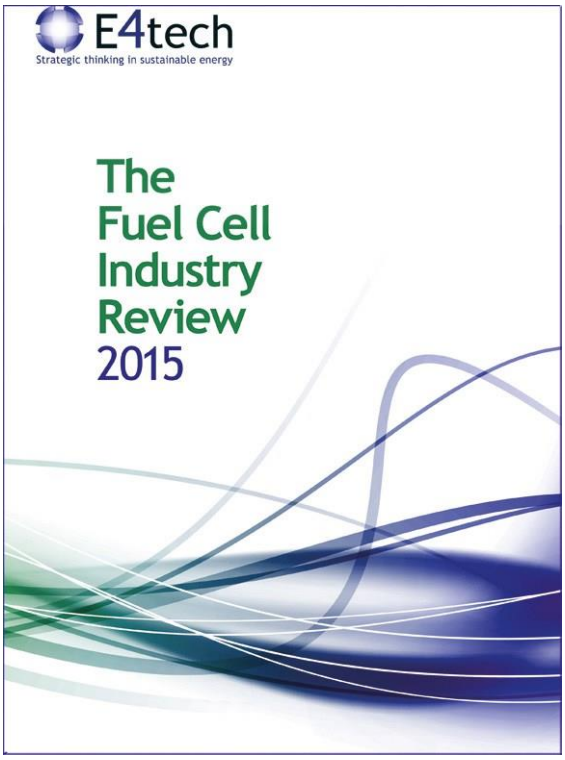
H2 international
E-JOURNAL ON HYDROGEN AND FUEL CELLS

H2-international – e-Journal

April 2016

Content

Fuel Cell Market is Growing



November 2015 saw the publication of the *Fuel Cell Industry Review 2015*, including market data and analyses for 2015. Since 2014, a team led by E4tech had contacted fuel cell companies around the globe, aggregated their supply figures and can now show the latest trends in the industry, much as *Fuel Cell Today* had done before its survey came to a halt. The following will present some excerpts from the review.

The number of 70,000 delivered fuel cell systems was only a slight plus compared to the two previous years. Still, the output in megawatts almost doubled compared to the year prior (see figure 2). The 2015 numbers include a forecast for the last months of the year, so that there is a certain margin for error as shown with the figures. The uncertainty in market development mainly stems from the introduction of new USB chargers – especially by MyFC – at the end of the year as well as the dynamic growth of the fuel cell car market.

FuelCell Energy, Bloom Energy – and in 2015 increasingly Doosan Fuel Cell America – were dominating stationary fuel cell applications based on the output supplied. The latter was able to snatch up large orders especially in South Korea. Additionally, the number of mini CHP plants (fuel cell heating systems) continues to grow under the Japanese ENE-FARM program.

The strong megawatt growth in the transportation segment is primarily a result of Toyota's market introduction of the Mirai and rising sales of Hyundai's *Tucson ix35*. The strong numbers are no surprise considering that ten fuel cell cars already constitute an output of one megawatt. In addition to 1,000 new fuel cell cars planned

in 2015, fuel cell range extenders were playing an increasingly important role for powered industrial trucks in France (see France's Own Energy Transformation). In terms of quantity, fuel cell industrial trucks are still dominating the transportation segment, where Plug Power has reported increasing sales. In 2016, the field will widen, as Nuvera – which was taken over by NACCO Materials Handling – enters the arena as a new competitor with ambitious plans for the market of fuel cell forklift trucks.

The expectations nourished in the past regarding portable fuel cell systems like USB chargers could not be fulfilled. The launch of new products by MyFC from Sweden and eZelleron from Germany gives hope to rising numbers in this segment in 2016. What continued its success story in 2015 were mobile or portable fuel cell devices for off-grid power supply in the leisure market (e.g., camping) as well as for measurement and control systems and other industrial applications. The same was true for portable fuel cells for military use, especially in the US.

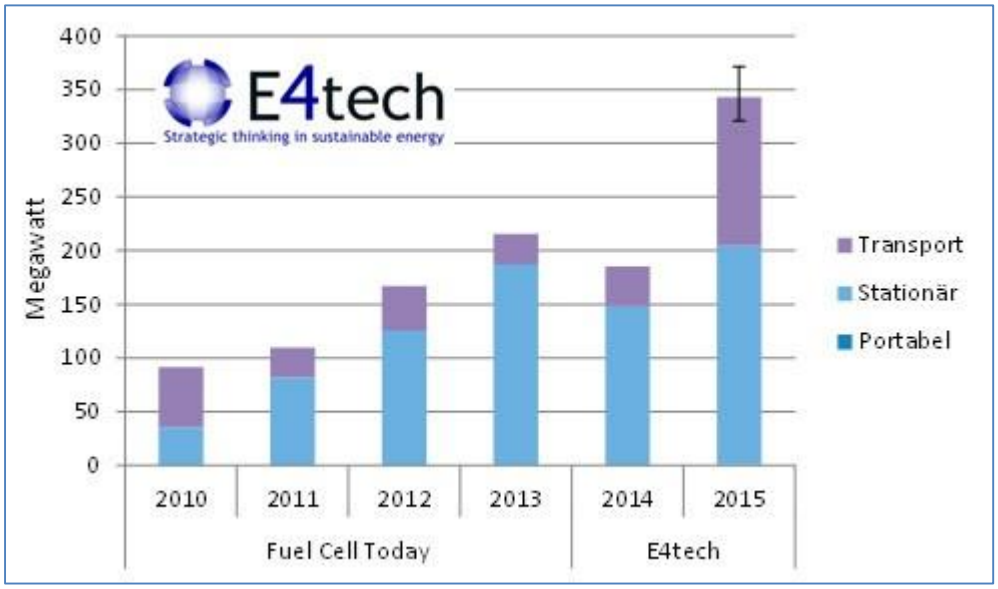


Figure 2: Yearly delivered fuel cell output broken down by application from 2010 to 2015 (in megawatts).

Cautiously optimistic outlook on 2016

Despite the strong growth in 2015, the fuel cell market still largely relies on direct and indirect subsidies. This includes especially the Self-Generation Incentive Program in California and the Renewable Portfolio Standard in South Korea. Even the Japanese market for fuel cell heating systems and its more than 150,000 installed units are not a guarantee for growth without further financial assistance. Expectations are that the subsidies there will continue. European manufacturers of fuel cell heating systems may get the long-awaited market impetus from the German subsidy program for the market ramp-up of fuel cells, scheduled for the beginning of 2015. But one will need to wait and see whether the number of systems subsidized will be sufficient to reach competitive cost ratios over the medium term.

Special markets, in which fuel cells have already stopped relying on subsidies (e.g., powered industrial trucks and off-grid or grid-supporting systems) are expected to continue their upward trend. Thanks to a special fuel cell bus subsidy, China could

already and all of a sudden become the leading market for this technology in 2016. Not least thanks to Toyota's time-consuming ad campaign, certain fuel cell cars were all over the headlines of industry magazines in 2015 and simultaneously sparked a change in the fuel cell industry whose impact could be felt throughout the market. Carmakers cannot expect to make money with fuel cell cars over the coming years. But they will help introduce the technology to the markets, so they have something up their sleeves in the face of ever stricter emission limits.

The full report with supply figures, data tables, analyses and comments is available for free at: www.FuelCellIndustryReview.com

References: D. Hart, F. Lehner, R. Rose, J. Lewis; The Fuel Cell Industry Review 2015. Nov. 2015

Authors: Franz Lehner, David Hart
Both from E4tech, Lausanne/Switzerland

Hopes for Fuel Cells under Trudeau Two

J. Trudeau, © Liberal Party of Canada

The overwhelming Liberal Party victory in Canada has caused a great deal of speculation in the Canadian fuel cell community raised hopes for a revitalized federal support program. The ruling Conservative party had bet heavily on oil and other primary resources, and lost when the nation's economic troubles were blamed on oil prices. The Conservatives lost nearly 40% of their seats while the Liberals won an outright majority.

Prime Minister Justin Trudeau's platform includes a variety of cleantech programs, including a plan to use federal buildings, procurement and energy purchases as a laboratory for clean technologies, and setting up a CDN$ 2 billion green bank financed by federal bonds.

Trudeau made "restoring" Canada's environmental image a campaign issue, and promised a big new commitment on climate change, including re-engaging with the international community, setting "a truly national" carbon reduction goal and supporting provincial efforts, including efforts to set a price on carbon emissions. After years in the wilderness, Canada's fuel cell industry is feeling that its turn for federal support may have come around again.

Author: Robert Rose

How Much Electric is in Hybrid?

Are cars like the BMW *i8* electric vehicles? A question hotly debated by many stakeholders in the electric transportation industry, not least since the government has planned to introduce various incentives for these types of vehicles. The German *Electric Mobility Act (EmoG)* passed in June 2015 says that communities can allow electric cars on bus lanes – whether or not the vehicles in question are actually running on gas or electricity while driving on there. Parking spaces near charge points can also be reserved for electric cars without the drivers having to use electricity to get to them. To illustrate the issue with an example, *H2-international* took a closer look at a BMW *i8* to determine how much a hybrid car actually relies on gas or electricity.

