progress are also seen as advantageous. Respondents see obstacles to dissemination in particular in terms of costs. They also assume that implementation processes will take a long time and fear technical problems. But the respondents also expect challenges in terms of user acceptance (see Fig. 3).

The results also show, among other things, that young people are more in favour of implementing the energy turnaround and welcome the rapid expansion of renewable energies. Compared to adults, young people rate the expansion of renewable energy plants and their impact on the landscape as less negative. 49% of young people see P2X technologies affecting their work and education in the next 10 to 15 years, but only 33% of adults.

The young people feel more influenced by P2X technologies, which is to be expected due to the development paths over time. It is therefore all the more important to enter into a dialogue with them as early as possible regarding the design of the energy turnaround and, for example, to demonstrate how occupational fields will change within the framework of the energy turnaround.

Für wie wichtig hältst Du die Entwicklung von Power-to-X-Technologien? (in %)

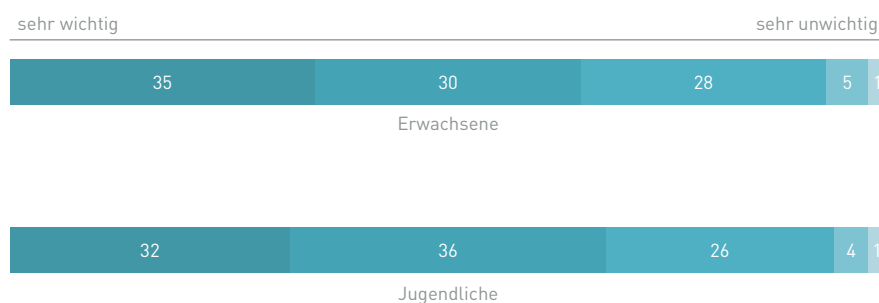


Fig. 4: Further development of P2X technologies (n = 510/1.036)

[Sources: Epp & Bellmann 2019]

The presentation of P2X technologies in a compact form and the scientific publication of the available results are consistent steps to disseminate knowledge about current developments in the energy turnaround. The differentiation of the individual technological strands and their processing into easily understandable criteria (e.g. advantages and disadvantages, costs, use of land, etc.) are indispensable. A further survey based on these criteria should be sought in order to assess the various technological applications and products of P2X technologies from the point of view of the population. The background to P2X technologies is very complex and difficult to understand for a target group that has not yet addressed the topic.

CONCLUSION The research work shows that respondents are generally open to P2X technologies. Although knowledge of these technologies is low overall, 94% of young people and 93% of adults surveyed consider the development of P2X technologies to be rather important to very important. In addition, since the acceptance of P2X technologies is expected to change significantly, it is important to repeat similar studies at regular intervals. This can be used to describe current trends so that changes in perceptions and attitudes can be taken into account.

Research work that informs and evaluates at the same time must take into account that respondents' attitudes can be influenced by the information provided. The study collected further data on knowledge about energy and traffic turnaround, anticipated changes due to P2X technologies (e.g. in the choice of transport system and working environment) and criteria for the use of P2X technologies. The detailed results of the study "Invisible Kids" were published in the joint anthology of the four Kopernikus projects "Acceptance and political participation in energy transformation – societal challenges beyond technology and resources". ||

Literature

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SHAREHOLDERS DISCOVER FUEL CELLS

Sven Jösting

The reports are overwhelming as far as the areas of application and potential of the fuel cell are concerned, and politicians in Germany have also finally woken up. The stock exchanges have led many FC companies into a real course euphoria. But also, contradictions find their way into the media, according to which China allegedly plans to reduce or even completely discontinue the promotion of battery-powered, but also fuel cell-powered electro-mobility. On the other hand, from a very well-informed source one hears exactly the opposite, namely that precisely the promotion of the fuel cell and the associated infrastructure in China is being set up anew, that only the battery promotion is being limited.

Individual Chinese provinces and mega cities are already in the process of paving the way for fuel cells and green hydrogen. The positioning – worldwide – in the various FC markets such as trucks, buses, ships, rail vehicles and many others is in full swing, which is also reflected in various joint

ventures and capital investments. We expect to see the right scaling effects from 2020 onwards. The stock exchange is already anticipating this future.

In fact, there are different data on the current march direction and promotion policy in China. In view of the several thousand fuel cell vehicles that exist in the People's Republic to date, the question arises as to why promotion should be discontinued now if the declared goal is to achieve 1 million FC vehicles by 2030. In any case, Ballard boss Randy MacEwen was relaxed when he returned directly from China to Hamburg to report on developments there (see interview p. 54).

On the stock exchange one should currently focus on the stocks or companies and their shares to which the greatest price potential can be allocated, which lead technologically, whose balance sheet ratios are right, whose market prospects are good, where the respective management is convinced and, above all, where the stock market valuation matches the various indicators (turnover, liquidity, orders on hand, technologies, etc.). The companies discussed here fulfil all these factors.

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Fig. 1: Share price development of the six discussed companies
Prices from 22 December 2019, [Source: www.wallstreet-online.de]

BALLARD POWER – GROWTH BEGINS IN 2020/21

Forget the quarterly figures for Ballard Power this year. They are only important to analysts. The CEO already said at the beginning of the year and recently underlined in a Bloomberg interview that this calendar year will be used to build capacity in China (production of the LCS stacks together with Weichai), among other things, to position themselves, to strengthen the central production and R&D location in Vancouver, to expand the workforce and to tackle pilot projects as a basis for orders. After all, the company wants to be the world market leader not only in the next ten months, but also in the next ten years.

Thus, 2019 will not bring more than \$100 million in revenue and will, at the end of the day, bring “logical” losses due to investment in corporate growth (R&D). Meanwhile, Ballard can finance all this from its petty cash, which at the end of the third quarter is still in excess of US\$ 150 million. The stock exchange is already anticipating all this and anticipating the future in successively rising prices.

Ballard is the clear key investment of the industry. As was apparent from the statements made by CEO Randy MacEwen at the International Hydrogen Symposium in October 2019 in Hamburg, Ballard will achieve very high growth with the LCS stacks from 2020 onwards and advance some projects in the field of rail vehicles with Siemens and CRRC, among others (see interview p. 54). Side events such as the bankruptcy of the Northern Irish bus manufacturer Wrightbus have now been resolved positively (see p. 5). Ballard's stacks for the 15 FC buses in Aberdeen should now be integrated and delivered as planned.

A positive solution now also seems possible in the relationship with Guangdong Synergy. Orders and purchase agreements for 130 million US-\$ had to be cancelled because the market had been misjudged. This could now change in a positive sense if the expected support programmes of the Chinese government take effect.

