H2-international – e-Journal

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Content

Sobering News for Early Adopters

David Wenger's Driving Experiences

Electric Transportation

People need to experience electric transportation on their own, something which is true for drivers of both battery and fuel cell cars. At least an adequate number of purely battery-driven vehicles have already made it onto the public roads in Germany. But how can people today gather their own personal experiences of driving fuel cell vehicles? Ordinary citizens will only have the chance to be allowed to take a short test drive during an industry trade show. David Wenger from automotive supplier Wenger Engineering was given the opportunity to lease and test a fuel cell car for two years. H2-international spoke with him about his experiences.

Fig. 1: Sometimes, the F-Cell was parked at the side of the road for weeks without being used.

A lot has been accomplished with hydrogen cars: They were driven toward world records in top speed, used for a 30,000 kilometer ride around the globe, and tested for day-to-day use during numerous demonstration projects. But either the company-own engineering staff came along for the trip or they at least stood ready in the background to be called upon and take over the steering wheel or control of the car. The only "customers" who have so far been able to test the most recent fuel cell models – temporarily – were actors and actresses or politicians, and they had the necessary technical support staff stand by as well.

David Wenger was one of the first “regular” German customers who had leased, meaning who had actually been able to rent a fuel cell car for two years, and had tested it on public roads instead of taking it out once in a while for a short spin during a demonstration project. In a long conversation with H2-international, the managing director of a 19-employee SME told us about his experiences.

Bottom line after 1.5 years

Around one-and-a-half years ago, David Wenger traded in the Mercedes-Benz C-Class he had driven for eight years for a Daimler F-Cell B-Class and made the fuel cell model available to his employees as well. His initial assessment of the car’s capabilities was certainly a positive one: “The car performs as expected. It starts when I turn the key – always – and it gets me from A to B. Output is OK, but not more than that. After all, it’s not a sports car. One thing that really stands out is the cold-start behavior: Really incredible how reliable this process is – even under the most adverse conditions: when cold-starting the car several times per day, during short trips or at -10 °C and 30 centimeters of snow.“

Wenger added: “At first, I was pleased and proud to own a fuel cell car, as we are one of the world’s around 100 first ‘real’ customers of such a forward-looking car – you could even say: in the history of mankind.” However, he was little enthusiastic about the whole package: “In total, the results are sobering, sadly. That really hurts too.”

What happened? Why broken dreams despite a technology that works and a driver’s obvious enthusiasm for fuel cells?

What went wrong?

As an automotive supplier, Wenger’s company was involved in developing the powertrain for the F-Cell, which is why he said: “Everything hydrogen-related in that car is top notch.” He also didn’t have any complaints about the vehicle’s reliability and road performance: “The car runs like a champ. But the truth is: It’s been standing around for six weeks.” (Quote from October 2015)

One essential reason for his employees’ lack of interest may be the Audi g-tron that the Ulm-based company acquired for testing purposes around the same time as the H_2 car. Staff can choose freely which car they want to pick from the company fleet. This freedom of choice resulted in the fuel cell model not having been moved for more than three months at the beginning of 2016. Wenger’s employees prefer the diesel – or the g-tron model, which runs on natural gas produced by renewable sources.

Fig. 2: Receipt for H_2 refueling

"Get used to driving with 'low fuel' being constantly displayed on the dashboard, or forget buying an F-Cell." Advice from Wenger

Of course, Wenger wanted to know why the fuel cell car praised for its innovative design did not go over well with his staff. Some of his team's answers surprised him, although he understood their reluctance to use the car:

- "You need an additional 30 minutes to get to the next H_2 filling station."
- "I need to refuel every time I use it."
- "When I drive to Frankfurt, I need to refill twice. I don't even need to do that once with our diesel model."
- "Sometimes, the filling station doesn't work." (Question: "But the map says that the filling station is online, right?" Reply: "Yes, it does. But once you're there, it may be a different story; remember what happened last time.")
- "I was running late, and I had no time for these kind of experiments."
- "My smartphone's Bluetooth connection isn't working properly."
- "I'm very tall and the seats are uncomfortable."
- "The other car has the better entertainment system."

Wenger echoed his staff's sentiments: "I know this may come across as a petty complaint, but there's some issue with the hands-free set. It's understandable, since the model is already seven years old, but it's annoying nevertheless." He does know that it's not quite fair to compare combustion cars that have been continuously optimized for around 100 years with new technology that hasn't even been available on the market yet. But the entrepreneur said: "People buy cars, not powertrains. That means they do purchase the whole package. To some, massage seats may be more important than hydrogen."

Potential for improvement

Wenger said about the fuel supply: “Most of the time, the H_2 filling stations are operational. When they are not, it’s typically due to a careless mistake, such as incorrect operation of the fuel pump by the previous user, too little capacity of the station, communication problems between store and fuel pump, errors when reading the card, or repairs being undertaken while the station is still shown as operational on the map.” Despite all of the above, Wenger likes driving to the refueling stations: “The receipt always gives me the feeling of being special and different from typical car drivers, who are still stuck in the twentieth century.”

When rating the refueling and billing solutions, the top spots were claimed by applications that provided all necessary information and where payment could be made directly. The ones which Wenger considered not appropriate entailed all the other variants, which sometimes made drivers pick up keys somewhere else beforehand or at which the card reader was located far away at easily missable locations. What was equally unacceptable to him were defective card readers or signs with phone numbers, which had to be called before the driver could refuel his or her car. (Typical phone call: “I don’t know whether the station is operational, but you could just drive there and take a look. No, I am not responsible for the station. Who told you that?”)

The interactive map of Germany should also still be optimized for ease of use. Wenger had already said in 2015 that the map, which shows all existing hydrogen filling stations as well as their availability, was extremely hard to find on the Clean Energy Partnership website and difficult to use on a smartphone (see also Emergency Stop). CEP has promised to revise it.

Emergency stop

“I remember that we once had a business appointment about 300 kilometers away. We were going to meet in the office at 5:45 a.m. At five in the morning, I received a text message from my employee: ’Sorry, I’m running late. The station doesn’t work. I need to drive to another one.’ I checked the map of H_2 filling stations: green (operational). So what happened?

Later, I was told that someone had inadvertently pressed the emergency stop button instead of the normal one. I was also told that the use of the emergency stop did not change the operational status of the station, although the fuel pump could no longer be used.”

Another challenge is certainly the barely existing network of filling stations, although drivers in the area around Ulm do have the choice among several: A refueling location for the B-Class in Nabern on the Daimler factory premises, three H_2 filling stations in the area around Stuttgart, and Ulm itself should have gotten one in the fall of 2015. However, it could take until this summer to finally set up the latter.

Additionally, there is the matter of “some stations only filling the tank up to 90 or 95 percent,” so that the effective range is not even close to the 400 kilometers stated. Wenger calculated that based on the 9,000 kilometers driven by him and his team, the actual average range was only 250 kilometers. It is the reason for him to say that you should always expect the unexpected. (“If there’s something wrong at the refueling station, I’ll be standing there for a while.”)

Wenger puts the average consumption at 1.18 kg_{H2} per 100 km if he drives the car. His apprentice is a bit more economical at it, whereas another colleague's sporty left-lane driving uses much more energy. Even more fuel is consumed by the many cold starts during winter.

So far, the price of EUR 9.5 per kilogram has had Wenger's car at fuel costs of EUR 10 to 11 per 100 km. That's almost double as much as for the diesel model, considering the latter's consumption of 6.5 L on 100 kilometers and the currently low cost for gas. Wenger said that regretfully, "From a financial perspective, it's a total disaster."

Early or too early?

Wenger sounds somewhat embittered when talking about electric transportation: "No-one really wants to. The little people are the ones losing out: They want to go along with it fervently, but corporate management signals them that the breakthrough may come rather later than sooner. The whole process is very cumbersome." Looking a bit down, he added: "If nobody wants to have these cars right now, then the question is whether you need them at all."

Off target

Wenger did not achieve his original aim of driving 20,000 kilometers with a fuel cell car within one year "because of few available filling stations, their less-than-guaranteed availability, and the low range of the car." On a positive note, there haven't been any problems with the car's hydrogen or fuel cell components, and no safety issues either. But Daimler's fuel cell model is not a car that could replace his company vehicle. Rather, the F-Cell is used as an additional means of transportation, incurring additional costs. Pretty disillusioned, Wenger sums up his experiences as follows: "If I haven't found any reason to buy such a car after one-and-a-half years, I have to say: I'm probably the 'too-early adopter.'"

Still, Wenger hasn't given up hope: He is calling on the fuel cell industry's stakeholders to try and pay much closer attention to customer needs, as it is the customer who ultimately decides whether to buy the car: "Please, change your focus: The research is done! Solve the challenges that I have mentioned and that greatly influence customer satisfaction (like defective card readers). There are people out there who are paying for what you designed!"

Wenger knows all too well that his criticism may look like one petty complaint after another, but in the end, he said, the motto should be: It's all about the customer and he or she is always right. He knows full well that one technology has been constantly enhanced over the last 120 years, whereas the other hasn't even really reached the markets yet, which means that any comparison may be flawed. However, Wenger said, these kinds of deliberations are ultimately irrelevant to customers because they simply demand adequate performance in exchange for a reasonable sum of money.

Constructive criticism

Wenger is CEO of Wenger Engineering. He is a candid talker, even though he knows that he may ruffle some people's feathers.

"At the World of Energy Solutions 2015 in Stuttgart, I had the opportunity to give a presentation on my experiences as a paying (!) customer. And I provided the H_2 community with honest feedback about what still needs to be done. The response

was astounding, in a positive and negative sense. After the event, I sent out my presentation to certain industry stakeholders. The first person to reply was the head of hydrogen development at Toyota, Katsuhiko Hirose (the 'father of the Prius'). He really liked my frank, but constructive criticism. He's also a great visionary and knows that the path from prototype to mainstream product is a long one.

Images: Wenger Engineering

There were some negative responses, however. People criticized me for not saying everything was just hunky-dory. I can live with that. People who know me also know: I strongly believe in renewable energies – I believe in clean fuels."

La Grande Nation Hangs On To Nuclear Power

Comment on the Current Situation in France

Global Market

In the 1960s and 1970s, France's industry and research departments used to be very proactive in fuel cell development. Then, 1974 came to pass and with it the slogan of "all-electric, all-nuclear" (tout-éléctrique, tout-nucléaire). The number of fuel cell projects fell drastically and remained at its low level until about the end of the 1990s. In the meantime, a great many subsidies have gone into nuclear industry developments: Billions were and are being spent through CEA (Commissariat à l'Énergie Atomique) in this field. Ironically, the resuscitation of fuel cell development was also CEA- financed, and this still plays an important role.