The *i8* is an eye-catcher – without a doubt. No matter where you drive, the eyes of people walking by will follow you. The sports car leaves a lasting impression, especially with the younger generation. As soon as you park it somewhere, you'll find them gathering around, gazing at the car. Sometimes, when the electric speeder has to stop at a red light, people nearby will spontaneously snap pictures with their smartphones. And the car is sparking emotions: The responses range from dropping jaws to surprised faces and sudden public displays of affection.

But as we all know, looks are only half the package. What lies beneath the well-designed carbon exterior?

Visionary design

The interior of the *i8*, for whose standard version Germans need to fork out around EUR 130,000 (incl. battery), has a design similar to the outside of the car: stylish, with colors matching the exterior, a digital display and curvy lines in black, grey and blue. The sports mode, however, will change the display color from a chilly blue to an aggressive red. While driver and co-driver sit low but comfortable in the front, the back is much more crammed and not made for people of average height. The scissor doors swing open and close very smoothly thanks to the lightweight CFRP (carbon-fiber-reinforced polymer) aluminum structure.

But infinitely more interesting than the "visionary interior design" (quote from BMW) of the 2+2 seater is what's hidden under the hood of the plug-in hybrid: a three-cylinder combustion engine (displacement: 1.5 liters) with TwinPower Turbo technology. It offers an output of 170 kW (maximum torque: 320 Nm) and powers the rear wheels through a six-speed automatic. Additionally, the car incorporates a hybrid synchronous electric motor (96 kW, 250 Nm) powering the front wheels through a two-speed automatic. Electricity is stored in a high-voltage lithium-ion battery (7.1 kWh) located in the middle of the underbody.

Altogether, the hybrid power train "makes the driver aware of the sporty temperament of the BMW *i8* at all times," as the Bavarian manufacturer puts it. Combustion and electric engine accelerate the vehicle (weight: 1.5 tons) and its passengers from 0-100 kph in 4.4 seconds – not only on paper, but on the road too. The company's i8 press release informs that the car "has an electronically controlled top speed of 250 km/h (155 mph), which can be reached and maintained when the vehicle operates solely on the gasoline engine."

Bayerische Motoren Werke touts the fact that the car's high performance is achieved at the "consumption and emission values of a compact car." Official EU test fuel consumption is said to be 2.1 liters of gas on 100 kilometers, the CO2 value is at 49 g/km (efficiency class A+). Here, at least, theory and reality are far apart, as our road test showed a fuel consumption of 6.7 liters and a power usage of 7.5 kWh per 100 kilometers (combined 66.2 kWh/100 km, i.e., CO2 of 156 g/km) – although, admittedly, the road test was not an eco-ride. The difference in consumption can be explained by the fact that sometimes it is not made clear that the power used has to be added to the gas needed (see box) and that on the road, the car will consume much more energy than in a lab environment (see current public debate).

Only half the story

The Munich-based manufacturer says in its international press release:
"The sprint from 0 to 100 km/h (62 mph) takes just 4.4 seconds, yet combined fuel consumption – as calculated in the EU test cycle for plug-in hybrid vehicles – stands at 2.1 liters per 100 kilometers (approx. 135 mpg imp) plus 11.9 kWh of electricity. This equates to CO2 emissions of 49 grams per kilometre."
This means that the specification of 2.1 liters per 100 kilometers is only half the story and cannot be duplicated under real-world conditions. Even the manufacturer knows that and adds:
"If the daily commute is combined with longer sections of motorway and country driving – on weekend trips for instance – the intelligent powertrain management in the BMW i8 is capable of keeping consumption below the seven litres per 100 kilometres mark (40.4 mpg imp). And even when [the car] is just being used for long-distance holiday driving, fuel consumption still averages below eight litres per 100 kilometres (35.3 mpg imp)."
BMW also states:
"The process for calculating the average fuel consumption of plug-in hybrid vehicles in the EU test cycle also takes into account the use of the available energy capacity in a fully charged battery."
This means:
"This figure is based on a driving profile where the high-voltage battery's capacity is initially used for all-electric driving, before switching to hybrid mode when energy is recuperated to recharge the battery, allowing further sections of the journey to be covered solely on electric power. This profile uses up 11.9 kWh of electricity and 2.1 litres (0.5 gallons) of fuel to complete the 100 kilometres (62 miles)."

BMW, however, seems to base its calculations on the assumption that the power for the car will be generated using renewable energies alone, as the emission values stated only consider the CO2 emitted by the gas consumed. The environmental balance is much worse whenever the car is charged by using household electricity generated by coal plants.

Entirely oversized

The vehicle dynamics of such a sports car are indeed impressive – especially for someone used to driving a station wagon or a compact car. Acceleration, roadholding and handling have been tuned to perfection, so that it is often tempting just to step on the gas and speed through the countryside – the combustion engine has just the right sound for this kind of experience.

A quiet and emission-free electric car: That surely isn't an accurate description of the BMW *i8*. Anyhow, the official figures confirm purely electric driving to be only possible up to 37 kilometers down the road and only at limited speed (< 120 kph or 75 mph). Normal operation (Comfort mode) is said to offer a mileage of up to 600 kilometers; the sports mode (incl. boost function) accordingly lower numbers. Despite all of the above, the i8 is an electric vehicle in the eyes of the law, even more so in terms of the new Electric Mobility Act: According to *EmoG*, plug-in hybrids enjoy the same benefits as other electric cars, as long as they do not emit more than 50 grams of CO2 per kilometer or can at least run 30 kilometers on electricity only.

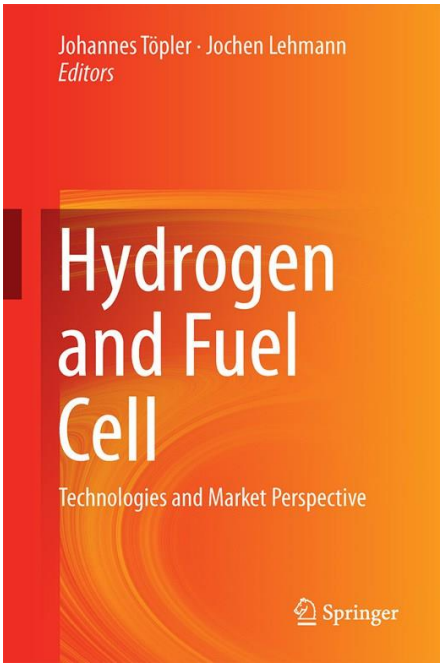
In brief, the BMW *i8* seems mainly to satisfy the expectations of the traditional motorsports fan base. What makes it all the more confusing is that so many i8 models are sold to customers abroad, despite Germany being the only country without a speed limit on its highways. But wherever someone gets into an i8, you can be sure it's all about the fun of driving – the electric-only mode will likely be a rarely encountered scenario. And regular visits to an available charge point may be rather the exception than the rule. Most of the time, the car runs on gas, which means labeling it an "electric car" is misleading and elevates it above other gas-driven cars, a position that the i8 obviously doesn't deserve.

Still, the good news for the Bavarian carmaker should be that this model combined with current legislation will be a big help in complying with emission regulations for new cars.

Off, overseas

The BMW *i8* is produced in a factory in Leipzig, but demand – especially from abroad – outmatches supply at the moment. Daily output of the hall in Saxony is 20 electric sports cars and 100 i3. BMW's Head of Development, Klaus Fröhlich, explained: *"Customers are currently waiting on an i8 for about a good half year."*
It's self-explanatory that the Bavarian carmaker has been focusing its sales activities on markets whose governments incentivize electric transportation – the currently bestselling BMW in Norway is the i3. Last September alone, the carmaker sold 1,710 i3 on the US market – as many as never before. The BMW i8 was sold to 182 stateside customers. Germany was never one of the lead markets, according to Fröhlich.

New Book About Hydrogen and Fuel Cell



It was exactly last Christmas that the Springer publishing company started to offer a new specialist book on *Hydrogen and Fuel Cells*. The book takes a broad approach toward the topic, including everything from H2 generation to future fuel cell applications. The editors are Dr. Johannes Töpler, Chair of the German Hydrogen and Fuel Cell Association (DWV), and Professor Jochen Lehmann, also from DWV's management board. The industry professionals asked renowned experts to enrich their 281-page book with chapters full of know-how and expertise on their specialist subjects. For example, the first chapter by Professor Thomas Hamacher from the Technical University of Munich already provides the reader with a very concise overview of the entire H2 and fuel cell field, whereas Dr. Philipp Kuhn may have put too many details of his recently finished doctoral thesis into Chapter Two. But in Chapter Three, Dr. Ulrich Schmidtchen again proves that the Federal Ministry for Materials Research and Testing is rightfully regarded as a highly competent institution in safety matters.