“Guangdong Synergy has been producing Ballard-9SSL stacks since the end of 2017. A new stack production was set up. At the end of 2018, the company faced a number of challenges, including liquidity, inventory build-up and market demand problems, as vehicle platform certification and fuelling infrastructure development took longer. In early 2019 it was announced that they had found someone willing to invest, Meijin Energy – a large coal producer in China that is switching to hydrogen from renewable energy sources. I’m cautiously optimistic that when the money comes back, we’ll be back in business producing Synergy 9SSL stacks in Guangdong.”

Randy MacEwen, Ballard

POWERED BY BALLARD Ballard has also received an order for a prototype mine truck from Anglo American (who are also shareholders). Something big can come from this. In Berlin, the Elektra push boat is operated with Ballard stacks (ship for transporting heavy loads between Berlin and Hamburg by water), and Van Hool awarded another contract for 20 FC buses. In addition, the Canadians seem to

be more deeply involved in fuel cell development for passenger cars than the statements by VW boss Herbert Diess suggest (see interview). As a result, I believe that other car manufacturers and suppliers will approach Ballard if they have not already done so. Further strategic investments also make sense for Ballard in order to position itself more broadly here (comparable with the Bosch investment in PowerCell). Ballard has many possibilities in this respect, as the Chinese major shareholders probably have only limited rights of objection. In short: Anyone who wants to be involved in fuel cells in the medium term relies on Ballard and thus covers various FC markets all-in-one.



Fig. 2: R. MacEwen

FUELCELL ENERGY – CHANCE FOR A NEW BEGINNING

What a farce it was that Shortseller FuelCell Energy set out to use toxic financing media (preference shares convertible into ordinary shares) to depress the share price and at the same time bring more and more shares into the market – without commitment. In addition, some project financing was subject to conditions that could be considered questionable (e.g. minimum return, guarantees). In addition, bank loans >>

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Fig. 3: Jason Few

were used as leverage against the company, as reference was made to safety margins and termination clauses, while FuelCell did not approach restricted cash. A vicious circle.

In my opinion, the business consultancy Huron did a good job in this respect, reappointed the Executive Board, had debts paid off on the stock exchange via a share issue and completely repositioned the company. Jason Few has been the new President and CEO since August. Since the end of October Huron is again no longer there.

"FuelCell Energy is well positioned to participate in the global future of clean energy. [...] We want to revitalise our customer relationships and the FuelCell Energy brand at the highest level and promote the fuel cell as a forward-looking solution in the global clean energy sector."

Jason Few, FuelCell Energy

This was followed by a number of excellent news reports: ExxonMobil awarded a first contract worth US\$60 million for carbon capture technology (two-year term). The financing company Orion Energy Partners also provided the company with a credit line of US\$ 200 million with a term of eight years, which now enables the company to process orders on hand of over US\$ 2 billion. In addition, Orion has now become a shareholder with up to 20 million shares based on the closing price at the end of October.

It is important that FuelCell Energy has been restructured and that customers (municipalities, companies) can regain the confidence to finally be able to award new contracts. Exxon may not be the only oil company wanting to improve its conscience through carbon capture, as the market is demanding this more and more and this makes it economically viable.

The stock exchange has catapulted the company's share from prices of US \$ 0.20 to US \$ 1.00 in the meantime, before traders returned to normal price profit taking. Nor can it be ruled out that, with over 200 million shares, the short sellers will continue to play their game, as several million shares have still been sold short. It remains very volatile. The further issue of shares cannot be ruled out either, as FuelCell

Energy plans to increase the authorised capital to 450 million or to put this to the vote at the next Annual General Meeting. A reversal split in a ratio of 1:3 to 1:20 has also been announced – theoretically for the time being – but this is probably due more to the stock market listing, as the share price has to rise to over US\$ 1.00 so that the share does not have to leave the Nasdaq stock market segment. As Orion Energy Partners is now the largest single shareholder, it is in its own interest that the company ensures that if a merger (reversal split) occurs, the share price is stabilised and new acquisitions are launched, according to my gut feeling.

Today's company is no longer comparable to the old one and has completely new and good growth prospects. The current stock market valuation of 120 million US \$ (depending on the number of freely traded shares and the respective stock market price) is in stark contradiction to the new prospects of the company, so that many large plant manufacturers could regard this as a bargain for a takeover.

That's why it sounds good that E.ON Business Solutions is partnering with FuelCell Energy in Europe to leverage its technologies and potential – a good sign. In my opinion, the share price is now tending to rise again with a high degree of volatility. In addition, I assume that we will only accept orders that are also worthwhile in terms of margins or can be easily financed so that the mistakes of the past and the former Executive Board are not repeated.

BLOOM ENERGY – SHARE PRICE FIREWORKS AFTER COLLAPSE

The figures for the third quarter were satisfactory: On balance, earnings per share were \$ 0.01, with the quarterly loss being due to stock-based compensation (issuance of shares and options to employees), which is "extraordinary" accounting and non-operating. More importantly, incoming orders rose by more than 45 percent. The forest fires in California and the associated shut-down of power lines by the major energy suppliers have indirectly benefited Bloom considerably, as 26 of the 89 FC micro grids are located in this US state and not a single one has failed. According to CEO and company founder K. R. Sridhar, Bloom has since been inundated with enquiries from companies and municipalities because they want to become network-independent. Bloom adds that in other US regions there is a similar problem with meteorological phenomena, but not with fires, but with heavy snowfall. So, you could say: Crisis as a productive state, even if unfortunately, this may sound rather sarcastic and cynical.

The world needs such off-grid FC power plants. Bloom will feel positive influences (orders) from this trend, as well as the expansion of activities to countries such as India promises further potential. After the IPO at US\$ 15 and the high at over US\$ 35, current quotations below US\$ 10 appear very low.

Bloom has a healthy financial position – around US\$ 358 million (including US\$ 23.8 PPA) – and a debt of US\$ 664 million. According to the company, approximately US\$ 261 million of this amount is non-recourse, i.e. it is attributable to other companies or partners. Of this, US\$ 330 million will have to be refinanced by December 2020, whereby this is to take place in the first half of 2020 – the investment bank Jefferies has already been commissioned. Bloom wants to do

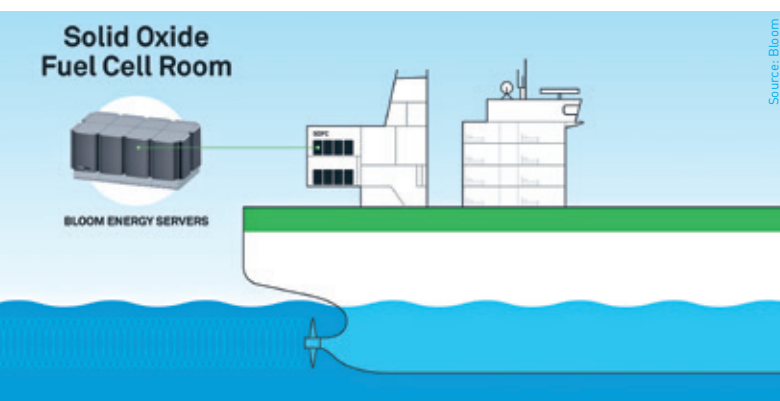


Fig. 4: Energy supply with Bloom SOFC systems on ships (see also p. 32)

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without dilution of the existing shareholder base as far as possible. I'm betting on a convertible bond issue. In any case, as things stand at present, Bloom will be able to solve this well with increasing orders on hand and good profit margins.