France is a country of big corporations and small enterprises – the nation's SMEs hardly come in medium size. This is true for the H_2 and fuel cell industry as well. With the exception of a few companies (e.g., McPhy), many market actors are too small (and sometimes underfunded) to become global players. Pragma Industries, Symbio FCell, Mahytec, Ataway, etc. all have fewer than 50 staff, some even fewer than 10. Larger organizations (Air Liquide, Areva) have severely reduced their activities in the fuel cell market (Axane, Helion). There is usually little exchange between France's universities and the fuel cell industry, something that can be observed in many other French industries too.

Associations like AFHYPAC are comparably active, but they have little influence over whether or not to commercialize pilot projects. Ambitious national or European programs have little or no chance to create a sustainable dynamism after they run out.

One of the reasons for the current situation is what people in France call "colbertisme" (Colbert was finance and economy minister under Ludwig XIV., and he was the first to promote the national industry with support from and under the control of the king). It describes a way of thinking that is still common among France's political class today: La Grande Nation only takes note of large corporations, where the government can exert influence (EDF, Areva, Alstom, etc.). National programs – for example, Nouvelle France Industrielle by Arnaud Montebourg – have a short lifespan and are altered or halted when the name of the minister at the helm changes.

Missing H_2 and fuel cell infrastructure

At the end of 2015, France had only five hydrogen filling stations in operation (and no public ones at that). The number of H_2 vehicles that are actually driven on public roads is hard to pinpoint, but is not very large (mostly, the Kangoo Z.E. with a fuel cell as the range extender; sells for around EUR 30,000). Neither Renault, nor Peugeot have made any efforts to develop the technology.

Some "regions" have their own program. What course it takes and for how long it remains funded depends on the financial situation and the interest politicians take in it. For example, south-west France had the PHyRENEES 2009 initiative, which was founded with ambitious targets (in 2012, the region should have produced up to 500

Nm^3/h of hydrogen). Unfortunately, no reports about the development of program have surfaced since it ended in 2014. The same has been true for national projects that were subsidized with public money. For example, the government initiated H2E in 2007, but has not updated its website since 2013.

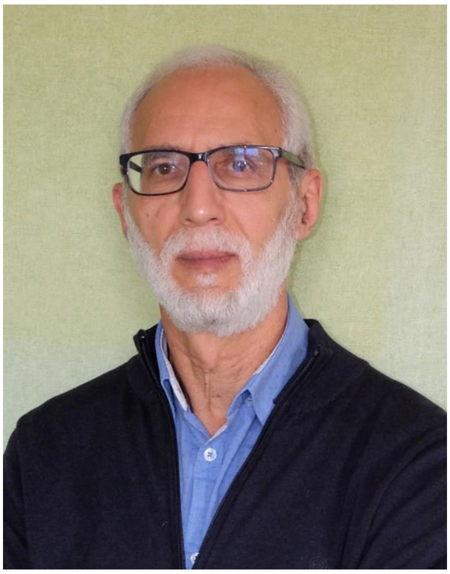
Since 2002, numerous fuel cells were part of a test run in households (CHP), although none of them have been marketed yet. There is one three-system trial, which has been running since 2014.

Regarding power-to-gas, the belief in nuclear power is just too strong and is hardly ever called into question. The only PtG system in France, MYRTE, was installed on Corsica in 2012 and has been running ever since, albeit results were mixed (capacity and efficiency too low, power costs too high). The other projects (GRHYD and Jupiter 1000) will come online at the end of 2017/2018 at the earliest.

Any hope for change?

The government continues to give priority to nuclear power (the dream of exporting EPR reactors is alive and well). A hydrogen economy that could be part of an energy transformation only exists as an idea (report of a France Stratégie in 2014). This means that there is little prospect of a hydrogen fuel cell alternative being developed in France despite some euphoric-sounding news articles. A re-evaluation in three to four years will show what will have become of the programs that are currently running.

Méziane Boudellal is a French national and holds a PhD in physical chemistry. The first edition of his book on hydrogen ("La pile à combustible – Structure – Fonctionnement – Applications") was published in 2007. The cover of the second edition added the subtitle "L'hydrogène et ses applications" (see HZwei issue from April 2012). His next book about power-to-gas will be available on June 1, 2016 – and will also be published under Dunod.



This article complements the report by Alexandra Huss published in the April 2016 issue of H2-international (France's Own Energy Transformation).

Author: Méziane Boudellal

The Invisible Flame

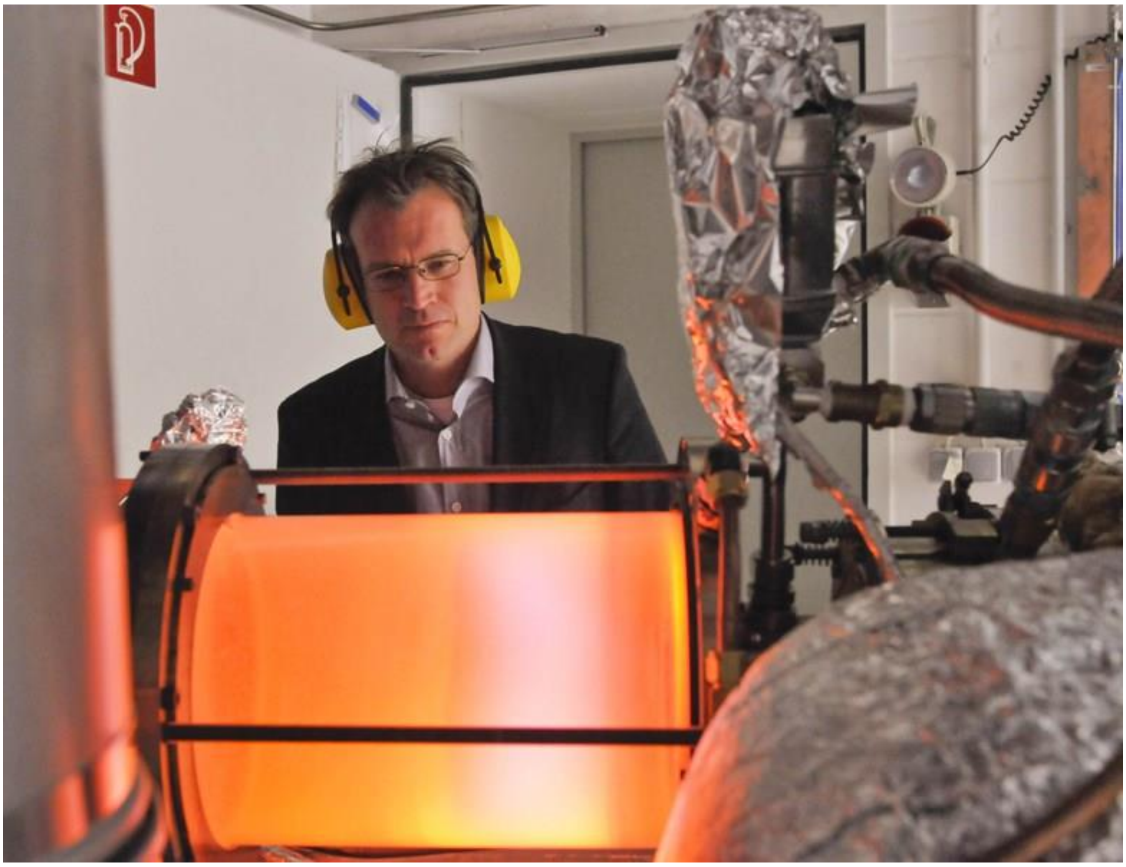
TU Berlin Researches Wet Combustion

Research & Development

The hope for future power plants has a name: BlueStep. A prototype at the Technical University of Berlin burns hydrogen and oxygen with the help of wet air – or, in other words, with the help of wet steam. The project's predecessor, Greenest, which was launched with the same intention of advancing the development of low-emission plants, also injected steam into the combustor of a gas turbine. This so-called "wet combustion" can increase gas turbine efficiency by up to 15 percent, not to mention that the renewably produced hydrogen will severely cut plant emissions.

Panagiotis Stathopoulos is developing the future of the gas turbine. He is project leader of BlueStep and Greenest at TU Berlin's Institute of Fluid Mechanics. A very narrow and steep staircase leads up to the fourth floor. When arriving at his office, visitors are rewarded with warm sunlight entering through the big windows. Here, Stathopoulos is working meticulously on a process that will enable the utilization of excess green power stored in hydrogen inside a gas turbine or steam plant without leaving many traces, many emissions. The project's name stands for: Blue Combustion for the Storage of Green Electrical Power.

Fig. 1: Professor Paschereit at a test stand for "wet combustion"



Source: TU Berlin/Ulrich Dahl oder Niels H. Petersen

“Theoretically, the hydrogen flame is invisible,” Stathopoulos explained during a tour through the laboratories. The researcher born in Athens, Greece, has worked in Berlin for two years after receiving his doctorate from the ETH Zürich. This may explain his slight Swiss accent. In practice, however, the flame would, most of the time, contain other gases besides hydrogen, which would indeed make it visible to the eye, he continued. And the right combination of gases in the mixture is precisely what he has been searching for in collaboration with fellow researchers.

New BlueStep technology

Burning hydrogen with the help of oxygen still presents a technical challenge, as there hasn’t been any material able to withstand the extreme temperatures resulting from the process. The new approach uses steam to dilute the mixture considerably. The steam is available as a byproduct of the combustion inside the turbine at every steam plant. Now, this steam should be recovered and fed back into the steam cycle to increase plant efficiency. To do that, Stathopoulos and his fellow researchers have investigated different strategies and intake quantities.

The inside of a conventional steam turbine has a temperature of 600 °C. Without the additional steam, the combustion temperature may rise to 3,500 °C. The researchers know that based on the Carnot efficiency, higher temperatures equal greater efficiency. But these higher temperatures put much more strain on the materials and metals used as part of the process, especially considering that the typical plant pressure is 300 bar. “Conversely, BlueStep is satisfied with temperatures between 500 and 700 °C and a pressure of 10 bar,” Stathopoulos said.