But the chapters were not all written by scientists; business representatives tell their own story, so that the book provides just as much insight into the research done by carmakers – from H2 storage in sodium borohydride to the freeze start-up of fuel cell cars, albeit the chapters may entail a bit of self-promotion. Somewhat confusing, however, is the statement by Hartmut Paul, who writes that UPS applications with fuel cells "can be economically viable," although his employer Rittal abandoned the segment years ago.

All in all, the book – which had already been published in German at the end of 2013 – offers a wealth of profound expert information from current research and development projects, making it professional literature for an interested readership. The main focus is hydrogen as an important secondary energy carrier for primary renewable energy sources. The authors see potential applications for fuel cells mainly in mobile or portable solutions, followed by stationary fuel cell systems in residential homes and for uninterruptible power supply. The main target audience: readers who like to stay up-to-date about the most recent findings. The book is now available in a hardcover version or in electronic format, although its price tag of USD 119 is more directed at university professors than their students.

Hydrogen and Fuel Cell – Technologies and Market Perspectives
Publisher: Springer Vieweg, Berlin, December 2015, 281 pages with 134 illustrations
Editors: Töpler, J., Lehmann, J., ISBN 978-3-662-44971-4, Store Price: USD 119

A Test Drive from Innsbruck to Amsterdam

Refill in Duesseldorf, © solutions in energy

This is a report from Mortimer Schulz, the owner and founder of *solutions in energy e.U.*, who drove a rented Hyundai *Tucson ix35 FCEV* on February 16th and 17, 2016 from Innsbruck to Amsterdam with a total distance of 1,099 kilometres (km). His

motivation was to gain experience in pursuing a journey in a fuel cell vehicle with a limited number of hydrogen refuelling stations along the way. The four stops were Stuttgart, Karlsruhe, Duesseldorf and Helmond.

Beginning with a full tank of hydrogen at Innsbruck, a total amount of 11.14 kilograms (kg) of hydrogen was refuelled in Germany and The Netherlands. The service was good at all stations. At some stations the hydrogen was reformed from natural gas and stored at the premise. At other stations the hydrogen was produced by means of electrolysis with the necessary power derived from renewable energy sources.

The 1st leg from Innsbruck to Stuttgart was mainly driven on country roads. Temperatures were mostly below the freezing point and the winding roads in the mountains were decorated with snow-covered trees; like in a fairy tale. After the Austrian-German border it was another 193 km to the hydrogen refuelling station in Stuttgart but took 3 hours to drive as again country roads were chosen over motorways and a light foot on the accelerator to make sure to reach Stuttgart at all. Driving faster, such as on the German motorway, would have meant a higher and faster consumption of the energy available. There still needed to be enough reserve to get to Karlsruhe in case refuelling would not have worked in Stuttgart. As Stuttgart has one of the oldest hydrogen refuelling stations in Germany and it being quite a frequented one, all went smoothly.

The 2nd leg from Stuttgart to Karlsruhe was a short stretch on the German motorway but gave no opportunity to drive at a faster pace since the next (at that point in time operational) hydrogen refuelling station, in Duesseldorf, was estimated to be 414 km away from Stuttgart, which however turned out to be 442 km due to a number of detours to avoid traffic en route. Less the 77 km between Stuttgart and Karlsruhe, the remaining distance from Karlsruhe to Duesseldorf was still 365 km.

The 3rd leg from Karlsruhe to Duesseldorf began at 14:30 and ended at 19:45, more than five hours. This was on the one hand due to deliberately driving at prehistorically low speeds, allowing my soul to catch up with me every once in a while, and on the other hand additional unplanned mileage because of heavy traffic and necessary diversions due to accidents causing traffic jams.

The 4th leg from Duesseldorf to Helmond was driven on the second day of the journey. Noticeably, after crossing the Dutch-German border the number of electric vehicles seen on the roads increased drastically compared to the entire rest of the journey, as well as a decent number of hybrids. Whereas from Innsbruck until the Dutch-German border I saw one Renault *ZOE* and one Tesla *Model S*, in The Netherlands there were electric or hybrid -BMW, -Mercedes, -Mitsubishi, -Nissan, -Opel, -Renault, -Tesla, -Toyota, -VW and -Volvo (compressed natural gas-cars not included here, such as for example one FIAT I saw). I mean: … fata morgana?

The final leg from Helmond to Amsterdam finished with a beautiful scenery with windmills and the sun was shining. It was 14:15 in the afternoon; just under 31 hours after having left Innsbruck, of which the net driving time was 17 hours.

In conclusion I am thankful to the friendly people at the hydrogen refuelling stations met during the journey. Two thumbs up to the manufacturers of a comfortable and

reliable fuel-cell vehicle. And sure I would seek to go on another hydrogen challenge; resources permitting.

Author: Mortimer Schulz, www.solutionsinenergy.eu

Mortimer Schulz is a German national residing in Vienna, Austria where he founded his company solutions in energy e.U. working as a consultant for renewable energy and fuel cell & hydrogen technology as well as financing solutions. He has an international banking background and studied a post-graduate Master Degree in Renewable Energy at the Vienna University of Technology (TU Wien). He is 40 years old and tests alternative mobility on a regular basis.

Pedal Cycles Run on Fuel Cells Too

The idea has already been tossed around for twenty years – now it is finally being realized: The development of a market-ready fuel cell bike. As gas specialist Linde announced in November 2015, it took in-house engineers less than three months to design an electric-assisted pedal cycle equipped with a fuel cell instead of a battery pack. The required hydrogen is brought along in a composite tank, which can hold 34 grams of the gas at 340 bar. The energy stored in it is enough to power the bike for around 100 kilometers. The intermittent storage of the *Linde H2 bike* consists of a 60-Wh battery.

The first “customer” of the limited pilot edition of 100 units was the Federal Minister of Transport, Alexander Dobrindt. It is doubtful, however, that there will be more versions of the 24-kilogram H2 eco-bike (fuel cell system: 3.7 kilograms), since Linde’s main goal was to show, “that hydrogen not only benefits cars, but bikes as well.”

Linde H2 Bike

Pragma Industries, on the other hand, does take the commercial route. In May 2013, the company presented its *Alter Bike*. Back then it was said that Pragma's H2 bike would be available to customers from 2016 on. And, in fact, the French business announced in the fall of 2015 that it would enter the market with the new Alpha model, priced at EUR 2,300. It is said to match the Linde bike's 100 kilometer range, but is equipped with a bigger battery (150 watt-hours). The initial production target is also 100 units, according to Pragma CEO Pierre Forte. In 2017, however, it could already be 1,000.

No Concern for H2 Feed-In in Natural Gas Pipelines

The German Technical and Scientific Association for Gas and Water (DVGW) presented a new study during the gas industry discussion forum, *gat 2015*, on Oct. 27, 2015. The new document says that "the existing natural gas infrastructure is generally suited for adding one to nine per cent hydrogen." In Essen, the association presented results from its research conducted under the auspices of the DVGW research project Hydrogen Tolerance of Natural Gas Infrastructure and Associated Facilities.

During the project, the authors of the study investigated a gas grid consisting of polyethylene pipes before and during feed-in. The researchers did not find any

irregularities, although the mixture contained up to nine volume percent of hydrogen. Nevertheless, there is more research needed, especially regarding natural gas reservoirs, gas turbines and natural gas tanks of cars. According to DVGW, “the 500,000 kilometers of natural gas pipelines in Germany are very well suited for the feed-in and storage of hydrogen from renewable electricity.”

France’s Own Energy Transformation

Not too long ago, France’s capital had been the venue for the *UN Climate Change Conference COP2*1. Even if hydrogen and fuel cell technology was not a separate item on the agenda, it is a good bet that many of the around 40,000 participants – from government officials to business associations and unions to environmental and religious organizations – have developed a basic understanding of this technology and its potential to combat climate change.

There is little reason to believe that either sustainably created hydrogen or its use in highly efficient fuel cell systems to support a globally more sustainable and ecologically viable energy supply and transportation will be considered in any agreement in the near future. The interests as well as the political, technological and social conditions of the 195 UN member states are simply too diverse. Still, the pressure is on in politics and the societies of industrial nations to develop new solutions.

La Poste uses H2 vans by © Renault

Even France, the country known for its civil use of nuclear energy, shows signs of a change in energy supply strategies. Under President François Hollande (see fig. 2), the French government has launched various initiatives and has passed several new

regulations since 2013, all in the hopes of making the country's economy fit for the future and "green up" the entire energy industry.

Re-industrialization and renewable energies

One of the focus areas of the national strategy for the re-industrialization of France (Nouvelle France Industrielle, NFI), which the French government had already introduced in 2013, is sustainable transportation, with batteries and hydrogen playing a central role. For example, the document sets the following precisely specified targets: Install 20,000 additional public charge points for battery-driven cars until the end of 2016; reduce CO2 emissions of new cars manufactured until 2021 by 30 percent; establish two industrial centers for batteries and hydrogen by 2017 as well as create up to 25,000 jobs by 2030 in the energy storage segment.