The margin between production costs (TISC) of US\$ 3,730/kW and the selling price of US\$ 6,618/kW (ASP/average) amounts to US\$ 2,175/kW. A good relationship from the company's point of view, even if the delta is likely to decline.

VARIOUS CLASS ACTIONS LAWSUITS One day before the publication of the quarterly figures, more than seven lawyers' associates renewed their class actions against Bloom. There could be more than fifteen law firms by now. The price explosion on the day the quarterly figures were published may have seemed very unfortunate to them, as they had certainly hoped to squeeze the share price – without any commitment. I am particularly looking at the level of short interest, which stands at over 24 million shares sold short, which is over 30 percent of the total number of 65 million shares issued (free float). So, there is a very high interest on the part of the short sellers to harm the company or to depress the share price. However, this has now run completely into emptiness or even been turned upside down.

Because other hedge funds (on the long seller side) could have used this – as possibly in the case of Tesla – to raise the price of the shares in order to get the short sellers to cover, because rising prices reduce their book profits or, on the contrary, cause losses and increase the pressure to cover and realise losses. This can continue until the number of shares sold short has visibly decreased.

More than 60 percent of Bloom Energy's capital is held by institutional investors – a very good sign, because they check exactly where they are investing. Why not expect prices of over US\$ 10 again in the short term, because that was the price level before these actions (newsletters, class action lawsuits) took place – without commitment.

EXECUTIVE BOARD PROMINENTLY SUPPLEMENTED Meanwhile, Bloom has brought two top managers on board for the Executive Board: Jeff Immelt as former CEO of General Electric (GE) and Prof. Michael Boskin, who already served on the Executive Board of ExxonMobil and Vodafone and is currently still with Oracle. Such top talents with the best contacts cannot be won without a fundamental basis, and this creates trust.

PLUG POWER – 1 BILLION US\$ TURNOVER 2024?

Full-bodied it comes from the company Plug Power: In 2024, the company aims to exceed the US\$ 1 billion sales hurdle and generate pre-tax profit of US\$ 170 million. But there's still a long way to go. First of all, it was possible to increase the billings (new bookings) by a good US\$ 61 million in the third quarter and the annual turnover is expected to be between US\$ 235 and 245 million. The loss in the third quarter of US\$ 0.08 per share – unadjusted – did not live up to expectations, but Plug is well on its way.

In the meantime, the second of four expected ground-breaking reports was published in 2019, according to which DHL (StreetScooter) and the French energy supplier Engie are now working together and the first order for US\$ 6

million is already in the books. Another is considered to be safe and will probably flow into the current fourth quarter. At the same time, Plug was also able to win Fiat Chrysler as a customer in the automotive industry. BMW, VW and others already are. 240 systems with an estimated order volume of US\$ 10 million were launched.



Fig. 5: DHL Express has ordered 100 H₂ Panel Van with fuel cell systems from Plug in spring 2019, delivery starts 2020

As far as the procurement of liquid hydrogen is concerned, Plug has won United Hydrogen as supplier of these consumables and expects a good margin increase. In my opinion, in the long run it will be the price for hydrogen anyway, which is the basis for sustainable profit growth for Plug. Furthermore, it remains unclear to me how the outstanding option rights/warrants granted to Amazon and Walmart will be accounted for. It is said to be 100 to 110 million units. (Are the approx. 40 million shares sold short related to this as hedge?) This is important to know because it could lead to high quarterly balance sheet fluctuations, depending on the share price.

In general, Plug has to think about the financing of the debts and has now announced the issue of another 40 million shares (plus 6 million more if oversubscribed). The good news that is still outstanding but has been announced can be precisely this basis that brought the share price to around US\$ 4 to justify a capital increase. With a strong increase (over US\$ 4) I would – theoretically – close out Plug then however and reinvest alternatively in Ballard and Bloom.

ITM POWER, POWERCELL AND NEL – TOO EXPENSIVE

I am watching these titles very closely. However, the valuations are now so high – relative to sales, equity, orders on hand – that one should rather remain engaged in the titles I have presented and even put the above-mentioned for sale and cash-in existing book profits. This is an opinion – without commitment – based on the comparison of the indicators. But what is clear: The more investors continue to focus on the fuel cell, the more all companies and their shares will be able to profit from it – the new mega-trend is only now really beginning.

BZVISION (WIKIFOLIO)

In view of the strong price increases at Bloom Energy, FuelCell Energy and Ballard Power, the depot value has since risen considerably by more than 40 percent in the quarter. In the meantime, I had closed out 5,000 of 20,000 Ballard at about D 4.85 (US\$ 5.50) and increased the position in Bloom to 10,500 as well as FuelCell to more than 39,500 – the latter, however then closed out. After the massive increase at FuelCell, I cashed-in the profit there and increased shares in Bloom Energy. This mix should be maintained for the time being, unless one of the titles rises so much that temporary profit taking seems sensible. According to the motto: Even trees don't grow into the sky.

Alternative investments, for example in ITM Power, Nel and PowerCell, are not beneficial – because these other stocks are relatively simply valued so much higher that an exchange simply makes no sense. A put warrant on Tesla (critical for models based only on battery technology) could be included in the depot. Here, however, I am still looking for the right one based on the term (6 to 24 months), the base rate (US\$ 250 to 300) and the leverage.

TESLA – PRICE BUBBLE THROUGH SHORT SQUEEZE?

Tesla's share price rose sharply from US\$ 230 to over US\$ 360 during the reporting period, after the third quarter did not close with a loss (consensus was a loss of US\$ 1.31 per share), but on the contrary with a profit of US\$ 143 million (US\$ 0.78 per share GAAP). Cash holdings were also maintained at US\$ 5.3 billion. Tesla claims to have greatly reduced unit costs and to be producing more efficiently. However, many analysts are wondering whether this result is not due to some accounting changes. This is because investments (capex) for the year as a whole are likely to be around US\$ 1.5 billion, whereas the company itself had once forecast US\$ 2.5 billion.

Investments in China (Gigafactory in Shanghai) as well as various new product launches (Model Y, Semi, Roadster) also require significantly higher expenditure. If one looks at stock-based compensation, which amounted to more than US\$ 822 million in the third quarter, a derivation could be made from this as well, as the reduction in warranties raises questions. A good US\$ 50 million could be derived from this for the result for the third quarter.