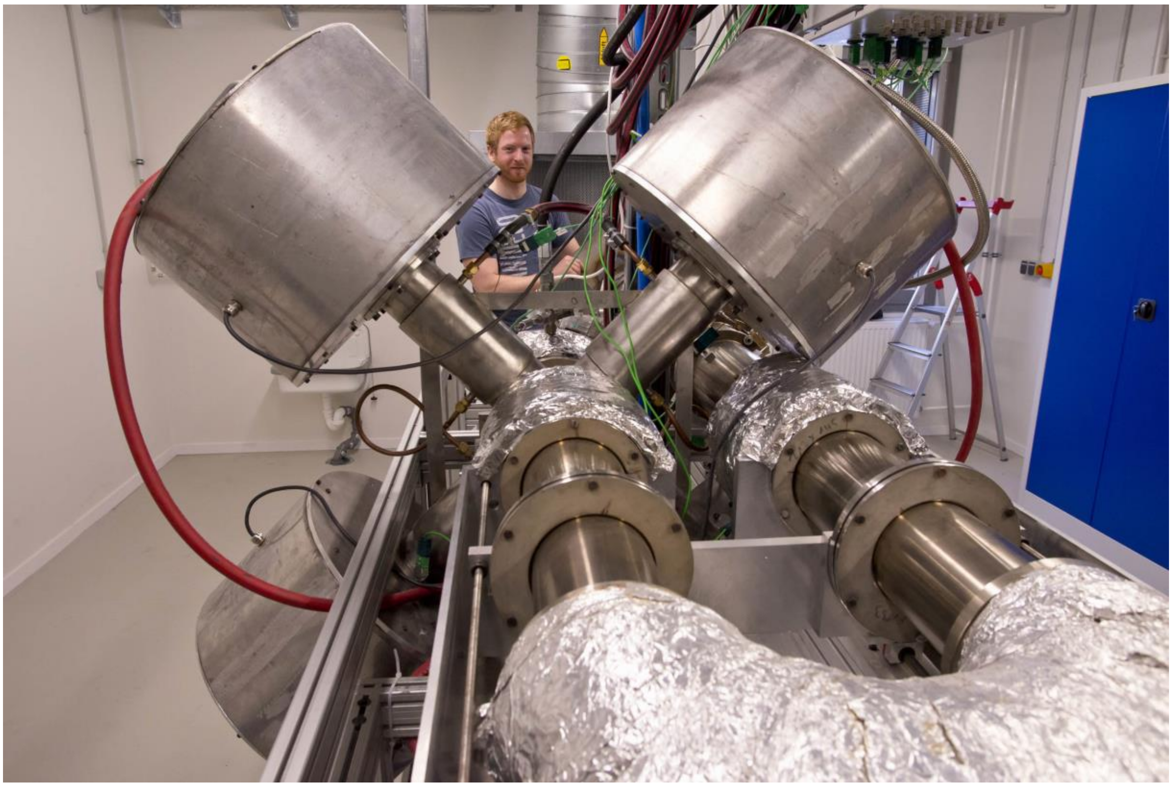
However, to meet the climate change goals set by the German federal government, the gas turbines must finally be adapted to allow for the combustion of biogas or hydrogen. The new BlueStep technology increases the efficiency of a 50 MW gas turbine by about 10 percent, to 45 or 50 percent in total. It is an increase that will be duly noted by gas turbine operators, for whom the process means money saved – particularly because they may think about also retrofitting currently operating gas turbines to up overall efficiency even more.

Despite the positive news on the research front, marketing gas plants remains a difficult task at present. New systems do not accumulate enough operational hours to amortize the initial investment. Consequently, utilities will refrain from putting any resources into retrofitting or upgrading plants, although this would provide the flexibility in plant operation needed for the country’s energy transformation.

Theoretical proof prompts award

The topic has already led to a small success story at TU Berlin. In a doctoral thesis from 2008, the currently tested procedure had been proven to work in theory. Additionally, it sparked the industry’s curiosity, evidenced by the RWE Future Award that the author of said thesis received. Later, researchers confirmed during trial runs that steam can be added to the combustion process without quenching the flame. Emissions went down considerably. These findings marked a milestone in gas turbine usage. To this day, plant builders have continued their search for an efficient and economically feasible method to reduce or retain CO_2 emissions from coal plants. Until mid-2014, two of the big energy providers – RWE and Vattenfall – had mostly relied on CCS to release, liquefy, press and store carbon dioxide in a time-consuming process, before abandoning the technology when it became clear that acceptance of it didn't grow. (Thus, new options are needed.)

Fig. 2: Sebastian Niether in the energy lab of TU Berlin



Source: TU Berlin/Ulrich Dahl

Only one year later, the European Research Council (ERC) awarded the idea-turned-project Greenest with the ERC Advanced Grant 2009, a well-respected title presented to only around nine percent of all submitted applications. The prize was endowed with EUR 3.2 million, which went to the faculty of professor Christian Oliver Paschereit. These newly gained research funds were used by the professor's working group to set up a new prototype of a gas turbine combustor within six years. The project will officially end this summer.

The technological frontiers, which researchers are trying to expand all around the globe in order to make gas turbines more efficient, range from complex cooling systems to materials research. Today's commercially available gas turbines are also not capable of burning hydrogen-rich fuels made from biomass or coal gasification without leaving trace emissions. High nitric oxide concentrations continue to offset environmental benefits – something that the researchers at the TU intend to change.

More steam to the rescue

Greenest stands for "Gas Turbine Combustion with Reduced Emissions Employing Extreme Steam Injection." The name describes the effective, low-emission feed-in of steam into the combustion process. It is a known method, but a rarely used one, as the flame must not go out despite the added hydrogen. "Measured against the air volume in gas turbines, the typical steam share is ten percent or lower," Stathopoulos explained.

The new TU technology provides a workaround for some difficulties of conventional gas turbines: The Greenest process of “ultra-wet combustion” enables a higher steam content. The large heat capacity of the steam can increase gas turbine efficiency without requiring greater combustion temperatures. Additionally, the steam could be used to cool the turbine.

Raising the steam share required a steam cycle considerably larger and more complex than the one found in gas and steam plants nowadays. “Ultra-wet combustion combines both processes inside one machine, which is easier to build and operate,” the researcher said, visibly pleased. This will increase turbine efficiency by up to 15 percent and save considerable resources. The steam also has a positive side effect: It suppresses the creation of nitric oxides.

Conventional gas turbines use only about half the compressed air for combustion, since emissions would otherwise go through the roof. In contrast, the new gas turbine developed at the TU utilizes almost all of the air available. This will not only improve efficiency, but also facilitate the storage of CO_2. The tests at the institute have been the first to prove not only in theory that the flame remains stable during the combustion process.

Combine with electrolysis-generated hydrogen

BlueStep goes beyond even that: The TU researchers have also demonstrated Greenest‘s wet combustion for storing power generated by renewable sources. Excess electricity splits water into oxygen and hydrogen through electrolysis. In turn, the H_2 gas could be burned efficiently inside the turbine by adding steam. The European Union is promoting the market-related ERC project with its Proof of Concept program. The 18-month test has been running since March 2015 and has netted the TU another EUR 150,000.

Despite the continuing success story, there was more work to be done by the research team, Stathopoulos said. On the one hand, there were relatively strict purity regulations in place for steam in steam-electric plants. “The process must leave almost no residual gases, so as to avoid impacting the materials of the steam turbine and the capacitor,” he explained. Compared to a typical burner, the gas must also not be burned entirely. The aim: “At the end of the project, the correct ratio to inject hydrogen and oxygen must have been found.”

However, there has been no decision on what follows or who continues the work of BlueStep. There were plans, Stathopoulos said. The aim was to set up a small plant either alone or together with a partner company. Because of their fast start-up, gas plants could meet the requirements for primary operating reserves without any problems. The current version could turn into an important prototype.

Energy lab of TU Berlin

The laboratory building was inaugurated in late fall of 2013 at the Faculty of Experimental Fluid Mechanics. The grey, massive complex was put on five decoupled foundations to lessen the impact of vibrations transmitted through the ground. On an area measuring altogether 125 m², there are four labs, which contain four combustion test stands. The automation of the test stand‘s technology alone required close to ten kilometers of measurement and control wires, which all lead into one datacenter.

Within the laboratory building, there are two test stands for thermoacoustics. They are used to study vibrations during combustion – so-called thermoacoustic instabilities – which can lead to an increase in pollutants inside the gas turbine or even destroy the combustor.

The total combustion capacity of all laboratories amounts to around one megawatt. The electrical energy generated by the micro-size gas turbine is fed into the university grid and supplies parts of the campus.

Author: Niels Hendrik Petersen

Quantity Metering of "Regenerative Gases" and the Need for Official Calibration

Hydrogen for the Energy Industry

Research & Development

"Regenerative fuel gases" like hydrogen generated through electrolyte processes constitute new product offerings in transport and trade. They create new material and energy flows and alter the product portfolio of the energy industry. Both materials and energy are traded and distributed. In Germany, these transactions require metering devices that have undergone official calibration, in order to allow for accounting and billing.

Two-hundred years of experience with hydrogen- and methane-rich fuel gases suggest that the energy industry's proven metering technologies will be adapted to suit quantity meters that require official calibration and measure "regenerative gases" (especially, hydrogen). But despite numerous past experiences with hydrogen as the major content of fuel gases, there are some new framework conditions to consider: One of them is that today's gas infrastructures are operated at much higher pressures than they used to be – in natural gas grids with up to 100 bar of gauge pressure.

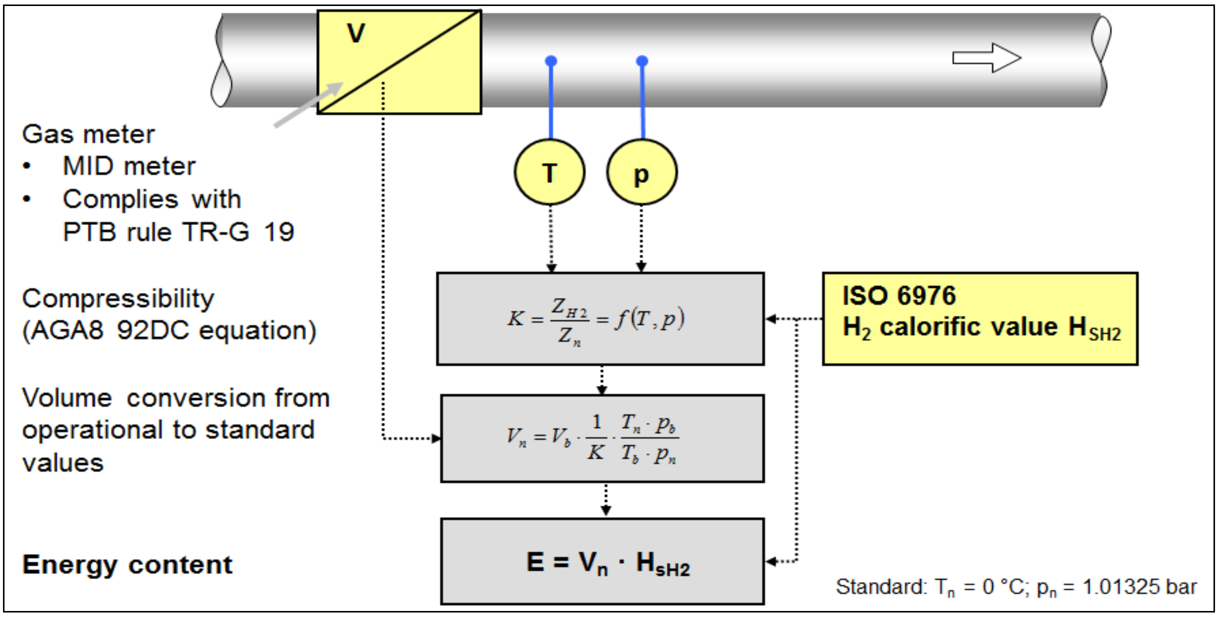
Metering systems to satisfy calibration requirements

A system that requires official calibration for metering gas with amounts of H_2 could consist of as little as a single gas meter which complies with PTB rule TR-G 19 "Gas meters" [1]. In principle, it would be possible to use approved natural gas meters based on any kind of technology, as long as the content of hydrogen was $XH_2 \leq 5$ %. If the share is higher but below or equal 10 %, the manufacturer needs to provide an additional certificate stating that the device is fit for purpose.