The spring of 2015 also saw the passing of a law on energy transformation (LOI n° 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte), in which hydrogen was specified as an important energy carrier and storage medium within a national renewable energy strategy. This law has allowed France to pave the way for the establishment and the further expansion of a hydrogen infrastructure. The relevant plans have meanwhile been presented by the consortium H2 Mobilité France. This consortium consists of French partners from the industry, science, the communities as well as the national hydrogen association AFHYPAC (Association Française pour l'Hydrogène et les Piles à Combustible) and the European FCH JU. The consortium has been funded and supported by the French Ministry of Ecology, Sustainable Development and Energy and the French environmental and energy agency ADEME.

Figure 2: François Hollande at the UN Climate Change Conference COP21, © Présidence de la République

France creates H2 cluster
The plans for expanding the H2 infrastructure are based on the results and experiences France made between 2012 and 2014 during the European *HIT (Hydrogen Infrastructure for Transport)* project together with Denmark, the Netherlands and Sweden. All four countries have developed national deployment plans for hydrogen infrastructures, which were agreed upon and aligned with each other as part of the project to enable coordinated border-crossing H2 filling station deployment along the major traffic routes in Europe.

Economic considerations led France to choose a cluster approach for its national deployment plan. This means that in the beginning, filling stations will be installed in certain cities and conurbations and initially used to supply vehicle fleets locally and across the region. The specified starting clusters are the Normandy region, Rhône-Alpes and Franche-Comté. The filling stations in those clusters will be connected in a second step along main traffic routes, while considering hydrogen connections to neighboring countries.

Electric cars with fuel cell range extender
To cut costs and reduce the risks to fleet operators, the project relies on battery-powered cars, for example, the Renault *Kangoo Z.E*. They will be equipped with range extender systems based on fuel cell installations by French manufacturer Symbio FCell to up their mileage. This reduces the price of the car compared to vehicles running only on fuel cells, as the fuel cell system and the hydrogen tank do not need to be as big. The same is true for the infrastructure costs, since it is enough at first to install smaller filling stations across the cluster. Main partner and biggest fleet operator is the French mail service, La Poste.

National planning for 2015 included the installation of 15 H2 filling stations and the operation of 200 vehicles, whose number is to be increased to 30 H2 filling stations and 1,000 cars in 2016 alone. The targets are bolstered by the infrastructure deployment plans of European initiative *Hydrogen Mobility Europe (H2ME)*, of which France is a member. This initiative was founded in summer 2015 with the aim of establishing a hydrogen network all across Europe and introduce fuel cell vehicles to the market. Among others, it is based on the agreement about a collaboration in the area of (border-crossing) H2 filling station deployment, which the French Minister of the Economy, Emmanuel Macron, and the German Minister for Economic Affairs, Sigmar Gabriel, concluded during the French-German government consultations at the end of last March.

Several other countries have meanwhile joined the *H2ME* initiative: Iceland, the UK as well as the Scandinavian nations of Denmark, Norway and Sweden. Austria, Belgium and the Netherlands have supported the European collaboration as observers. H2ME has clearly stated the target of bringing 200 fuel cell cars and 125 delivery vans with fuel cells as a range extender to Europe's roads by 2019, as well as setting up 29 new H2 filling stations in the ten participating countries during the same period. These plans, in turn, are closely intertwined with the countries' market introduction strategies.

French Power-to-Gas projects
In addition to its activities in the transportation sector, France has also set the foundation for hydrogen to become an important source of energy supply. To enable

the (intermittent) storage of power generated by renewables, France relies on hydrogen from Power-to-Gas. The feasibility of this approach was demonstrated by different projects, such as *GRHYD* (Gestion des Réseaux par l'Injection d'Hydrogène pour Décarboner les Énergies) in Dunkerque or *MYRTE* (Mission hYdrogène Renouvelable pour l'inTégration au réseau Electrique) on Corsica. The construction of a first megawatt pilot system is scheduled by 2017. Three of the organizations involved in this project are energy provider Engie (until recently called GDF Suez), energy systems provider Areva and the operator of the French gas grid, Gaz Naturel GRDF.

Author: Alexandra Huss

Conference of the Showcase Electromobility

It was almost four years ago that the subsidy program *Showcase Electromobility* (Schaufenster Elektromobilität) was launched. A lot has happened since then. To present an overview of all the different projects carried out during the three-year run time of the program, the four Showcase regions will organize a conference to present the program results on April 14 and 15, 2016. On behalf of the federal government, the organizers scheduled a one-and-a-half-day conference, which takes place just after the *New Mobility* (April 12 to 13) on the Leipzig trade show premises, offering a look back and a look forward on developments in the field. One of the aims of the conference is to present a joint platform for the experiences made with the technology and create recommendations for actions that could be taken in politics and in the industry.

Whereas some showcaseprojects still received an extension into 2016, the state government of Lower Saxony had already ended funding for Metropolregion Hannover Braunschweig Göttingen Wolfsburg on Dec. 31, 2015. The staff of the project office has already been cut down. Raimund Nowak and Kai Florysiak, however, will stay on as chairpersons – albeit under a new logo and tagline – until all projects subsidized across the country end altogether, at minimum until June 30, 2016.

www.schaufenster-elektromobilitaet.org

H2IntraDrive – Testing Industrial Fuel Cell Trucks

Quick H2 refill, © Linde MH

The presentation of the results of the *H2IntraDrive* project was not a sales event or press conference – it was both. On Nov. 23, 2015, the project partners as well as representatives of prospective new partners and some reporters gathered in the BMW factory in Leipzig to take a look at the results of two years of development. The important thing to take away from the event was: Even today, industrial fuel cell vehicles can be commercially viable provided that they meet certain specific requirements.

Robert Mitchell, research assistant from the Institute for Materials Handling, Material Flow, Logistics (fml) at the Technical University of Munich (TUM) revealed the most important information only at the conclusion of the event. In a professionally presented result report, he explained the project approach, evaluation criteria and the ecological aspects before concluding that forklift trucks and tow tractors running on fuel cells can indeed be marketable and “have already been commercially viable today, without the need for subsidies.”The *H2IntraDrive* project, which received EUR 2.9 million in grants from the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP) was launched in December 2013 – but first in a test run. Regular operation commenced in 2014. Back then, five forklift trucks (type Linde *E35 HL* und *E25 HL*) as well as six tow tractors, all running on pure hydrogen, started their work in the production factory of the BMW Group. Here in Leipzig, where 5,000

employees primarily manufacture innovative units exemplifying the brand image (besides the 2 Series, daily factory output includes 100 i3 as well as 20 i8), the first thing that was installed was an H2 filling station to test the powered industrial trucks in intralogistics. Linde Material Handling (MH) was responsible for developing the power train and retrofitting the vehicles while fml conducted the research.

22,000 hours in operation

The base for the test vehicles were commercially available electric forklift trucks and tow tractors, which were retrofitted for H2IntraDrive and developed further during the project's run time. For example, two tow tractors were equipped with Fronius fuel cells and four received units from HyPulsion. The forklift trucks were all equipped with HyPulsion units. The hydrogen needed was delivered three times a month from the nearby steam reforming plant of Linde Gas in Leuna. Together, the eleven industrial trucks and tractors soon had 20,000 operational hours behind them. In total, they consumed 4,200 kilograms of hydrogen.

Powered industrial trucks running on fuel cells are regarded as having advantages over battery-driven versions when it comes to ease of use and refill times. For example, there is no need to check the acid level as opposed to batteries equipped. Additionally, fuel cells avoid replacement batteries and long charge times; the same is true for lift equipment, drench showers, etc. A filling station for hydrogen saves quite a lot of space in comparison, and refills are quickly done (station size: 15 m2; see table). The main downside is still the high costs involved – both for the fuel cell systems as well as for their maintenance and the H2 infrastructure.

Table: Time saved through fuel cell use

	Forklift truck	Tow truck
Battery change	approx. 10 min	approx. 5 min
H2 refill	2.2 min	1.5 min

Significant knowledge deficit

A big majority of 93% of the all in all 109 industry experts asked by TUM employees in summer 2015 sees clear advantages when using hydrogen engines as opposed to purely battery-driven vehicles. At the same time, however, almost 80% of the respondents felt that they still knew too little about the opportunities of the new technology. Professor Willibald A. Günthner, Chair of fml at the TUM, confirmed: "There is still a significant knowledge deficit." To close the information gap, the project partners created a Guide on the Use of Hydrogen-Powered Industrial Trucks as well as a comprehensive research report.

Christophe Lautray, CSO of Kion-owned Linde MH, explained: "The project has closed a knowledge gap." Regarding new prospects who could be interested in using the technology and were invited to the event, Lautray added: "It is an important signal to our customers that during the long-running test, hydrogen has become a tried-and-proven technology as part of the bodywork of the BMW i and is now ready for the mass market."

No question about it!

Asked by H2-international which technology he would favor, Jens Markert, driver of a forklift truck at BMW replied: "No question about it – fuel cells, since they are easier to operate. I just hop on and start up the truck."