A look at the sales figures is interesting: In the USA, these fell by a substantial 39 percent in the third quarter. China should balance this out. At the same time, more and more e-cars are being sold via leasing and no longer directly. This also has an impact on the valuation of these vehicles and liquidity.

In short: In my opinion, the supposedly better-than-expected figures were mainly used to trigger a short squeeze, i.e. institutional investors and hedge funds should take the quarterly figures as an opportunity to buy massively in order to put pressure on the short sellers (who are betting on falling prices). After all, approximately 22 percent of the outstanding shares or over 34 million shares have been sold short, so that the squeeze can be a logical consequence of this.

CYBERTRUCK – A COURSE DISASTER You can argue about the beauty of a vehicle. At the recent debut of the Cybertruck, the stock exchange gave a clear answer: On the very day of the presentation, the share fell by US\$ 20 and caused a stock market loss of just over US\$ 4 billion. A clear statement on how the majority of investors find the truck. Words like “ugly” can be found in the forums. And the accompanying tweet by Elon Musk, according to which advance orders have already been received for more than 146,000 cybertrucks (most recently even more than 250,000), must be questioned several times. Because the advance payment of US\$ 100 per unit seems ridiculous. Was Musk allowed to send such a tweet at all in view of the agreement with the SEC, as it could have influenced the stock exchange price? This could get expensive.

NEW GIGAFACTORY IN BRANDENBURG The state's politicians are overjoyed that Tesla is planning to launch their next Gigafactory in Brandenburg. € 4 billion invest- >>

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"Elon's saying about efficiency is no longer relevant ('Fuel cells are fool cells' – Elon Musk). Today, we are talking about solar and wind energy for 2 to 3 cents per kilowatt hour, with renewable energies often being cut off. So, there is nothing inefficient about using over capacities and using these emission-free resources for hydrogen production. The efficiency argument is irrelevant here. The only question is, what are the costs of producing this green hydrogen and delivering it to the place where it is used? We are therefore talking about the sensible use of this cheap electricity by converting it into hydrogen for short to long-term storage and then reusing it as fuel. Low-cost renewable energies have brought this discussion forward. More and more countries, companies and people understand this extraordinary potential."

Randy MacEwen, Ballard

ment is expected. But how much must the German taxpayer pay? Tesla has so far received more than US\$ 6 billion in funding, be it via grants or ZEVs. I view this rather sceptically, since Tesla is active at too many construction sites at the same time. The plant in China is to cost US\$ 2 billion, US\$ 0.5 billion was received in advance as a loan. How will Tesla now pay for the factory in Brandenburg? And are there also conditions as in China, according to which certain minimum investments have to be made or otherwise the land falls back to the state? Does Tesla guarantee a certain number of new jobs? Many question marks.

THE FOURTH QUARTER MAY BRING A DISILLUSIONMENT

But what happens next? The fourth quarter would have to reduce liquidity through necessary investments and repayment of debts (bonds). In China, Tesla plans to expand to 63 (29) service centres and 362 rapid charging stations (plus 39 percent). The start of production of Model 3 in China is predicted for the turn of the year, although the planned output will certainly not necessarily reach the targeted level of

3,000 units per week but will perhaps first reach 1,000. In China, however, there is a general slowdown in the sales of electric cars, as important funding has been reduced and are still heading in the direction of zero, while the opposite is likely to happen for fuel cells and hydrogen.

In my opinion, with a company valuation of over US\$ 60 billion on the stock exchange, all possible positive expectations have been "fed in" – but not the potentially negative ones. Whoever wants to engage in speculative trading and shares my opinion is for Put Warrants (put warrants, highly speculative with the risk of total loss) on the basis of 250 to 300 US-\$ (Strike) and with a term of 12 to 24 months in the expectation of prices that completely eliminate the price increase when Tesla can no longer bring good news, which the market expects and has already fed into the current stock market valuation. I think it's very ambitious that Tesla boss Musk's full-bodied forecasts will come true, according to which Model Y, which is derived from Model 3, will even be able to exceed the total sales of Model 3, S and X. We will see. Prices below US\$ 150 per share over the next two years remain my declared goal, as I believe that the fuel cell and green hydrogen for long-haul applications have much greater potential over the next one to three years. ||

RISK WARNING

Every investor must always be aware of his own risk assessment when investing in shares and also consider a sensible risk diversification. The FC companies and shares mentioned here are small and mid-caps, i.e. they are not standard stocks and their volatility is also much higher. This report is not a buy recommendation – without commitment. All information is based on publicly available sources and, as far as assessment is concerned, represents exclusively the personal opinion of the author, who focuses on a medium- and long-term valuation and not on a short-term profit. The author may be in possession of the shares presented here.

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Fig. 6: Cybertruck – with the usability of a truck and the performance of a sports car

A LEADING FUEL CELL SOLUTION

Interview with Randy MacEwen, President & CEO of Ballard

Ballard Power Systems is a pioneer in the fuel cell industry. Since 1983, fuel cells have been developed in the company founded by Geoffrey Ballard in Burnaby near Vancouver. Randy MacEwen has been President & CEO of the Canadian fuel cell manufacturer since 2014. On October 23, 2019, the International Hydrogen Symposium brought him to Hamburg where H2-international seized the opportunity for an interview.



Randy MacEwen

H2-international: Is it your first stay here in Germany, or how come you are visiting Europe, and Hamburg in particular?

R: I have been in the hydrogen, fuel cell and renewables industry for a long time. So I have visited Germany many times, including Hamburg. And we have two fuel cell buses by Solaris operating here currently. There is also a tender out right now for another 30. So it is a market we know well and I am really pleased with the momentum we are seeing in Europe particularly. The conviction level on hydrogen is very strong here, so we have to seize the moment.

What is your perspective from Canada, from North America? What is the role of Germany in the worldwide fuel cell sector?

I would start a little bit broader in terms of Europe. I would say Europe is leading the international charge on decarbonization of mobility. Europe is the most aggressive on reducing emissions. So when you look at things like climate change, energy security, air quality, Europe I think has the highest conviction level genuinely to address these issues. In my mind Europe, while it may not be the largest market, is perhaps the most important.

Where do we stand right now in our process of decarbonizing the mobility sector?

What we see happening is a major and exciting transformation occurring in mobility right now. And I think the transformation is just as profound as it was a hundred years ago, when we saw the first great transportation revolution – from

horse and buggy to vehicles powered by combustion engines. That transformation brought with it a whole new ecosystem: the manufacturing of engines with powertrains, the manufacturing of cars and buses and trucks, building of roads and highways, parking facilities, fueling stations, dealerships, air pollution, and traffic. That was a whole new value chain that has been in place for a hundred years until now.