Values above 10 % require a certificate of non-objection by the German National Metrology Institute (PTB). The appropriate meters for pure hydrogen would be Coriolis type if they are designed for the relevant pressure range. The PTB allows the use of rotary piston meters, provided that the manufacturer declares them suitable for the task.

The approval of commercially available natural gas meters for H_2 metering that requires official calibration enables said calibration and the inspection of these meters on known PTB-approved test stands. This will eliminate the need for official hydrogen inspection devices.

Fig. 1: Converting the volume and assessing the energy content of the H_2 flow (by means requiring official calibration)



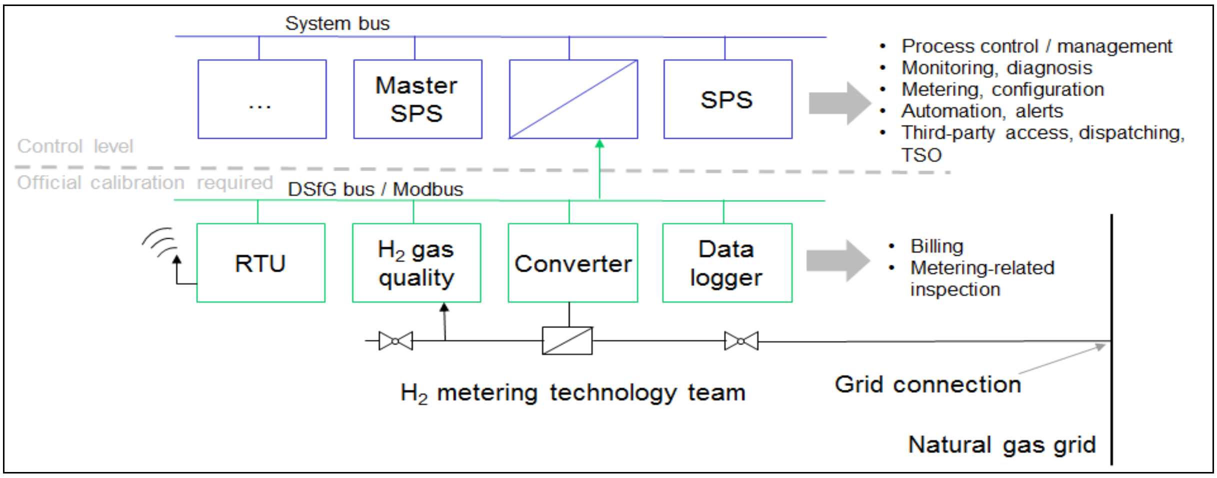
Source: P. Schley, E.ON [2]

The aforementioned types of gas meters are subject to the EC Measuring Instruments Directive (MID). The manufacturers guarantee compliance of the device with metering-relevant minimum requirements based on state-of-the-art technology, harmonized EN norms, type examination certificate and certified production monitoring. Putting gas meters out on the market may also require a test on an official inspection device that has PBT approval. The CE label put on the meter displays conformance with MID, meaning that the gas metering device underwent "initial calibration." Usually, making these devices available on the market also requires compliance with the standards laid out in the Pressure Equipment Directive (PED) and the Equipment and Workplace Directive regulating explosion protection (ATEX).

Volume conversion is done by using commercially available units that meet MID requirements. The AGA8 92DC equation is used to calculate compressibility (DIN EN ISO 12213-2, DVGW worksheet G486 with second addendum, see figure 1). The impact of the hydrogen can be neglected if its share is below 0.2 %. The same is true if the multiplication of gauge pressure (numerical value in bar) and H_2 share (numerical value in percent) is smaller or equal to 15.

TR-G 19 stipulates regular inspections of hydrogen purity by means such as continual sample-taking and analysis in an accredited laboratory. If the gas purity is 99.9 % or above, the calculation of the energy content will be based on the calorific value of the hydrogen as stated in ISO 6976. Any lower hydrogen content is to be measured continuously and the content metering will be based on the calorific value found at the ISO 6976 material data. The use and selection of devices to measure H_2 shares should be agreed upon with the public authority that performs the calibration.

Fig. 2: H_2 metering system that legally requires calibration and is connected to the natural gas infrastructure



Control level and metering technology requiring official calibration

PTB 50.7 describes what requirements need to be met regarding electronic equipment that is added to the metering system and requires official calibration. The devices are connected through a local bus (see figure 2). A remote data transfer enables device monitoring, the remote launch of self-calibration routines and feedback-free data readings. The transferred data is primarily used for accounting and billing purposes. Information can also be communicated to the control level and the metering-related inspection team. The latter is part of the company and is used to monitor and maintain the functionality of the measurement devices requiring official calibration.

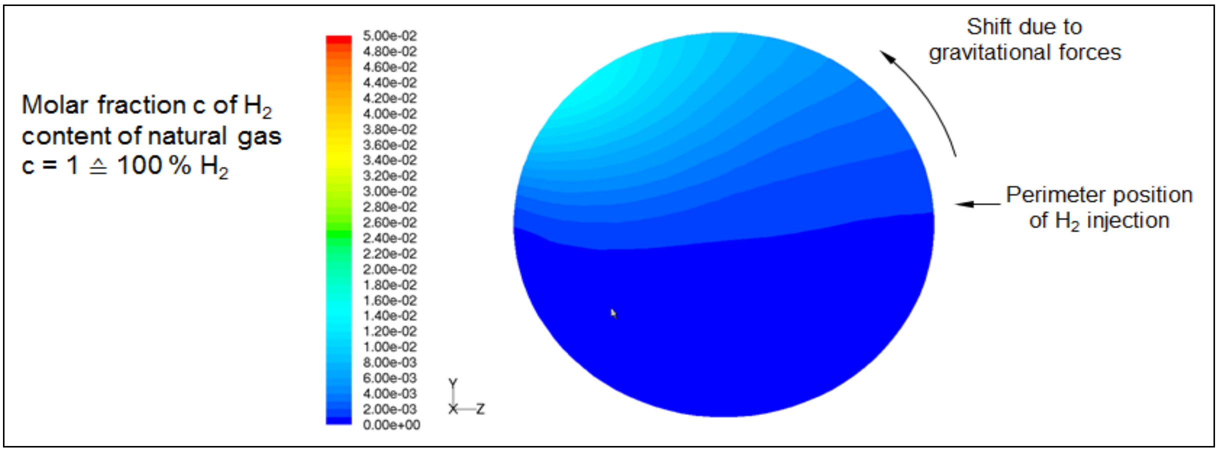
Normally, the control level is separate from the devices requiring official calibration because of their different responsibilities and qualities of data. The tasks of the control level are process-relevant functions, such as set, control, regulate, monitor, diagnose and measure, including display and operating matters. The response to changing situations needs communication in real-time, especially in regard to safety-relevant functions. Billing data will also be captured as soon as possible, although the communication for billing and accounting can be triggered at a later time. This means it will be sufficient to log the volume consumed and time-stamp the stored data to identify the consumption period.

Process-related requirements

Hydrogen metering systems requiring calibration cannot be operated without conforming to process-related regulations. Please note DVGW factsheet G265-3 in case hydrogen is fed into the natural gas infrastructure. This sheet informs about material choices, safety-relevant isolating equipment, gas quality, operational matters and explosion protection. The Energy Industry Act (EnWG) considers feed-in hydrogen that was generated mainly by electrolysis using renewable sources to be biogas for pipe-bound supply of the public. This means that the EnWG and its regulations apply when setting up and operating a system to create and feed hydrogen into gas distribution networks. If it is fed into high-pressure pipelines, the High Pressure Gas Pipeline Ordinance (GasHLV) may be used for generation and feed-in (including metering) instead.

The feed-in of hydrogen into the natural gas grid also requires meeting the minimum technical standards of the gas grid operator in question. Besides the metering technology, the operator may also be interested in how well mixed the hydrogen and the base gas in the pipeline are and what quality the gas within the mixture has.

Fig. 3: Simulated H_2 distribution in a natural gas pipeline 20D after H_2 feed-in (DN 600, 50 bar); H_2 feed-in capacity at 360 Nm³/h



Source: A. Schmücker, Open Grid Europe

Figure 3 shows a mixture of hydrogen and natural gas in a high-pressure pipeline 20D after the feed-in location (20D = 20 x pipeline diameter). Assuming a flow speed inside the pipeline of 3 meters per second, the maximum hydrogen concentration will be 1.5 %. The mixture strongly depends on the speed of the gas flowing inside the pipeline. If flow speed slows down to 0.2 meters per second, a comparable mixture will only be available after 2,500 meters. You may even have to expect a hydrogen layer above the natural gas when close to the feed-in spot. This needs to be considered if there is a consumer of fuel gas within the mixing zone. In general, the calorific value that should be billed needs to be measured at the feed-out locations or by using another kind of method. The suitable option in case of variable multi-vector feed-in within supply grids would be a commercially available calorific value tracking system [3].

Additionally, H_2 enrichment may create non-permitted, non-compliant gas properties, requiring the operator to lower or interrupt the feed-in. There is also the issue of not exceeding upper limits of H_2 supply in parts of the gas grid infrastructure. Systems that prove to be especially limiting are natural gas stations, condensers and storage units. Natural gas stations typically restrict molar H_2 shares in natural gas to 2 %. The other infrastructure systems need to be examined on a case-by-case basis. The most recent metering campaigns of the DVGW about H_2 compatibility of the distribution grid show that end consumer systems do not display notable functionality impediments at H_2 shares of up to and including 10 % [4]. Other studies are being carried out to assess the hydrogen tolerance of underground gas storage [5].

Conclusion

The trade and transportation of regenerative fuel gases like hydrogen in the energy industry have prompted a number of metrological questions. Technical rules have meanwhile begun to state on paper the requirements for metering technology that requires official calibration, in order to give planers tried and proven spec recommendations. Recognized metrological methods from the energy industry were adapted to fit hydrogen metering. A similar approach is being taken in case of carbon dioxide metering that needs to undergo official calibration, hydrogen-enriched natural gas and biomethane [2].

Commercially available (and calibration-ready) metering technology for the assessment of hydrogen and other fuel gas volumes as well as studies on the compatibility of the natural gas infrastructure further the acceptance of hydrogen among the energy industry's stakeholders. The technological solutions developed so far have played a crucial part in raising the economic potential of regenerative gases.