Evaluating the results

All in all, there have been 16 fuel cell industrial trucks in operation across Germany (eleven at BMW, two at Mercedes, three at Hoppecke). Considering that the NIP granted the segment around EUR 7 million between 2007 and 2015, this corresponds to over EUR 0.4 million per unit. Volkswagen does have around 60 additional units in the pipeline and has submitted its application for NIP subsidies, but the funding hasn't been confirmed yet.

Wolfgang Axthammer

Across Europe, there were around 63 units in operation in spring 2015, whereas the number of units in the US was around 7,000 back then and is meanwhile approaching 100,000. Wolfgang Axthammer (see figure 2), CEO of NOW, admitted: "To catch up to the competition from abroad, we'll still have some way to go."

Asked about why the differences between Europe and the US were so striking, Dr. Michael Ströbel, lead purchaser at BMW, explained: "There were a lot of hurdles to overcome, both in terms of regulations and in terms of the technology." Notable differences can also be observed concerning the size of the premises: While the factory in Leipzig uses ten to twelve kilograms of hydrogen per day, the BMW facility in Spartanburg in the US consumes eight tons during the same period. It is not only that the number of vehicles is higher in the United States. As the TUM researchers concluded, the work intensity is greater while H2 costs are lower (EUR 3.6 to 5 per kilogram compared to EUR 7 to 8 per kilogram, respectively).

Günthner, W., Micheli, R., Leitfaden für den Einsatz von wasserstoffbetriebenen Flurförderzeugen, TU München, 2015

www.h2intradrive.de

Other projects

Fuel cells only
In October 2015, French food supplier Prelodis inaugurated a new distribution center near Orleans, where the only powered industrial trucks are fuel cell versions by Jungheinrich. Instead of a charge point, the company installed a hydrogen filling station, so that there are now a total of 35 units by HyPulsion driving on 10,000 m² in Saint-Cyr-en-Val. Prelodis President Philippe Giroux had the following to say about the decision: “Our motivation was the costs we could potentially save, the ease of use that the trucks offered, the space we gained not needing a room for a charge point as well as our enthusiasm to be able to equip a new location with innovative technology.”

200 units for Halle
The supermarket chain Colruyt Group in Belgium has had twelve systems from different manufacturers in operation since the end of 2014 (forklift trucks and order picking units). In two stages, the number of powered industrial trucks in the distribution center in Halle is planned to rise to 200. This includes an initial 75 units by Plug Power and a later delivery of another 125. Project head Jonas Cautaerts explained: “Hydrogen is one of our main means of reducing our environmental impact.”

OWI Undergoes Restructuring

OWI Oel-Waerme-Institut underwent business restructuring at the end of 2015: Since Nov. 17, 2015, the RWTH Aachen affiliate has had a new parent company in Tec4Fuels. The new and sole head of the business venture is David Diarra. The engineer has been a long-time employee of OWI and had shared management of the company with Dr. Klaus Lucka until last October. Lucka had been OWI's CEO for 15 years and is now a managing partner of Tec4Fuels. The other partner of Tec4Fuels is the Institute for Heating and Oil Technology. Second Tec4Fuels executive and IWO's marketing head is Olaf Bergmann. Bergmann explained: "IWO is committed to further developing Oel-Waerme-Institut to use its technical and scientific expertise for the benefit of the industry."

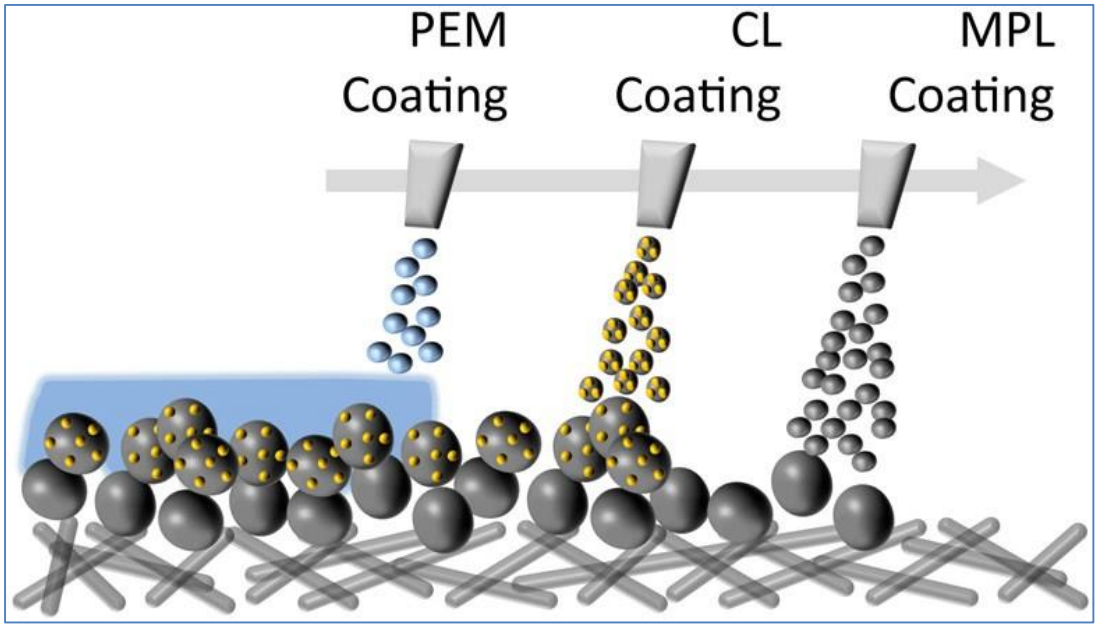
David Diarra, © OWI

see also: OWI develops APU package of diesel and fuel cell

Simplified Production Method for PEM Fuel Cells

The heart of PEM fuel cells is the membrane electrode assembly (MEA), which has so far been produced by using only polymer electrolyte membranes. The manufacture of these membranes, however, is highly complex and expensive, limiting MEA production to a few companies around the globe. An innovative method discovered by researchers from the Department of Microsystems Technology (IMTEK) at the University of Freiburg makes the membrane process technology obsolete: A polymer electrolyte solution is directly processed between electrode and membrane. This technology is not only easy to employ and inexpensive, but it increases fuel cell performance compared to currently commercially available technologies. The extremely simplified process for PEM fuel cell production earned the MEMS Applications research team the f-cell award research & development in Stuttgart.

Fuel cell performance is highly influenced by the functional characteristics of the individual layers, their thickness and even their borders (see figure 2). All these performance factors will require optimization if one wants to produce a commercially viable fuel cell in the near future. A focus area of research into this field has always been the catalyst layer based on platinum. Ideally, it should display excellent electric and proton conductivity, create a high specific surface and contain as little as possible of the expensive and precious metal.



Another component moving into the focus of research is the polymer electrolyte membrane. Here, efforts are concentrated mainly on synthesizing new polymers with high chemical and mechanical stabilities combined with excellent proton conductivity. The border areas of the catalyst layer and membrane, however, have so far received

not more than a little attention, although they harbor great potential for reducing the electric resistance of the cell. And despite the great cost saving opportunities, innovative methods to manufacture this tripartite layer combination have sparked little research efforts up until now.

Development at IMTEK

These were exactly the two factors considered by the prized invention from the Freiburg scientists: In April 2015, they published a method to produce MEAs with optimized border areas of catalyst layer and membrane. The highlight: The entire MEA can be produced using only a single device.

Through ink jet print, a polymer electrolyte dispersion is printed in liquid form directly onto the catalyst layers of a fuel cell. The ink jet print can also process catalyst layers and microporous gas diffusion layers, so that every functional layer of the MEA can be processed with the same device. Thanks to the initial liquid state, the presented method creates a perfect link between the printed membrane layer and the catalyst layers. The liquid electrolyte enters the porous catalyst layer at up to a few hundred nanometers before it hardens, which strongly decreases the proton contact resistance of both. The direct deposition of the membrane on the electrode also allows for extremely thin membrane layers, which further contributes to reducing proton resistance.

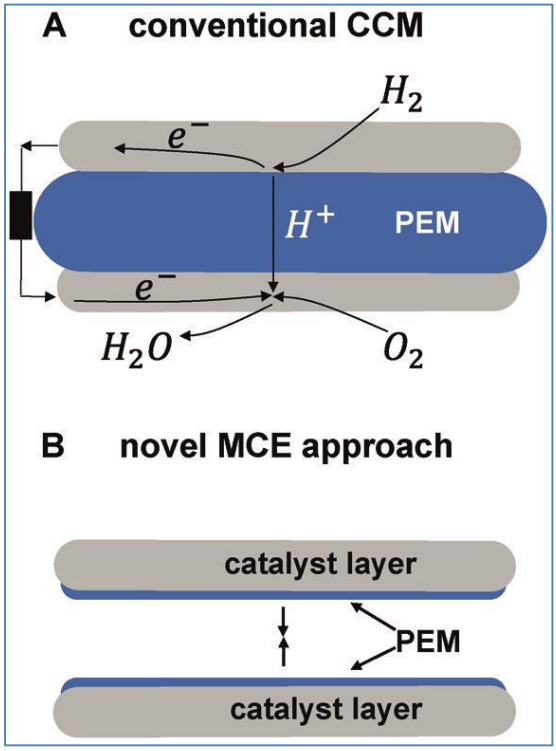


Fig. 2: MEA of a low-temperature fuel cell with anode, cathode and proton exchange membrane as well as the related electrochemical reaction. A: Catalyst coated membrane (CCM, conventional technology): The catalyst layers are applied onto a relatively thick foil-type membrane. B: Recently presented membrane coated electrode (MCE): Thin membrane layers are applied directly to the catalyst layers of anode and cathode.