And we are now at the point where the macro drivers of climate change, air quality, energy security have never been stronger, and are pushing policy change. But at the same time, technology is stimulating significant change as well. So we have the so-called ACES trends: Autonomy, Connectivity, Electrification, and Shared Mobility. These trends plus the macro drivers are leading to what McKinsey has characterized as a second great inflection point in transportation. What you will see perhaps within the next dozen years is mobility becoming safer, cleaner, more efficient, and lower cost. And mobility is, I think, the key driver in making that happen, together with a number of technologies. The key to achieving decarbonization is electrification.

How do you think this process works?

We are seeing disruption for auto OEMs, for tier one suppliers, anyone that has exposure to internal combustion engines. I think this issue is particularly important in Germany, because there is a major labor disruption that is occurring with electrification. About 35 to 40 % of the economics of a battery electric car relate to the battery pack. The auto OEMs are now losing that part of the value chain. If they are sourcing a battery pack from China, which is worth 35 to 40 % of the economics of a car, the profit pools will change dramatically, as well as the labor pool. I think Germany is looking at being an early adopter of hydrogen-based technologies. This can help make the disruption much smoother, more of a transition.

What is your opinion about battery-driven electromobility?

When you start looking at things like over 60 % of the world's cobalt coming from the Congo, you have major issues on the supply chain side, including ethical sourcing and price volatility. There are a lot of challenges. There is child labor in the artisanal cobalt mining. So I am just saying there are a lot of issues that I do not think have surfaced up fully yet. Another thing is the scaling of infrastructure. It is one thing to recharge one car in a garage, or maybe five buses in a huge yard. It is another to recharge, say a fleet of 200 cars or a fleet of 400 buses. So recharging infrastructure becomes a lot more complicated and gets more costly with volume. By contrast as you scale fleets with hydrogen the costs come down because you get better utilization.

Where is the fuel cell sector going right now?

We believe the high volume adoption in the near term and mid-term for hydrogen fuel cell technology will be in what we call the Heavy Duty Motive area. Bus, truck, rail, and marine vehicles – in that order. There are three reasons why we

believe in this: Number one is the value proposition for fuel cells is strongest in these markets where you have use cases with heavy payload, long range, high utilization, therefore a need for fast refueling. Fuel cell electric offers a far superior value proposition compared to battery electric.

Number two is with a lot of these use cases in Heavy Duty Motive, you have the ability for centralized depot refueling, much like with diesel today. You do not need to have a distributed refueling infrastructure because fleet vehicles return to base at night. City buses for example, or coaches that go point to point. So you are going to have centralized depot refueling.

And the third reason, which is really important to me personally, is that Heavy Duty Motive has a disproportionate emissions profile. If you displace one car, you have a relatively minimal impact on the market. But if you are displacing a bus, the impact is significant. If you look at class eight trucks, long haul trucks that are driving all day, your impact is significant. In the U.S., around 8 % of vehicles are Heavy Duty Motive, but they produce 25 % of all GHG emissions.

And what about passenger cars? Years ago you left the automotive part to Daimler and Ford.

Right, we were not active in the passenger car market for a period of time. We had Daimler and Ford as shareholders of the company, and then they subsequently disposed of their position in Ballard. And when they did that, we actually had a period of time where we could not compete in automotive. That period stopped in 2013, when we moved back into the passenger car market, and it is not very well known, but I believe today we have the leading automotive passenger-car fuel cell stack. We are working with Audi and Volkswagen Group, and their publicly announced plan is to launch small-series fuel cell cars in the 2021/22 timeframe.

Okay. That is very interesting because, here, it is almost unknown that fuel cells are so important for VW.

Yes. We do 100 % of the design work on the Audi fuel cell stack. And so there are two points to make on this. One is that we are very active in the passenger car market. And secondly is that I believe the stack we have designed for Audi is world leading. It is going to be, I believe, a leading fuel cell solution when Audi launches these vehicles.

When you look at connected autonomous cars and shared mobility platforms, they need more power. In the future, maybe a car is being used, say, 16 hours a day. The number of kilometers traveled per day will be very high. You do not want to have long recharging, but fast refueling and long range. So my view is that fuel cells will offer a much stronger value proposition than battery electric for a range of passenger car use cases. If you look out to 2030, autonomy will be available and cars will be highly connected. This changes the dynamics of car ownership, and therefore changes the utilization of the vehicle. And high utilization favors fuel cells.

If we were sitting here two years ago and you look at all of the fuel cell vehicles in the field, the numbers would have been very small. But today, there are about 2,000 trucks and buses in operation in the field – 300 buses with Ballard engines inside. On the forklift side, there are about 28,000 fuel cell systems in the field. There are about 15,000 fuel cell cars on the streets today. That is a dramatic shift.

What about your fuel cell buses?

We are very focused on the bus market, and we have deep relationships with all of the bus OEMs. Ballard engines are



inside almost all of the offered fuel cell electric buses. Our market share is over 85 %. We have fuel cell engines that have been operating in the field now for more than 35,000 hours, which is an industry durability record. You will struggle to find any other company that has fuel cell technology with that level of durability proven in the field. We have 16 million km of bus operation. And, our availability rate over the last 18 to 24 months is 97 to 98 % in terms of the fuel cell engine.

We recently tested the fuel cell bus of our partner New Flyer with a Ballard engine inside for Orange County transit authority in Southern California. And that bus ran 560 km. So it is extraordinary if you contrast that with a battery electric bus, which would be constrained to perhaps 200 to 250 km.

Here in Europe it is very difficult to get a fuel cell bus. The regional government in Brandenburg just said they want to spend a lot of money on fuel cell buses, but I do not know where they shall come from. From Solaris or from Toyota? Here, no German manufacturer is able to deliver.

The car manufacturers do not have fuel cell engines designed for Heavy Duty Motive use. They are designed for passenger vehicles. Their fuel cell engine durability is 5,000 to 10,000 hours. But, we have engines running for 35,000 to 40,000 hours. It is quite a difference. And that is the durability you need for this market.

The move to fuel cells is happening now because cities are saying that they are moving away from diesel. And there is a realization that battery electric buses have limitations. So there is a real recognition of the opportunity for fuel cells in the bus market. If you look at the last six months, Solaris, Van Hool, VDL, Wrightbus all have Ballard engines inside. Now, to your point, there is not a German champion yet. In my opinion, however, there will be. The smaller bus OEMs are the leaders now in terms of being more aggressive in the market. But the larger OEMs will be coming to the market in the next year or so, in my opinion.

The big issue has been cost. And if you go back to 2009, a fuel cell bus could cost close to a million and a half euros. By 2014 it would cost about a million euros and more recently 650,000 euros. However, these are deployments of ones and twos. Now what we are seeing with the JIVE funding program is about 294 fuel cell buses being deployed in clusters, with 10 or 30 buses in one place. But it is still not the volume we need.