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High-Throughput Method to Develop Alkaline Fuel Cells

NEMEZU – New Non-Precious Metal Membrane Electrode Units for Future Use in Fuel Cells

Research & Development

The NEMEZU project launched at the beginning of 2016 is expected to develop high-throughput methods to screen new types of material combinations quickly but close to a real-life fuel cell environment. This project is planned to map the entire supply chain involved in producing alkaline fuel cells – from electrolyte materials and the manufacturing of electrocatalysts in nanoparticle size to the production of a membrane electrode unit and the integration of the components into an individual cell.

The path toward clean energy supply without the need for fossil fuels requires energy conversion systems that produce no CO_2 emissions and operate at great efficiency. Additionally, electricity produced by renewable sources must be stored intermittently in form of chemical energy to counter the high volatility associated with them. Fuel cells and electrolysis systems are regarded as key technologies to do just that.

The availability of the polymer electrolyte membrane Nafion® strongly favored the development of acid PEM fuel cells and their corresponding catalyst systems. But despite considerable progress, the use of catalysts made from precious metals remains essential to manufacturing these cells, and corrosion (e.g. at the carbon carrier material) leads to limited lifetime.

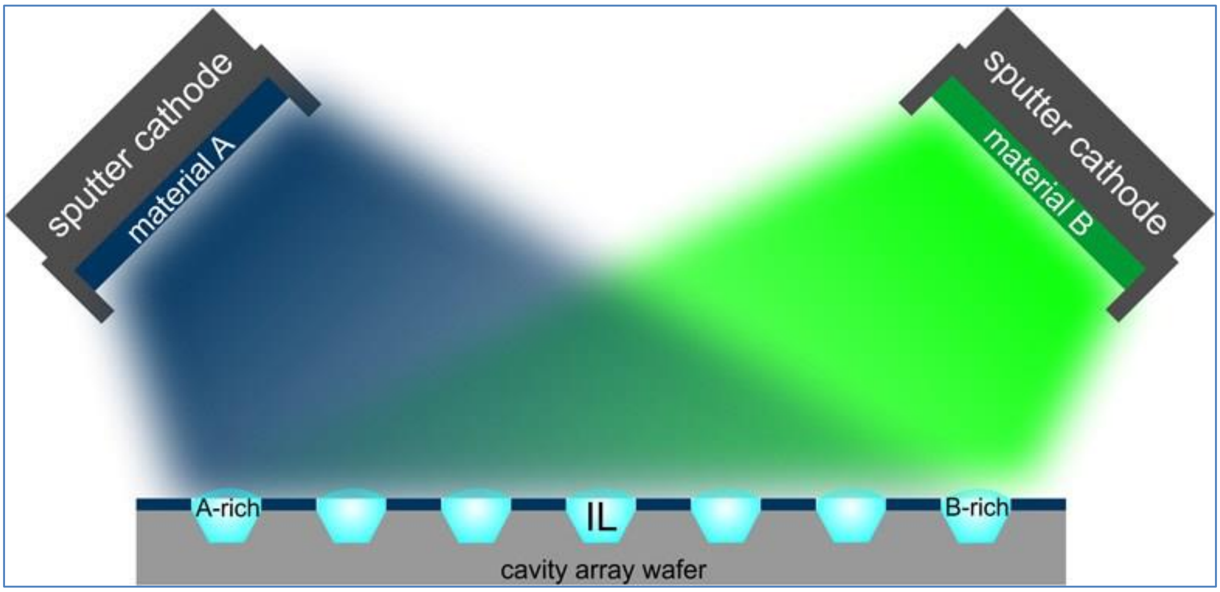
Benefit of alkaline fuel cells

Conversely, alkaline fuel cells present manufacturers with the tremendous opportunity to initiate the reaction by using catalysts made from non-precious metals, such as cobalt, nickel or manganese as well as their alloys. The greater availability of these materials compared to precious metals facilitates the ecological use of fuel cells and allows for great cost savings. To tap into the extensive technological and economic potential, the researchers participating in the NEMEZU project, which has the backing of the German Federal Ministry of Education and Research, intend to develop new types of catalyst systems for alkaline fuel cells based on the aforementioned metals in nanoparticle size. The spotlight is on the cathode, as it shows high overvoltage because of the complex four-electron transfer, which limits the entire reaction.

Developing materials libraries

To adequately cover the large number of possible variations during catalyst development, the project should design a high-throughput process that enables screening as fast and close to real-life systems as possible. Over the next years, the Fuel Cell Research Center (ZBT), the universities in Bochum and Duisburg-Essen, the Institute for Microelectronics in Stuttgart and the EWE Research Center Next Energy from Oldenburg intend to employ the redeveloped methods of combinatorial materials exploration in order to create libraries on materials that will be measured and analyzed at the same time.

Fig. 1: Schema of the combinatorial co-sputtering of two elements on a carrier filled with ionic liquid



Source: Ruhr-Universität Bochum, WdM

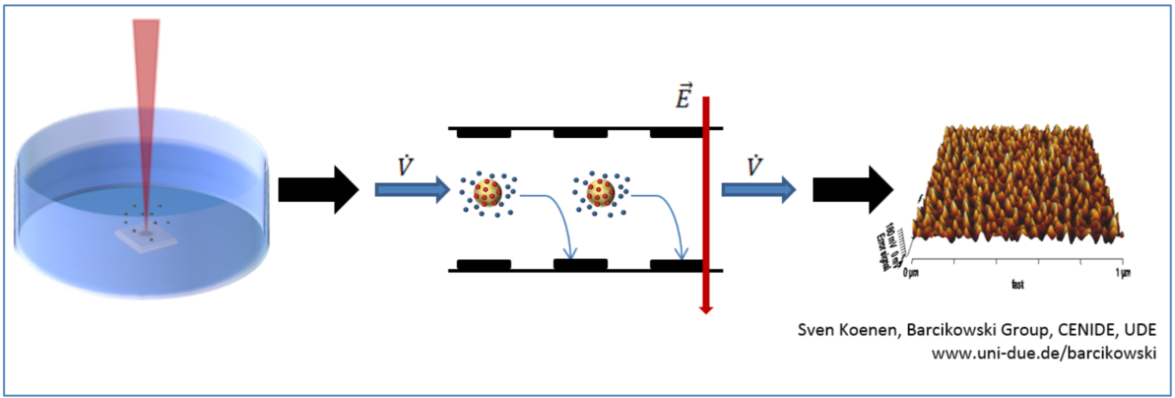
Especially the combinatorial creation of catalytically active nanoparticle libraries through co-sputtering in ionic liquids is the innovative research approach with which the large number of material combinations in nanoparticle size can be tested for general suitability as catalysts.

The combinatorial sputtering design makes it possible to synthesize binary and ternary alloy particles besides the monometallic ones while the chemical composition can be defined in detail. The separation of the nanoparticles into an ionic liquid is performed on a gold-plated carrier sample with indentations. Consequently, a library of nanoparticle materials would consist of particles in different compositions, depending on the distance to the targets.

The sputter targets of the individual elements are located opposite to each other and have a 72° rotation relative to the sample carrier. Their placement allows for the creation of an almost linear concentration gradient, which is mirrored in the chemical composition of the created nanoparticles (see figure 1).

After successfully identifying particularly powerful material combinations, laser ablation is used to produce the nanoparticles in larger quantities within liquids (see figure 2). These nanoparticles will be separated for screening by means of dielectrophoresis. The innovative manufacturing process, which makes it possible to produce greater quantities of the kind of material in question, has already been marketed by affiliated industry partner Particular in case of other metal nanoparticles.

Fig. 2: Laser ablation of a substrate within a liquid (left); electrodeposition of the produced nanoparticles on a carrier (middle); AFM view of nanoparticles evenly distributed on a plated surface (right)

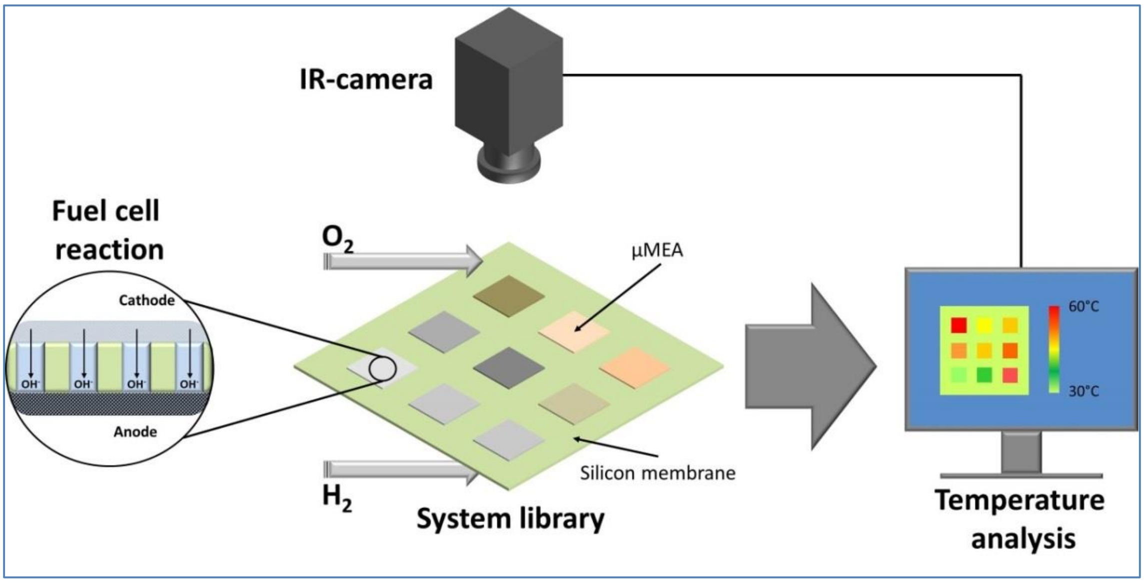


Source: Universität Duisburg-Essen, TC1

In situ high-throughput screening

From the alloy catalyst nanoparticles produced by the aforementioned, individual sample systems – which now mirror the entire three-stage threshold – will be used and subsequently put, together with alkaline electrolytes and a graphitic conductor, in extremely small volumes onto thin microstructure carrier membranes made of silicon nitride. The use of microstructure membranes in combination with a functional conductive layer eliminates the need for an electrically conductive gas diffusion one. This will grant researchers optical access to the fuel cell membrane and, consequently, to the reaction itself. The fuel cell reaction can then be analyzed by means of IR thermography in situ. Figure 3 shows an example of a conventional PEM fuel cell membrane and the relationship between heat and polarization curves. The high-throughput approach that was put forth is novel in that it allows for testing complete micro-membrane electrode assemblies (µMEA) in situ.

Fig. 3: Working principle of analyzing micro-membrane electrode assemblies (µMEAs) through IR thermography: The heat produced by the fuel cell reaction is captured and analyzed with the help of an infrared camera. By comparing the samples, researchers can determine the capacity of µMEAs.



Source: Zentrum für BrennstoffzellenTechnik

After successfully analyzing and identifying new, powerful material combinations, the project members are planning to perform thorough measurements of these combinations and validate the development methods. It will be the task of Next Energy to assemble different MEAs with the newly developed powerful electrocatalysts as well as to set up a test cell with which to determine the size of the MEAs on the test stand available. FuMa-Tech will be the supplier of electrolyte materials.