The combination of the two effects has resulted in a fuel cell with extraordinary high proton conductivity, leading to power densities of above 4 W/cm² (300 kPa of

absolute pressure, including H2 & O2 as combustion gases). Another benefit of the thin membrane was evidenced by a favorable self-humidification of the cell. Measurements showed less than a ten per cent reduction in performance between entirely wet and dry reactive gases, which renders the use of active humidifiers unnecessary.

Simplified production

Besides the high performance, removal of the conventional foil-type membrane offers another advantage: simplicity. Future mass production could entail spraying the microporous gas diffusion layer, the catalyst layer and finally the membrane subsequently and directly onto the gas diffusion layer as a substrate (see figure 1): Drawing showing the mass production of fuel cell half-cells: Subsequently, the microporous layer (MPL), the catalyst layer (CL) and the membrane (PEM) are sprayed in form of a substrate onto a gas diffusion layer (GDL). This process saves costs and time during production. The fuel cell can be produced by combining any of the half cells available.

Spray coating has already been a large-scale industrial method for manufacturing gas diffusion electrodes. Since the spraying process for the diffusion and the catalyst layer has already been state of the art, it would now need to be complemented only by spraying the membrane onto the fuel cell as well. The researchers from Freiburg have already tested and proven the feasibility of such a process. Together with cooperation partners from the Canadian Simon Fraser University, a first trial shows that an entirely spray-coated fuel cell shows competitive power densities in comparison with current processes (see figure 3).

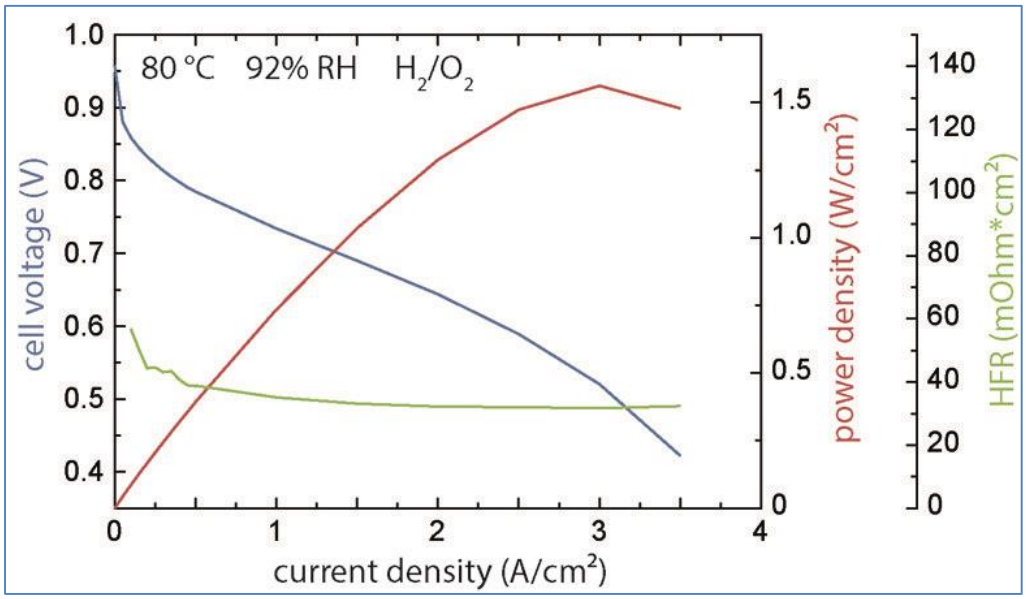


Fig. 3: Performance characteristics of an entirely spray-coated fuel cell with a cathode loading of 0.3 mgPt/cm².

The use of the reactive gases hydrogen and oxygen resulted in a maximum power density of 1.5 W/cm² (at 80°C, 92% relative humidity, atmospheric pressure). Additionally, it showed that entirely spray-coated cells can be manufactured with large surfaces in mind, meaning a transfer to industrial throughput is possible. The new manufacturing method would also no longer require any knowledge about foil-

type membranes. Instead the importance would be on expertise in the production of functional dispersions, suspensions or solutions as well as their processing as ink for coating systems, such as spray coaters or screen printers. This means that the new technique is especially interesting to all those companies which have know-how in one of these areas and want to establish a presence in the fuel cell market as lateral entrants.

Room for novelties

This invention can also be the foundation of other innovative approaches in manufacturing composite membranes (e.g., use in mid-temperature fuel cells up to 120°C). The layer structure of the fuel cell enables the simple integration of reinforcing elements into the membrane layer, which manufacturers had so far only been able to do by putting a lot of effort into it (see figure 4).

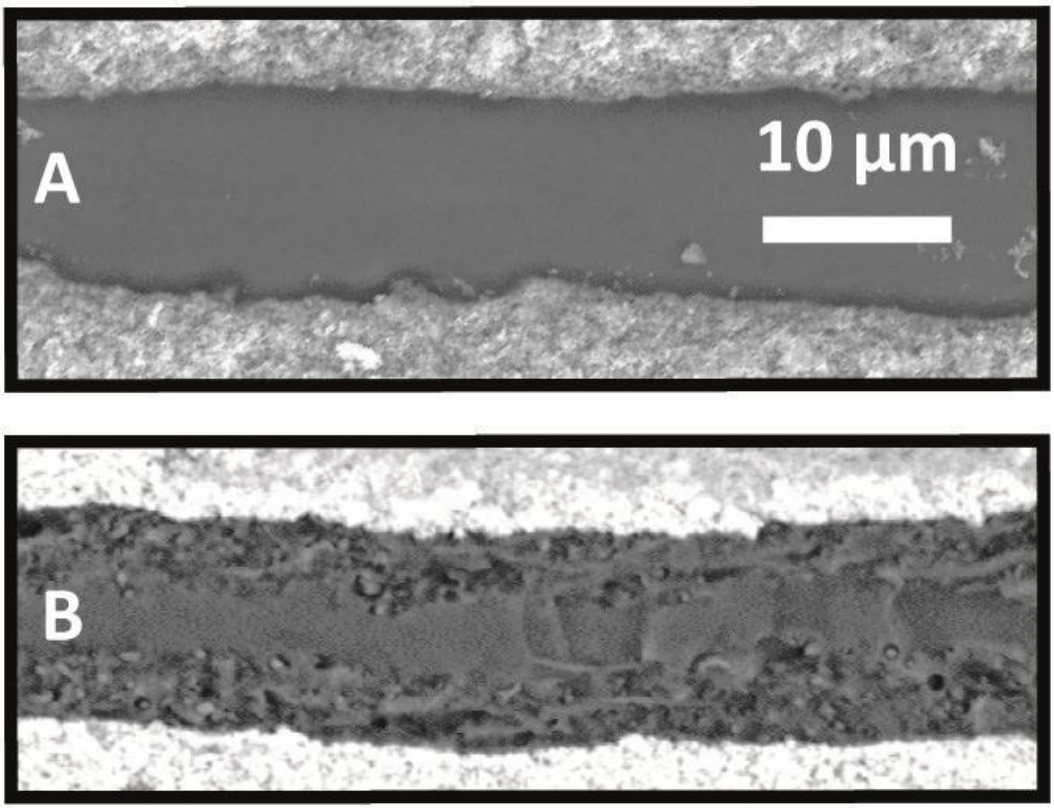


Fig. 4: Standard MEA without reinforcement; B: Fiber-reinforced MEA

An obvious application would be the addition of colloidal nanoparticles to the membrane ink before processing. This method has already been in use in foil-type membrane production, but can as well be applied to the new technology. At IMTEK, research showed that TiO2 nanoparticles enable the fuel cell to operate at higher temperatures without a significant loss of performance.

Another forward-looking method to reinforce the membrane has already been under development: A stable fiber compound consisting of nanofibers (e.g., known from bullet-proof vests or cut-proof pants) is planned to be incorporated into the membrane through electric spinning, in order to stabilize them mechanically (see figure 4B). This is especially noteworthy in the case of processing polymer electrolytes, which do have very high proton conductivity but rather low mechanical

stability on their own. In the future, the process of creating powerful and durable composite membranes could be a very inexpensive one.

There are plans for future projects on the aging and upscaling of the new fuel cells. Here, the questions posed would revolve around the durability and transfer at stack level.

This research was subsidized by the BMBF in the framework of the GECKO project (Subsidy ID: 03SF0454C).