Earlier this year we announced a consortium for a thousand fuel cell electric buses. And what is powerful about this is we brought together different players in the value chain >>



and ecosystem and were able to determine for a modest volume – a thousand buses is not a high volume – we are able to offer a compelling solution with a fuel cell bus priced at about 375,000 euros with green hydrogen at five to seven euros per kilogram, and service at 30 euro cents per kilometer driven.

So you are offering the whole package, including electrolyzer, including hydrogen?

The consortium partners are offering a fuel cell bus and delivered green hydrogen. Doing it on a cost of ownership basis that is compelling. If you look at the capital costs, the fuel costs, and the operating costs altogether, we are checking all of the boxes. And we are able to do that for 1,000 buses. So, in my mind, cost should not be the issue if we get the right volume.

This is the European market. In China the market is much larger.

Yes. It is important to understand the size of the markets. In North America every year there are about 5,100 new buses manufactured. In Europe it is about 13,000 to 15,000 buses. China, depending on which numbers you believe, is anywhere from 200,000 to 400,000 buses. The size of the market is significantly larger. And so the size of the market lends itself to volume. And that is a real key if we want to drive down cost with high volume. So what we have seen is that China has put in place fuel cell subsidies to support the adoption of fuel cell electric buses. That is stimulating early demand.

I believe that China is trying to position itself to leapfrog to fuel cell technology and surpass Europe and the U.S. They were at risk of losing leadership on the technology, but with these market opportunities China is able to move very quickly and very aggressively.

But right now, the Chinese government said the subsidies will be reduced, but the money spent by the provinces is increasing. What have you heard?

You are probably talking about an open letter that was sent to the chair of SAIC about a week or two ago. I think that is very confusing. I just was in China and no one really understood what this meant. But in my opinion, there was nothing new in that letter. So personally my belief is there will be subsidies in China for the adoption of fuel cell vehicles through 2025.

And in Japan and Korea? Japan is also very involved in hydrogen with its Olympic Games 2020. So what about the market over there?

Those are important strategic markets. There is a lot of development work that has been done, but on a relative basis,

they are much smaller than China and Europe, and even the U.S. for that matter, when the U.S. decides to move. The key driver for those economies is how do they get energy independence. I think it is part of their political and long term economic plans to get more energy independence with decarbonization with suppliers that they have longer term trusted relationships, probably. But you will only see a hundred fuel cell buses at the Olympics next year in Japan [2020]. When you go to China for the Olympics, the number has not been resolved yet, but it will at least be a thousand. It could be 10,000.

Okay. And what about the U.S., about North America? President Donald Trump is not in favor of fuel cells or renewable energy.

It is a tale of two cities in some way, with divergent views. At the national level, the hydrogen and fuel cell story is not part of the landscape right now at all. But when you go to California, it is very key. So if you look at Ballard's strategy, we characterize ourselves as having three key markets: Europe, China, and California. We do not characterize it as North America or as the U.S.; we characterize it as California. It is so big and very, very advanced in hydrogen. You have got 6,000 fuel cell cars there right now. You have about 50 fueling stations there. Not as many as Germany, but a significant number. And Nikola is doing a very good job generating thought leadership in that market, and they still have a lot of work to do, obviously, to get a winning solution in the market. And I am confident they will. However, we have been working with Kenworth at the Ports of Long Beach and L.A. on a class A drayage truck. It is a market we are very bullish on.

Wasn't Toyota also working together with Kenworth?

Toyota took a Kenworth truck and refurbished it. We are working directly with Kenworth, and they put our fuel cell engine in the Kenworth vehicle.

Now another topic: How about your cooperation with CRRC?

CRRC is our China train partner. CRRC is larger than Siemens and Alstom put together if that had occurred, which it did not. We delivered ten engines for trains to CRRC already. What happened is that there was construction of a new train line in Guangdong province in the city and that construction has just taken longer than expected. It has nothing to do with their trains or our technology. But, the first fuel cell-powered tramline in Gaoming is expected to be in operation before the end of 2019.

We are also working with Siemens, though in Europe. Siemens is working on the Mireo train. And we have a program where we are developing the fuel cell engine for a purpose-built fuel cell train. That fuel cell train will be launched next year [2020] at an important conference.

In Europe now, Alstom has the early lead for sure, and they have done a very good job on the marketing side. But what you will see going forward is both Alstom and Siemens having a competitive offering for fuel cell trains in Europe. I am very excited about this market.

I don't know if you are aware of this, but in May 2019 there was a report published. It looked at the fuel cell train market in Europe. The conclusion of the report was that by 2030, the base case is that the fuel cell market penetration will be about 20 %. I expect Siemens and Ballard will secure a very good market share, because again Siemens is designing a purpose built fuel cell train that I think will meet the market requirements much more strongly than a train that takes fuel cells on an aftermarket basis and adds it. ||

BALANCING ACT BETWEEN COMMERCIALISATION AND PROJECT BUSINESS

Fuel Cell Industry Review from E4tech

The new Fuel Cell Industry Review 2019 with market data and analyses was published in January 2020. Since 2014, E4tech's team has been contacting fuel cell companies worldwide to build it, aggregating their supply figures and creating an independent annual reference point on the current state of the fuel cell industry. Some excerpts are presented below.



The sales market for fuel cell systems continued to grow in 2019. Although unit sales have remained at the level of around 70,000 for some years now, the much more important indicator is the output delivered. This correlates with the fuel cell areas produced and thus with the sales and manufacturing capacities achieved. According to the preliminary figures for 2019, this figure again grew strongly: From around 800 MW in the previous year to over 1,100 MW. The final figures for 2019 will be published in the Review 2020. However, it is considered certain that for the first time we can talk about one gigawatt market per year, a not unimportant psychological signal in times when there is considerable talk of Gigafactories.

The trends from previous years are solidified in the current figures. The growth of the industry continues to be primarily attributable to transport applications. Between 2014 and 2019, their share of the overall market grew from 20 to 80 percent, measured in terms of the megawatts delivered. This development is mainly attributable to the strategic investments made by the car manufacturers

Toyota and Hyundai. The Koreans have outstripped the Japanese in the current year and have already sold almost 4,000 Nexso models in the first ten months. This contrasts with 2,200 Toyota Mirai in the same period.

For the year as a whole and together with the other providers, around 7,500 new FC passenger cars are expected in 2019. This vehicle segment alone thus contributes 750 MW to the preliminary total figures for 2019, representing almost three quarters of total sales. This growth of over 50 percent in unit numbers and megawatts is primarily attributable to Hyundai. In contrast, many of the other market segments have hardly changed substantially.