The first step should be a comparison to conventional alkaline MEAs, in order to document the opportunities for improvement created by the innovative material combinations. Different gas diffusion layers and electrode compositions will be investigated by analyzing the MEAs through current-voltage curves under different conditions, in order to guarantee optimal connections between the individual components. The operation parameters, such as gas flows, temperatures and relative humidity, will be adapted to match the newly developed MEAs and to achieve a perfect reaction and transfer.

Highly promising market opportunities

The combination of high-throughput processes based on one another should be used as part of the NEMEZU project to identify powerful MEAs for alkaline fuel cells. This will mirror the value chain in its entirety, from catalyst and membrane manufacturing to membrane electrode assemblies aligned with one another to the integration of individual fuel cells. The early involvement of producers of industrial catalysts and membranes in on-going developments will enable an implementation of the project results in the industry in a timely manner.

Alkaline fuel cells offer enormous cost-reduction potential, as they require neither catalysts made from expensive precious metals, nor pricy polymer electrolytes. Since the other components (e.g., H_2 tank, pumps, sensors, etc.) can be the same as in PEM fuel cell manufacturing, the opportunity arises to develop a fuel cell system which is not only technologically superior to prior acid fuel cells, but which is also economically viable enough to be established as a mass-market product.

Alkaline fuel cell workshop

This year is the fourth during which Next Energy will organize a workshop primarily dealing with alkaline fuel cells. In cooperation with the Korea Institute of Science and Technology (KIST, South Korea) and the Jagiellonian University (Poland), international experts from industry and research were invited to attend the Workshop on Ion Exchange Membranes for Energy Applications – EMEA 2016 in Bad Zwischenahn, Lower Saxony, from June 27 to 29, 2016. But this year will also be the first in which there will be a peer-reviewed special edition of the Journal of Electrochemical Energy Conversion and Storage (JEECS) entitled “Anion Exchange Membranes and AEM Based Systems.”

www.next-energy.de/emea2016.html

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New CPN Deputy Spokesperson

News

*Source: Deutsche Bahn*

The members of industry network Clean Power Net (CPN) have elected a new deputy spokesperson during this year's annual assembly in Berlin. Whereas Henrik Colell, CTO of Heliocentris Energy Solutions, was confirmed as the spokesman for the fifth year in a row, the members voted for a "new face" when it came to the deputy position: Frank Luckau is senior construction manager EEA North/East at DB Bahnbau Gruppe, which was recently admitted as the twentieth member of the CPN. Before Luckau, the position as deputy spokesperson had been held for several years by Karsten Menzel from E-Plus (see HZwei interview from October 2012). Wolfgang Axthammer, CFO/COO of NOW and CPN project manager, explained: "Typically, the deputy spokesperson comes from the user side, while the spokesperson is suggested by the manufacturers." Telefónica's takeover of E-Plus meant that Sebastian Goldner from Proton Motor temporarily assumed Menzel's position in 2015.

Wind Energy Storage in the North East

Notes by H. Sandlaß and J. Lehmann

Energy Storage

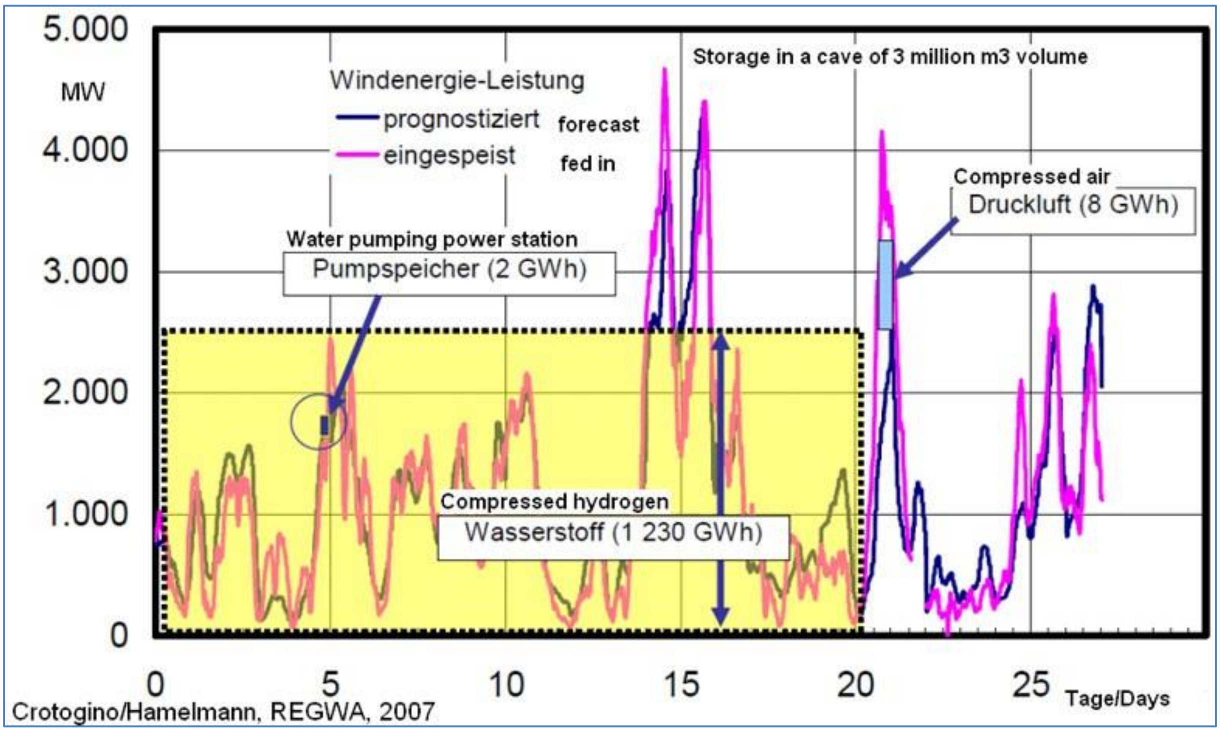
The 2014 version of the Renewable Energy Sources Act (EEG) allows operators in case of a grid overload to "reduce the feed-in" of green power, but with the obligation to log the incident. The ones who pay for it are the utility customers because the owners of wind farms receive their usual feed-in payment – even if the network operator takes the park off the grid. Use of the permission is

rampant: It regularly hits close to 20 wind farms with a capacity of more than 20 MW each in Mecklenburg-Western Pomerania (MV) alone [1].

The events to stabilize the grid are unfolding pretty dramatically: Whereas in 2014, EUR 128 million were spent on shutting down and restarting wind energy systems, the figure jumped to EUR 329 million last year. Conventional power plants needed EUR 74 million in 2014 for the same procedure, whereas the amount had shot up to EUR 225 million in 2015. Additionally, the costs for calling off grid reserves increased from EUR 92 million in 2014 to EUR 152 million last year. [2]

It can be assumed that in many cases, the shutdown period was longer than required by the state of the grid, since the restart of a wind park can sometimes be quite time-consuming. Apparently, the principal reason for the stated shutdowns was that strong winds overloaded the relevant 110 kV lines and electrical substations when power was transferred from the 110 kV distribution network to the 380 kV one. This shows that the lines still have not been adapted to the output of wind farms set up at the beginning of the 1990s, which results in conventional power plants contributing more than is needed to electricity supply during those periods, and the opportunity to reduce CO_2 emissions is wasted.

Fig. 1: Total amount of wind power generated, including deviations from the 24-hour forecast during a sample month in the north-east (2007), in comparison to demand [4]



Where is the electrical energy storage?

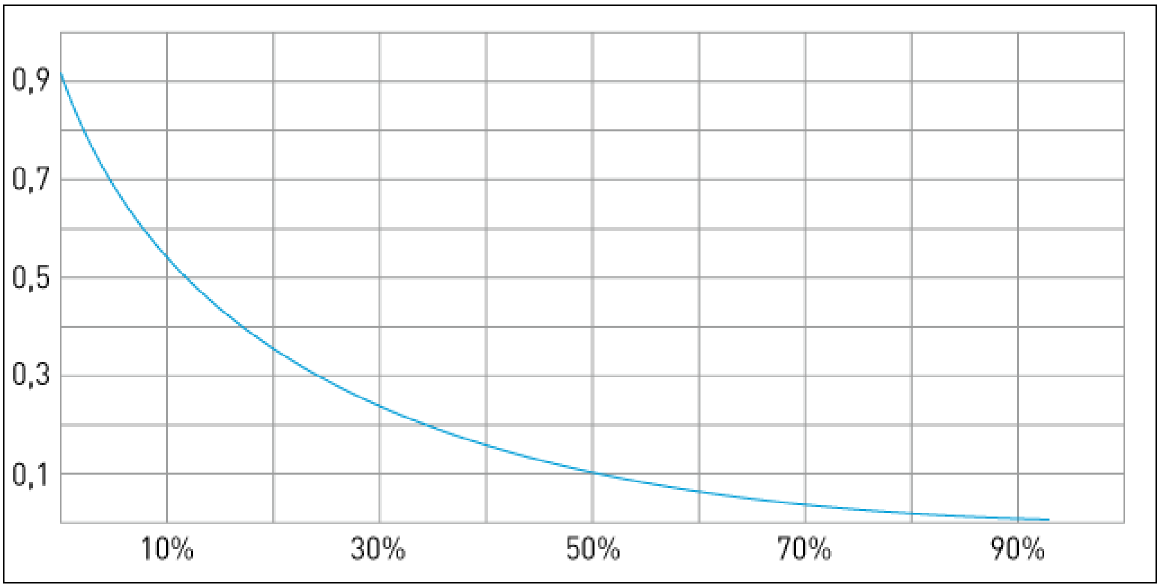
Usually, power generation is reduced whenever demand goes down. This reduction would still be necessary in the future, even if the transmission network was designed to cover all kinds of loads. Additionally, the enhanced electricity highway itself would not be of any use if – for example, in the early morning hours on Whit Monday – almost no-one is working in industry and trade and private customers are hardly consuming any energy, but heavy winds resulted in power-generating turbines to run at full speed. Any type of heat system could be operated below the Q-point (at low efficiency and high wear), but it is easier to the shut down the affected renewable systems.

Grid expansion alone will therefore not prevent the shutdown of wind and solar systems. But these systems should be incorporated into an energy supply system at an early stage: According to current targets, wind and solar power account for a growing share of grid energy and their volatility will require storage units anyway. It is the only way to guarantee the best possible utilization of the installed technology, although it would also mean that the green sector at least shared responsibility for providing operating reserves [3].

It has been proven that – in contrast to pumped and compressed air energy storage – hydrogen is the perfect choice to store huge amounts of electricity (see figure 1). For example, H_2 could offer the opportunity of seasonal storage. It also could be used to establish national energy reserves of electricity and fuel if storage is moved to underground caverns.