Authors: Dr. Simon Thiele, Matthias Klingele, Matthias Breitwieser, Roland Zengerle
All from IMTEK, University of Freiburg

Alexandra Ernst is Newest Member of DVGW Team

Alexandra Ernst, © DVGW

On Oct. 1, 2015, Alexandra Ernst became the CFO of the German Technical and Scientific Association for Gas and Water (DVGW). The association's executive board had decided in a special session in Bonn on creating this new post, making the economist born in Recklinghausen the second salaried executive besides Professor Dr. Gerald Linke. The main responsibility of Ernst, who had been CEO of juwi Service & Solutions between January 2013 and January 2015, will be the commercial as well as the product and service-related management of the DVGW Group. DVGW President Dietmar Bückemeyer explained: "Her personal qualities, management skills and business knowledge immediately convinced all of us here at the board. With Alexandra Ernst, we were able to add an established expert on energy to our team."

Results of the Feasibility Study RHyntal Fuel Cell Ferry

Ferry Rheinthal, © Jobst Johann

A ferry over the Rhine has for many years been the link between Rüdesheim and Bingen, a cross-over between the federal German states of Hesse and Rhineland-Palatinate. The car ferry is highly frequented: both by local tourism and by commuters who want to get to Ingelheim and Mainz, but also into the other direction to Wiesbaden and the Frankfurt area, including its adjacent communities. This part of the Rhine belongs to the world heritage site Upper Middle Rhine Valley, meaning it is protected by law. This also means that there are no plans to build a new bridge at this section of the Rhine; the ferry is and will be the only local connection between both sides of the Rhine for many years to come. A group made up of different stakeholders from the industry, science and the two initiatives for hydrogen and fuel cells from Hesse and Rhineland-Palatinate has now conducted a feasibility study to determine whether electric engines could meet the necessary technical requirements for an emission-free ferry operation.

The calculations of the feasibility study were based on the actual conditions under which Bingen-Rüdesheimer Fähr- und Schiffahrtsgesellschaft operates the current *Rheinfähre* ferry line (see figure 2).

Feasibility study: objective and design
The aim of the study was to investigate in several steps whether it was possible to replace the existing ferry line by emission-free water transportation or if insurmountable hurdles would prevent such an endeavor. The steps included measuring the performance of the diesel engine, in order to obtain points of reference for the design of a fuel cell engine, and to answer the question if and how the fuel cell system would have to be complemented by batteries. Additionally, there was the issue of the H2 infrastructure that needed to be resolved, as the ferry line is not far away from the Energiepark Mainz (around 30 kilometers). The Energiepark generates 200 tons of hydrogen each year in a sustainable way through a Power-to-Hydrogen plant. Other steps dealt with the energy balance of the engine, the H2 supply, approval procedures and last but not least, economic viability.

The water transportation industry depends on the high reliability of its ships. This means that the conventional design of ship engines includes high power reserves as well as safety margins. Thus, the first step was to determine how much engine power was actually used when the ferry was in operation and how much energy would be needed on board in case of an emergency. In the framework of a master thesis, a measurement project collected ferry data on standard operation across several days and compared the measurements with the power output of the engines.

The *Rheinfähre* is equipped with four identical engines of 215 kW each. One trip requires only two engines and the other two are used as a reserve. The power required was determined by recording the output of one of the engines. The results showed that the usual output per engine during normal ferry operations amounted to no more than 33 kW, which represents merely 15% of the engine power installed. Thus the engines are far removed from optimal levels. The measurements and actual consumption values of the diesel refills enabled the research group to calculate the consumption of a fuel-cell engine and the dimensions of a hydrogen engine needed to match actual consumption.

To avoid overloading the fuel cell systems and to be able to meet peaks in demand, the group found a hybrid system of fuel cells and batteries to be the best solution in terms of energy demand and safety. Requests were sent to manufacturers of such systems and calculations were ultimately based on those which had already had maritime approval of Germanischer Lloyd (now DNV GL). The power train design with two fuel cell systems to supply the engine with energy was designed with redundancy in mind: The systems for propulsion and onboard power supply were supposed to be available twice to allow a so-called N+1 redundancy. The calculated hydrogen demand added up to 120 kg per day in summer and 80 kg per day in winter, corresponding to the difference in seasonal frequency of ferry runs.

Storage design
The aim was to use sustainably sourced “green hydrogen” from the beginning. Currently, the ferry tanks are refilled with diesel at a special dock every other week. A similar scenario was requested for a hydrogen refill. But it proved impossible to adapt the planned hybrid system of fuel cells and batteries to fit a two-week interval. Business partner Linde thoroughly investigated different options until ultimately, the plan was to integrate an H2 container co-developed by Linde for pressure levels of

300 to 500 bar. This container is a fast-exchange version, which allows the operators to replace an empty container by a full one within a short period. It would mean that refilling the ferry tanks could be done during the usual unloading and loading times.

Legal issues

When the feasibility study was conducted, one focus area was the if and how of approval of this kind of car ferry, the question of which authorities would be responsible for the approval, what legal, safety or other regulations had to be observed and whether the approval of such a ferry would be possible at all. All of these questions could be answered with yes, as some of the rules had already been adapted for retrofitted engines. The relevant technical regulations can partly be found among existing rules of the Inland Waterway Vessel Inspection Ordinance (BinSchUO from 2013) or can be derived from them. The added application of regulations issued by Germanischer Lloyd on the use of fuel cells onboard water vehicles (GL, 2002) leads to a high legal certainty regarding approval of the ferry.

Funding

To get an idea of the costs, the research group conducted a rough investment estimate during the project run. Additionally, it calculated the cost of capital, consumption and operation and compared them with the old values.

Regarding the design favored by the study, costs were estimated at around EUR 9.1 million based on current prices of fuel cells and the related hydrogen infrastructure. A conventional ferry costs around EUR 5.5 million today, plus VAT. This means that costs would be at least 65% above the ones for the conventional version.

But it is not only the high additional investment – which could be offset by subsidies – that poses a challenge to possible realization. Today's combustion technology, whether it is based on diesel or diesel and electricity, also still has an edge over fuel cells regarding economic and useful life. Simulations showed that the fuel cell stacks would likely have to be replaced after six years. It can be assumed, however, that it will be possible to overcome this limitation within the next years.

Regarding operational costs, the research group investigated – in addition to regular maintenance of the technical systems, engines, fuel cells and batteries – especially the consumption costs for diesel in comparison with hydrogen. The current price of around EUR 10 per kilogram (Linde Gas, 2015) does not constitute an advantage over diesel. This means that the use of hydrogen in ferries would require both initial investment subsidies for ship and infrastructure (e.g., for a demonstration project or a later market introduction) and subsidies to cover operation costs or funds to offset the added fuel costs for hydrogen (e.g., through higher taxes on fossil fuels).

To create the feasibility study, the consortium planners, together with the two research organizations, Transferstelle Bingen and Hochschule RheinMain, submitted an application to the ministries of economy in Mainz and Wiesbaden. At that time, the ferry operator was planning to purchase a new ferry, although it was clear that such an H2-fuel cell ferry would be a prototype and the research or demonstration aspect would up the price tag. It meant that the plan could not be realized by the ferry operator without government support.

To present the results of the feasibility study in detail and to discuss further applications of fuel cell systems in the water transportation industry, the Transferstelle für Rationelle und Regenerative Energienutzung Bingen and HA Hessen Agentur organized a workshop, Sustainable Marine Propulsion Systems – Water Transportation on Rhine & Main Using Batteries and Fuel Cells, together with the hydrogen fuel cell network from Rhineland-Palatinate (H2BZ Kooperationsnetzwerk RLP) and the hydrogen and fuel cell Initiative from Hesse (H2BZ-Initiative Hessen) in the Rhine-Main area on Feb. 24, 2016.

The project partners were HA Hessen Agentur, Hochschule RheinMain, Transferstelle für Rationelle und Regenerative Energienutzung Bingen, Linde Gas, H2BZ-Initiative Hessen, H2BZ Kooperationsnetzwerk RLP as well as Bingen-Rüdesheimer Fähr- und Schiffahrtsgesellschaft. The project was subsidized by the State Ministry of Rhineland-Palatinate for Economic Affairs, Climate Protection, Energy and Regional Planning and the Hessian Ministry of Economy, Energy, Transport and Regional Development.