In China, more than 1,500 FC trucks and buses will be added in the course of the year, which corresponds to the previous year's level. The goal of having 5,000 FC vehicles on the roads by the end of 2020 is therefore within reach. After China, Europe is currently the second-largest sales market for FC buses. Among the more than 15,000 FC vehicles expected for 2019 as a whole are more than 5,000 FC forklift trucks, a segment that has now settled at this level for several years.

Other transport applications such as rail vehicles, drones and ships currently contribute little to the overall figures. The announced large numbers of Hyundai, Nikola and Horizon/JMC trucks are only expected in the coming years, as are some larger bus projects, for example as part of the H2Bus consortium in Europe.

GROWTH ONLY IN TRANSPORT APPLICATIONS? As in previous years, the transport sector continues to grow, while stationary applications remain at the previous level. At around 220 MW, distributed among around 52,000 systems delivered, sales in the stationary sector were practically unchanged year-on-year according to the preliminary figures for 2019. The main market segments for stationary FC systems have hardly changed and are usually still linked to certain promotional measures. >>

A total of over one hundred companies were contacted as part of the annual industry survey and the responses compared with publicly accessible data and, where necessary, supplemented. It is important to note that in the transport sector the completed vehicles are counted, but not the FC modules.

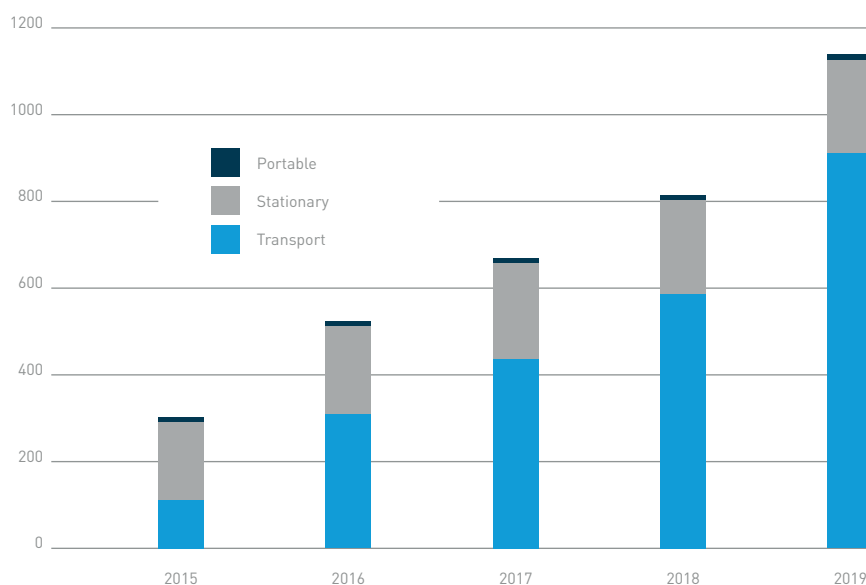


Fig. 1: FC output delivered annually by application type 2015 to 2019 (megawatts)

f: 2019 includes a projection for the fourth quarter (forecast)

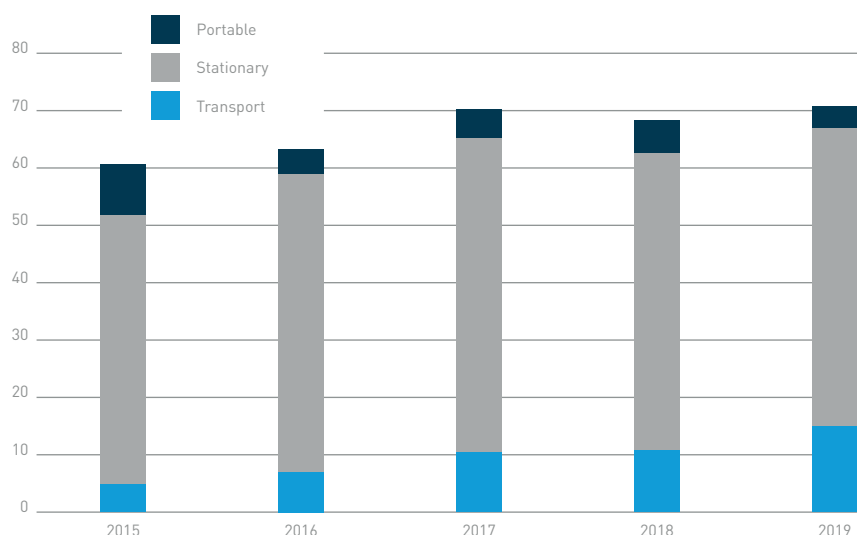


Fig. 2: Units delivered annually by type of application 2015 to 2019 (1,000 units)

f: 2019 includes a projection for the fourth quarter (forecast)

In Japan's Enefarm programme for micro-CHP, the delivery figures are down slightly to around 45,000 units in the 2019 calendar year. Although the programme thus falls short of its original objectives, it can demonstrate the success that the expansion is continuing, even though the funding is now coming to an end. The only significant sales market for FC micro-CHP outside Japan has now emerged in Germany. Since the introduction of the corresponding KfW433 funding in 2016, almost 9,000 decisions on support had been issued by the end of September. In 2019 alone, more than 4,000 new plants can be expected, and the trend is rising. In addition, there are several hundred systems in the European PACE programme. While the German KfW programme currently seems to be dominated by PEM systems from Viessmann with Japanese modules from Panasonic, the share of competing SOFC technology in Japan has already grown over the years to around 50 percent.

With larger systems for commercial users in the range up to 100 kW, some Japanese companies continue to develop mainly SOFC systems. Larger quantities, however, have not yet been noted there. In Korea, on the other hand, this market segment is developing very positively, also thanks to an attractive funding environment. Here, PEM technology from S-Fuelcell and Doosan is used the most.

In the segment of large stationary FC systems from 100 kW upwards, the familiar patterns of recent years have continued: Korea and the USA remain the main sales markets here. Doosan primarily serves the domestic market in Korea. There, fuel cells are an attractive option for energy suppliers to meet their add-on quotas for new technologies thanks to multiple crediting in the Renewable Portfolio Standard. In the USA, Bloom Energy brought SOFC systems onto the market in 2019 to a similar extent as in 2018. FuelCell Energy, on the other hand, can reflect on a particularly difficult year. However, the announcements made towards the end of the year give reason to be cautiously optimistic again.

The portable fuel cell sector hardly appears in the megawatt survey. However, relatively small systems in the 100 W range generate significant sales here, such as for military applications. Direct methanol fuel cells (DMFC) as well as small SOFC devices play an important role in this segment. The year-on-year decline in unit sales is only due to the fact that myFC, the last remaining supplier of FC-powered USB chargers, has now also left this segment.

ASIA IS THE LEAD MARKET The megawatt of FC output for the Asian market almost doubled from 2018 to 2019. This is primarily due to the ramp-up of production at Hyundai, which has already sold more than 3,000 Nexa in its domestic market in the first ten months of the year, compared with a good 700 units in 2018 as a whole. In most other segments in Asia, including the transport sector in China and stationary applications in Japan and Korea, there were no major changes compared with the previous year.