However, one question that has so far not been answered is how to design the electrolysis systems needed for the process: Assuming all of the wind power generated should be stored in the form of hydrogen, a typical wind load curve (figure 2) shows that the relatively few hours of strong winds would leave an accordingly sized electrolysis system with little demand for its full capacity. The situation would be a similar one if only excess power was used for electrolysis. Our recommendation [5] is to utilize only a percentage of the wind power not needed right away (figure 3).

Fig. 2: Typical annual power curve of wind turbines (Power over Time)



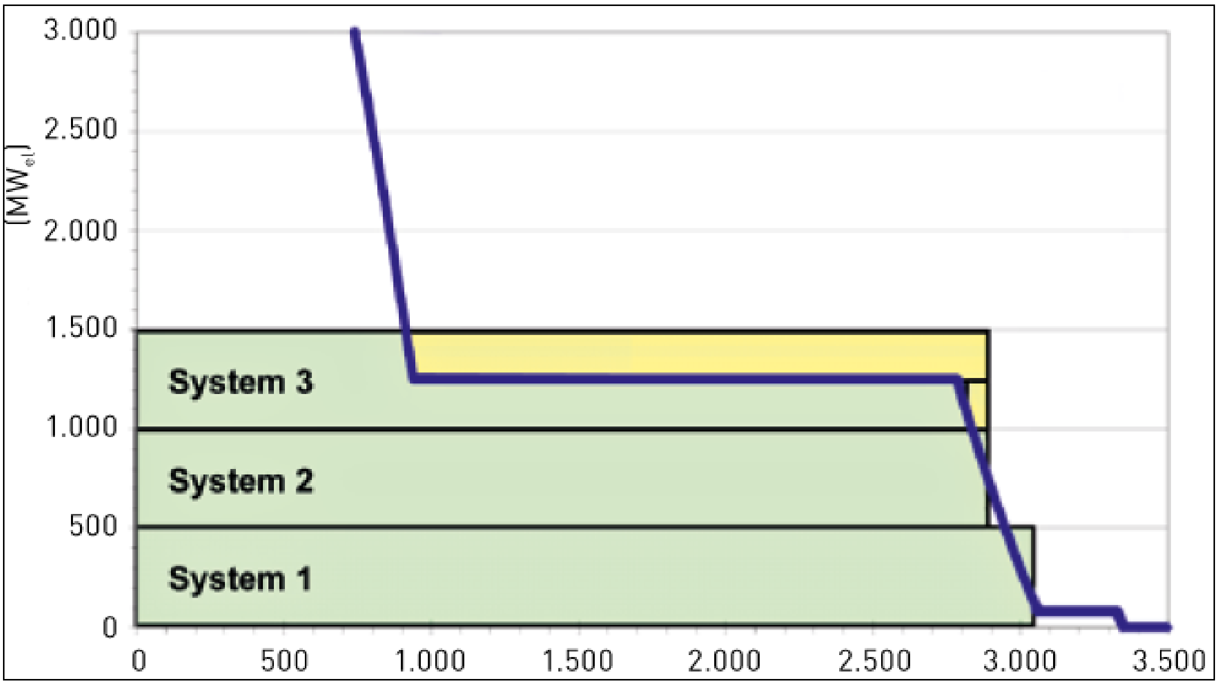
Converting back electricity stored as hydrogen would provide a boost in operating reserves, whereas a deficit would occur if electrolysis was used less extensively. All in all, the focus should be on producing more hydrogen than required to stabilize the grid over short periods. In contrast to conventional power plants, hydrogen storage systems will be able to offer a second product besides power for operating reserves: Green hydrogen as fuel for the transportation sector or as a basic component in the chemical industry.

This green hydrogen could be transported by trailer at acceptable cost to H_2 filling stations in a 300 kilometer radius, the aforementioned study said. Basically, this one hydrogen storage plant could supply filling stations all across MV. The use of synergies and compensatory pricing could additionally lower the price for green operating reserves.

Expand wind-hydrogen storage

One customer group readily available to use the hydrogen are owners of fuel cell vehicle. Two Asian manufacturers also produce for the German market, and local automotive factories have said that they had market-ready models available. However, the number of refueling stations is growing at a somewhat slow rate: Whereas some German metropolitan areas now have the necessary 700 bar filling stations or are scheduling their installation, the outlook for the rural regions north-east of Berlin and Hamburg is rather gloomy. So far, there have only been plans to install stations in Neuruppin and Rostock. The gap in supply present in the other areas could be overcome by partial refueling at 300 bar for around a third of the usual range, as had been demonstrated during the 22nd Stralsund Energy Symposium at the end of 2015. The exact same type of public filling station has been available in Barth since 2003.

Fig. 3: One-year duration curve of excess energy in the north-east region, including use of that energy by three systems (e.g., 3,052 hours per year for 500 MW of electrolysis) [5]



There may also be new impetus from the soon-to-be-expected introduction of more fuel cell vehicles to the market, as the manipulation of emission values has shown that the legally required reductions are practically out of reach at this point. Seen in that light, it seems almost embarrassing to hear the recommendation by the California Air Resources Board to dismiss the punitive damages against VW in favor of having the company put the money into the development of engines consuming renewables.

Meanwhile, there is a growing need to find other consumers of green hydrogen besides the transportation sector. The initiative “performing energy” – a working group within the DWV – suggested that the hydrogen needed in refineries be produced by eco-friendly electrolysis using renewable sources instead of natural gas. One economic incentive could be the technology’s guaranteed compliance with EU requirements to reduce greenhouse gases. It would become the first business case for green hydrogen.

These deliberations lead us to conclude that organizations in north-east Germany also need to find new consumers of green hydrogen to avoid imposing limitations on the furtherance of wind energy generation. A sufficiently large storage space would be the prerequisite for utilizing wind energy and enable an increasingly greater added value.

Wind-hydrogen projects in the north-east

So far, MV has had in place only one pilot plant for wind power generation at a single location, in order to test hydrogen electricity storage and provide relief to the grid: In 2013, WIND-projekt brought online a 1 MW electrolysis system in Grapzow. The hydrogen it creates is mainly used for self-consumption. In the state of Brandenburg, Enertrag was contracted in 2011 to set up and operate a hybrid power plant that stores green hydrogen, supplies it for operational reserves or in the form of fuel, and can also feed it into the natural gas network. Additionally, E.ON has been operating a power-to-gas plant near Falkenhagen since 2013 (2 MW of electrolysis capacity). There, the hydrogen is fed exclusively into the natural gas grid and can no longer be used for stationary or mobile low-temperature fuel cells – which means no green hydrogen for fuel cell electric vehicles.

Right now, national and EU laws are still presenting some challenges to successful implementation. For example, whereas they consider biogas and ethanol to be green fuels, green hydrogen does not share the same privilege. It is simply not allowed to convert green hydrogen back into electricity and sell it as operating reserves or market hydrogen as green fuel. And it typically takes a long time before changes to any legislation come into effect. The only choice at the moment is to launch convincing demonstration projects and fast-track innovation through real-life experiences.

Conclusion

We see it as a political responsibility of the government and local authorities in Mecklenburg-Vorpommern to assume a more active role in this field and support the state in its deserved pioneering efforts by offering subsidy programs. Together with the neighboring states (there has already been some collaboration with Brandenburg through MORO), MV could be turned into a European region of newly found strengths. The second offshore wind farm coming into operation off the state’s coast in September 2015 could be used to set up H_2 storage at its feed-in location in Bentwisch. Lubmin, where additional offshore wind power is planned to be fed into the grid, looks like yet another predestined location for such an endeavor because of its superb connection to the natural gas grid. A power-to-gas system at these locations could provide actual relief to the high-voltage transmission lines running south.

It all depends on the state and the federal government’s willingness to grow the wind power industry in the economically underdeveloped north-east into a crisis-proof production area for green electricity and clean fuel way beyond the region's own demand. It certainly would be of considerable benefit to the entire region.

This article summarizes some of the issues discussed during the 22nd Stralsund Energy Symposium. The conference proceedings can be found here:

www.fh-stralsund.de/forschung/institute/ires/veranstaltungen

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No Emissions on Inland Waterway Trips

Electric Transportation Is Not a Carmaker's Privilege

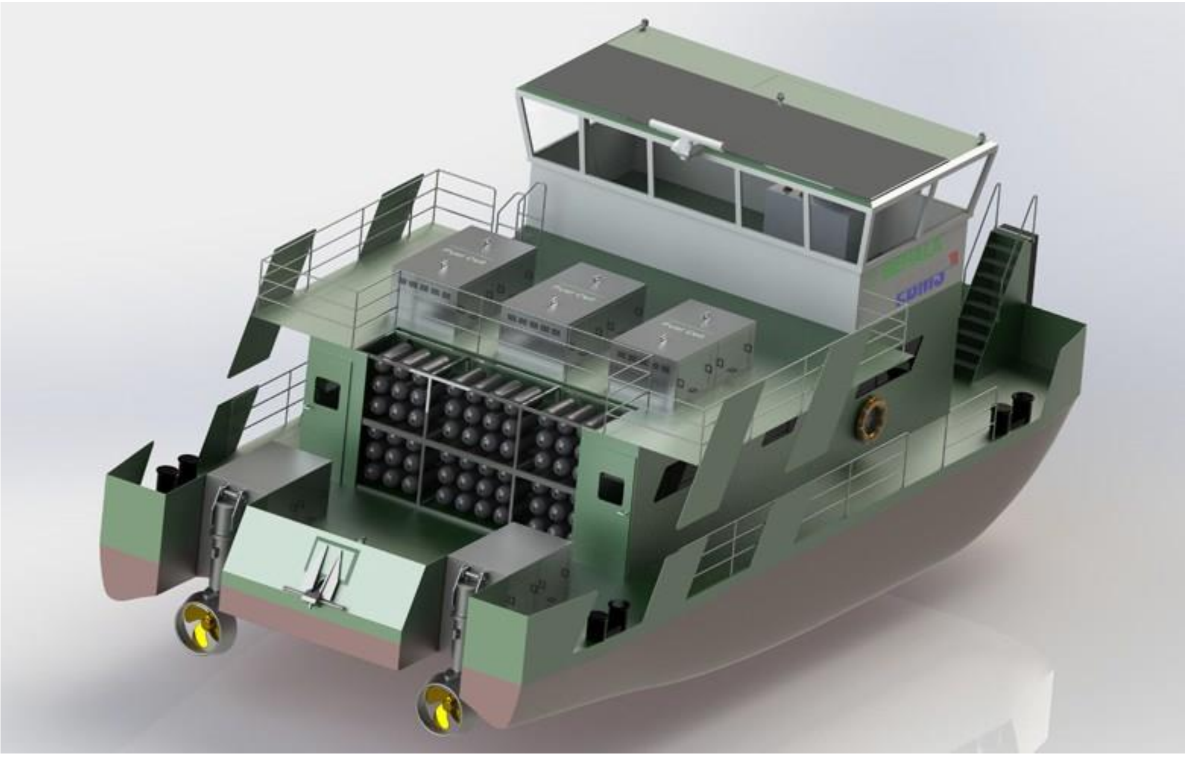
Research & Development

The expansion of renewable energies in the transportation sector requires new types of propulsion and energy supply systems for all means of transport, as environmental hazards can have an impact on a country's population, especially in metropolitan areas. Transportation on inland waterways shows enormous potential for improvement because today's propulsion systems will not be able to comply with upcoming environmental regulations. Fuel cells like the ones used in the maritime demonstration project e4ships/RiverCell/ELEKTRA are proof not only of the technology's ecological benefits compared to conventional cargo ships transporting goods on inland waterways, but also of their ability to compete on the market.