References: Machbarkeitsstudie Rhyntal, B. Scheppat, M. Werner, O. Türk, J. Schied, J. Walter

Authors:
Professor Dr. Birgit Scheppat, Matthias Werner
Both from Hochschule RheinMain

Professor Dr. Oliver Türk, Jochen Schied, Joachim Walter
All from Transferstelle für Rationelle und Regenerative Energienutzung Bingen (TSB)

Markus Lämmer
HA Hessen Agentur GmbH, Geschäftsstelle Wasserstoff- und Brennstoffzellen-Initiative Hessen

---

Events

- April 13th to 14th, 2016, **Grove Conference Fuel Cells Science and Technology**, in Glasgow, United Kingdom, organized by Elsevier, www.fuelcelladvances.com
- April 25th to 29th, 2016, **Group Exhibit Hydrogen + Fuel Cells + Batteries**, in Hannover, Germany, www.h2fc-fair.com, www.hannovermesse.com
- April 27th to 28th, 2016, **Electric Vehicles Europe 2016**, in Berlin, Germany, www.idtechex.com/electric-vehicles-europe
- May 30th to 31th, 2016, **The Future of Electric Vehicles**, in Frankfurt am Main, Germany, www.claridenglobal.com
- June 13th to 16th, 2016, **World Hydrogen Energy Conference 2016**, in Zaragoza, Spain, www.whec2016.com
- March 15th, 2016, **The Commercialisation of Hydrogen & Fuel Cell Technology**, in Birmingham, United Kingdom, www.climate-change-solutions.co.uk
- July 5th to 8th, 2016, **European SOFC & SOE-Forum**, in Lucerne, Switzerland, www.efcf.com
- March 15th to 17th, 2016, **International Renewable Energy Storage Conference (IRES 2016)**, Düsseldorf, Germany, www.eurosolar.de
- March 16th 2016, **5th Conference Power-to-Gas & Power-to-X for Europe's Energy Transition**, at Messe Düsseldorf, Germany, www.otti.eu

read more: www.h2-international.com/events/

Companies

Electrolyzers

- **AREVA H2Gen GmbH**, Maarweg 137, 50825 Cologne, Germany, Phone +49-(0)221-888244-88, Fax -67, www.arevah2gen.com

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

- **Giner, Inc.**, 89 Rumford Avenue, Newton, Massachusetts 02466, USA, Phone +1-781-529-0500, information@ginerinc.com, www.ginerinc.com

- **Hydrogenics GmbH**, Am Wiesenbusch 2, 45966 Gladbeck, Germany, Phone +49-(0)2043-944 141, Fax -6, hydrogensales@hydrogenics.com, www.hydrogenics.com

- **Proton OnSite**, 10 Technology Dr, 06492 Wallingford CT, USA, Phone +1-203-678-2000, info@protononsite.com, www.protononsite.com

Energy Storage

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

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

Event Organizers

- **22nd Group Exhibit Hydrogen + Fuel Cells + Batteries**, HANNOVER MESSE 2016, April 25 – 29, Tobias Renz FAIR, Phone +49-(0)30-60984556, tobias@h2fc-fair.com, www.h2fc-fair.com

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

- **GL events Exhibitions**, 59, quai Rambaud, CS 50056, 69285 Lyon Cedex 02, France, Phone +33-(0)478-17633-0, Fax -2, www.gl-events.com

Fuel Cells

- **FuelCell Energy Solutions GmbH**, Winterbergstr. 28, 01277 Dresden, Germany, Phone +49-351-2553739-0, Fax -1, www.fces.de, Stationary fuel cells for commercial and industry: CHP solutions, hydrogen production and power storage

- **Heliocentris Energy Solutions AG**, Rudower Chaussee 29, 12489 Berlin, Germany, Phone +49-(0)30-340601-500, Fax -599, info@heliocentris.com, www.heliocentris.com

- **Tropical S.A.**, 17 Krokeon Str, 10442, Athens, Greece, Phone: +30-(0)210-5785455, Fax: -7, info@tropical.gr, www.tropical.gr

Fueling-Recirculation and Air-Supply

- **Busch Clean Air S.A.**, Chemin des Grandes-Vies 54, 2900 Porrentruy, Switzerland, Phone +41 (0)32-46589-60, Fax -79, info@buschcleanair.com, www.buschcleanair.com

Gas Diffusion Layers (GDL)

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

Hydrogen Distribution

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

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

Membrane and Separator

- **FuMA-Tech Gesellschaft für funktionelle Membranen und Anlagentechnologie mbH**, Carl-Benz-Str. 4, 74321 Bietigheim-Bissingen, Germany, Phone +49-(0)7142-3737-900, Fax -999, www.fumatech.com

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

Organization

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

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

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

Reformers

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

Research & Development

- **Fraunhofer ICT-IMM**, Reformer and Heat Exchanger, Carl-Zeiss-Str. 18-20, 55129 Mainz, Germany, Phone +49-(0)6131-9900, info@imm.fraunhofer.de, www.imm.fraunhofer.de
- **Fraunhofer ISE**, Heidenhofstrasse 2, 79110 Freiburg, Germany, Phone +49-(0)761-4588-5202, Fax -9202, www.h2-ise.de

Suppliers

- **Anleg GmbH**, Advanced Technology, Am Schornacker 59, 46485 Wesel, Germany, Phone 0281-206526-0, Fax -29, www.anleg-gmbh.de
- **Borit NV**, Bipolar plates and interconnects, Lammerdries 18e, 2440 Geel, Belgium, Phone +32-(0)14-25090-0, Fax -9, contact@borit.be, www.borit.be
- **HIAT gGmbH**, Schwerin, Germany, CCMs / MEAs / GDEs for PEFC, DMFC & PEM-Electrolysis, www.hiat.de

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

System Integration

- **Deutsche Zentrum für Luft- und Raumfahrt (DLR) / German Aerospace Center**, Institute of Engineering Thermodynamics Energy System Integration, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany, Phone +49-(0)711-6862-672, Fax -747, www.dlr.de/tt, www.dlr.de/tt
- **FLEXIVA automation & Robotik GmbH**, Power Electronics – Hybrid Energy System Solutions, Weißbacher Str. 3, 09439 Amtsberg, Germany, Phone +49-(0)37209-671-0, Fax -30, www.flexiva.eu

Testing

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

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

Valves

- **Bürkert Werke GmbH**, Mass Flow Controllers, Christian-Bürkert-Str. 13-17, 74653 Ingelfingen, Germany, Phone +49-(0)7940-10-0, Fax -91204, www.burkert.com

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

read more see: www.h2-international.com/companies/

Do you also want to be part of this **List of Companies on H2-international?**

It only costs US-$ 199 (185 Euro) and includes a free subscription for H2-international e-Journal.

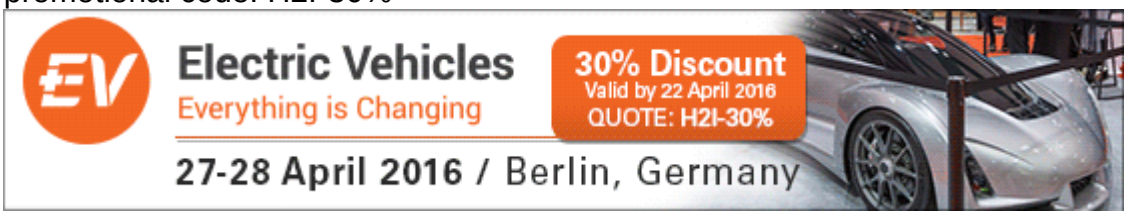
Advert

Specials

Free tickets or special discount only for H2-international subscribers:

- **Free Tickets** for the fair:
  Hannover Messe, from April 25th to 29th 2016, in Hannover, Germany
  Please register on: www.hannovermesse.de

- **Special 30% Discount** for the conference:
  Electric Vehilces Europe, from April 27th to 28th 2016, in Berlin, Germany
  Please register on www.idtechex.com/electric-vehicles-europe/ and use the promotional code: H2I-30%



- **5% Discount** for the conference:
  The Future of Electric Vehicles, from May 30th to 31th 2016, in Frankfurt am Main, Germany
  www.claridenglobal.com

Please contact *H2-international* for more details.

Literature

Free Book about Hydrogen and Fuel Cells

Both the author Arno A. Evers and the publishing house Hydrogeit Verlag decided to donate the book

The Hydrogen Society – More Than Just a Vision?

to the worldwide H_2-community.

This book written by Arno A. Evers was published in April 2010 on the annual Hanover Fair where the author had established a global meeting point for companies and interested people from commerce and politics as well as science and media who are involved in the implementation of hydrogen and fuel cells since 1995.

Right now all printed copies of the Hardback-book which contains 168 colorful pages, lots of illustrations and also a preface from T. Nejat Veziroglu, IAHE-President are sold out. But it is still **available as e-book**.

Because of the visit of US-President Barack Obama on April 24th, 2016 during this Hanover Fair (USA is selected partner country) the e-book is provided – **for free** – for all interested readers who are invited to start discussion about all the ideas and topics which are mentioned by Arno A. Evers.

The Hydrogen Society – More Than Just a Vision?

written by Arno A. Evers

published by Hydrogeit Verlag

Oberkraemer, April 2010

ISBN 978-3-937863-31-3

Price: for free

Please have a look on:

www.hydrogeit-verlag.de/hydrogen-society & www.hydrogenambassadors.com

Imprint & Social Media

H2-international – Hydrogeit Verlag, Sven Geitmann, Gartenweg 5, 16727 Oberkrämer, Germany, Phone +49 (0)33055-21322, Fax +49 (0)33055-21320

E-Mail: info@h2-international.com, Homepages: www.h2-international.com & www.hydrogeit-verlag.de, UID/VAT: DE221143829