In North America, slightly fewer vehicles are expected to be noted than in 2018, while little change can be observed in the stationary sector as a whole. Whether there will be year-on-year growth in unit sales for the North American market will ultimately depend on how sales of FC industrial trucks develop by the end of the year.

The strong growth in Europe compared to the previous year is attributable to several developments: The fuel cell vehicles from Asia are the main contributors. But the various bus projects also contributed to the growth. And last but not least, the positive development of micro-CHP plants in Germany has played its part in this. In addition, a growing number of grid replacement systems with fuel cells were recorded.

Markets in the rest of the world (RoW) can hardly be observed at present and are largely limited to FC grid replacement systems and currently one or two transport applications in South Africa.

THE DECISIVE UPSCALING IS YET TO COME

Overall, a comparison of the actual market development with the numerous announcements for future projects and fleets shows that the critical phase of upscaling has not yet been passed. The FC industry has yet to meet the expectations placed in it. Toyota and Hyundai will each increase their production capacities by a factor of ten in the coming years. The two OEMs are increasingly assuming the role of FC supplier and are now also offering their FC systems, which have been well proven in passenger cars, to other vehicle integrators, such as for buses and trucks. It will be exciting to see how traditional fuel cell companies will face up to this competition from the two Asian OEMs.

Although the classic FC players often have a lot of experience in system design for heavy-duty applications, they have less capacity and resources available at their disposal. They also need the appropriate customers for larger volumes. Ballard has various partners who could provide for growing quantities. For Hydrogenics, Cummins' involvement could be a path to higher volumes and for PowerCell, the licensing agreement with Bosch, which in turn works with Nikola. In the short term, in the coming years, however, the gap in production figures between Hyundai and Toyota on the one hand and the rest of the industry on the other is likely to widen.

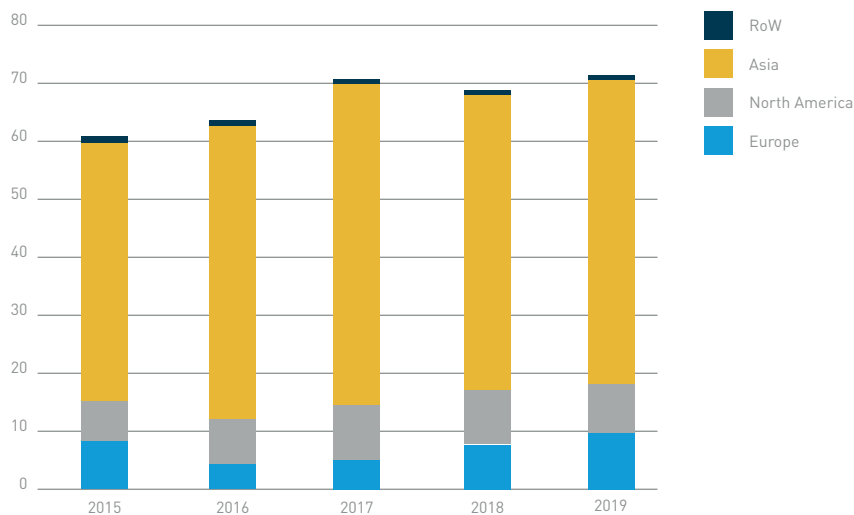


Fig. 3: Units delivered annually by market region 2015 to 2019 (1,000 units)

f: 2019 includes a projection for the fourth quarter (forecast)

For the time being, the music seems to play mainly in transport applications. With the partial exception of Japan, the stationary sector is still dependent on supportive framework conditions in the individual main markets. However, with greater availability of green hydrogen in the medium term, stationary fuel cells could become more interesting again and benefit from the cost depression achieved by transport applications until then. ||

It remains interesting to see how quickly China can implement the announced ambitions to create an internationally competitive FC industry. Although more and more components from domestic production are being used in local vehicles, imports continue to play a major role in meeting short-term demand. Different signals with regard to the extent and duration of government funding have also recently led to a certain degree of uncertainty. It remains to be seen how long the gold rush in China will last and whether there are only going to be a few big winners in the end.

In Europe, automobile manufacturers are not planning any major vehicle series before the middle of the decade. Some OEMs are currently catching up on their battery electric offerings and are focusing their investments on this, leaving little room for fuel cell technology. By contrast, many traditional automotive suppliers have already actively positioned themselves in the FC value chain in order to benefit from growth in other regions of the world. For example, it can be assumed that the majority of ElringKlinger's fuel cell production is currently being supplied to China from Germany. Other suppliers such as Bosch, Michelin and Faurecia via Symbio, Freudenberg and Schaeffler are also very active, but naturally also need the corresponding customers for their new products.

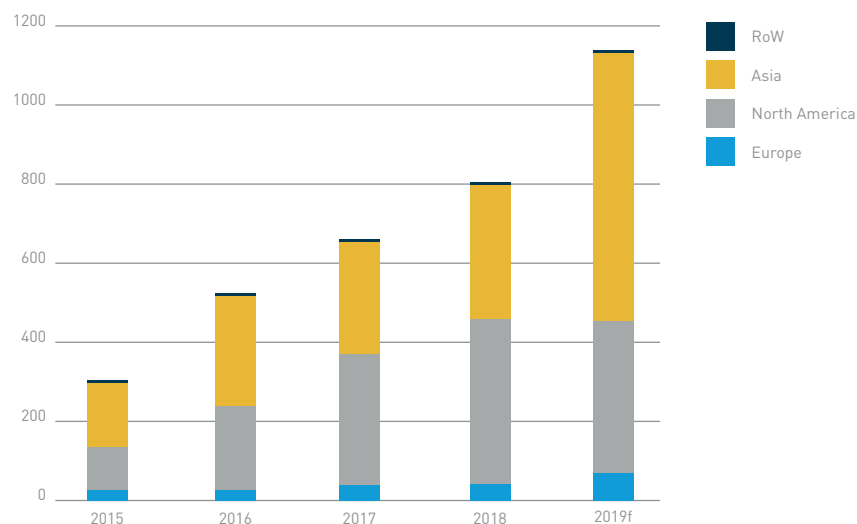


Fig. 4: FC output delivered annually by market region 2015 to 2019 (megawatts)

f: 2019 includes a projection for the fourth quarter (forecast)

Complete report with delivery figures, data tables, analyses and comments on company-specific developments as free download: www.FuelCellIndustryReview.com

Literature

D. Hart, F. Lehner, S. Jones, J. Lewis; The Fuel Cell Industry Review 2019. Jan. 2020

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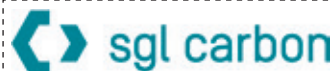
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