The idea of a fully electric propeller has existed since the end of the 19th century, despite the profound mistrust of rechargeable batteries at that time. Today, professor Gerd Holbach has revived the idea of all-out electric equipment within his department, Design and Operation of Maritime Systems (EBMS) at the Technical University of Berlin. The EBMS designed a towboat that covers basic propulsion and energy demand by batteries and employs a fuel cell to extend the mileage even further. The combination of battery and fuel cell is an innovation in the hybrid energy supply of maritime vessels. In cooperation with Berliner Hafen- und Lagerhausgesellschaft (BEHALA), the planned energy-efficient and hybrid-driven towboat was given the name ELEKTRA (see figure 1).

The ELEKTRA demonstration project is part of RiverCell, which in turn is part of the lighthouse project e4ships within the National Innovation Program for Hydrogen and Fuel Cell Technology (NIP). ELEKTRA has been running since July 1, 2015. The design and planning stage for the fully electric means of inland waterway transportation is said to be completed until the end of 2016, so that construction can start at the beginning of 2017. Commercial operation is scheduled for the end of 2018 in Berlin's Western Harbor.

Fig. 1: CAD draft of towboat ELEKTRA



Task and target

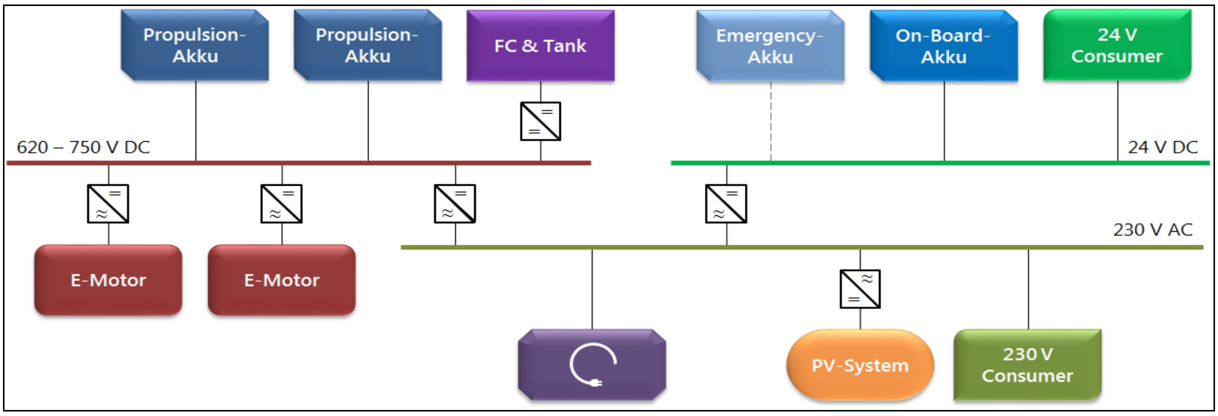
The ELEKTRA that the project participants will design should push the barge URSUS, designed eight years ago by the EBMS department, and numerous project cargoes. One of the most important tasks will be the transportation of Siemens turbines, which have to be shipped from the production site in the center of Berlin to the Western Harbor or to Hamburg. But also scrap metal, coal, gravel and breakbulk of up to 1,200 tons are being transported as part of BEHALA's daily operations in regional shipping. The implementation of this project makes it possible to establish a pioneering example of electric transportation – this time, on water – in Germany. Besides the reduction in fuel and noise emissions, ELEKTRA‘s hybrid energy supply can also contribute to meeting the agreed-upon Kyoto Protocol targets. Internal estimates point to an around 40 % reduction in CO_2 emissions in inland waterway transportation across the Berlin region.

Design and specifications

Creating an operational profile of the ELEKTRA required theoretical calculations as well as real-life measurements from trips on similar vessels. Based on both approaches, BEHALA and EBMS agreed on a regional and cross-regional operation of an inland waterway ship with a maximum size of 16 x 8 meters. Starting at the Western Harbor, the ELEKTRA will travel up to 70 kilometers around Berlin or across Brandenburg on battery-supplied energy alone and at speeds of eight to ten kilometers per hour. A composite of lithium, iron and phosphate is the combination of choice for the propulsion, the onboard and the emergency battery, which have a capacity of 3 MWh each. Located within a steel frame inside the ship's hull, they weigh around 40 tons and come in a module-based design. The Regulations on the Inspection of Inland Waterway Vessels (BinSchUO) stipulate redundancy as well as the separation of supply, which explains why there are two electric motors of 200 kW each supplied by two electrically isolated battery banks.

The propulsion batteries are designed for a daily operation at 600 volts DC. Voltage supply for small and large consumers is provided by the battery onboard at 230 V AC and 24 V DC. In case of an emergency, an additional battery pack will make energy available for thirty minutes (radio, lights). The ship will also have a photovoltaic system installed, which will primarily be used to recharge the emergency battery when it goes below a certain voltage level. The remaining PV energy will be distributed in a given sequence to other consumers.

Fig. 2: Source and sink topology, including the corresponding voltage levels



Because of limited hull space, the ship will only have a low range. To allow for cross-regional transports, it will have a hydrogen-driven low-temperature PEM fuel cell with around 200 kW installed on deck as a range extender. The fuel cell will double the range and the time the ship can go without refueling to around 140 kilometers and 16 hours, respectively. This means that the battery will continue to be used for rapid changes in the number of consumers or short, temporary acceleration maneuvers, while the fuel cell shores up basic supply. This design, originally developed in the automotive industry, makes it possible to redirect energy from the fuel cell to the battery.

The co-existence of battery and fuel cell enables this hybrid-electric propulsion system to transport goods out of the region and up to Magdeburg, Stettin or even Hamburg. The hydrogen consumption for the route between Berlin and Hamburg will be around 13 MWh. The project will also investigate the use of conventional pressure storage tanks (GH_2) at 500 and 700 bar as well as liquid storage (LH_2) and metal hydride units. In light of the aforementioned space limitations, LOHCs (Liquid Organic Hydrogen Carriers) would be another attractive and serious alternative for water transportation. The oil-like carrier liquid releases hydrogen at a temperature of around 300 °C (dehydrogenation). To reach operating temperatures, part of the released hydrogen will be used to heat the process.

Another novelty concerns the development of a steer assist. Equipped with a special profile selection, it is used to help with ship navigation, prompting the powertrain both to respond quickly and use energy more efficiently.

Loading and refueling

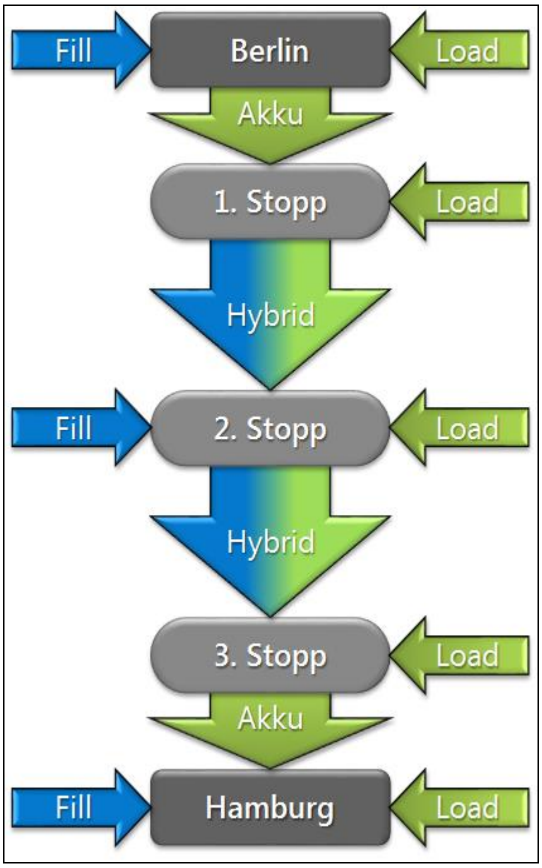
The combination of ELEKTRA and URSUS means that the route between Berlin and Hamburg requires three stops and four days in total. This provides ample opportunity for making a loading and refueling strategy part of the project. To ensure an economical 392 kilometer long run, both the battery and hybrid mode will be used during that time (see figure 3). The available infrastructure will play a crucial role here. In the metropolitan areas of Berlin and Hamburg, it is the hydrogen filling stations closest to the water that are under consideration, and they could receive an extension to supply ships.

Halfway through the trip, however, the ship will require refueling with hydrogen at berth. This refill is to be done with semi-mobile H_2 tank storage units in mind. The units could first be filled by an H_2 trailer before the hydrogen is ultimately stored on the ELEKTRA. The LOHC idea could render stops for hydrogen refills unnecessary, as the total quantity needed would be supplied at Berlin's Western Harbor. Regarding charging points, there are different port-side designs being drafted right now. While the ship is at berth, the batteries should be fully charged within seven hours. Any electricity demand while at berth would be directly supplied by the grid on land.

Initial plans

The first hurdle for fully electric inland waterway transportation was the exact and practically minded design of specifications, a matter that was successfully dealt with by using extensive operation profiles of existing ships used in regional and cross-regional shipping. This stage also included analyses of energy output compared to the operational hours of similar ships. The measured data (speed, diesel consumption, motor torque), together with the information gathered by the analyses, was put into a CFD simulation, in order to forecast energy and performance at given hull specs. These forecasts resulted in weight and size specifications for the hull batteries and the fuel cell on deck. The main consideration in the calculation was the interaction between the hull's water resistance and the integration of the batteries. This means that the different hull specifications go through the CFD simulation, prompting a change in forecast, until the last hull in the iteration loop shows an optimal balance between hydromechanics and hull space requirements. The iterative design process, however, is limited by the batteries' space requirements.

Fig. 3: Loading and refueling strategy for transports between Berlin and Hamburg



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Events

- July 4th to 5th, 2016, in Birmingham, United Kingdom, **International Hydrail Conference**, University of Birmingham Centre for Railway Research and Education, www.hydrail.org
- July 5th to 6th, 2016, in Berlin, Germany, 7. German Hydrogen Congress 2016, Wasserstoff – Wegbereiter der Dekarbonisierung, www.h2congress.de
- July 5th to 8th, 2016, in Lucerne, Switzerland, **European SOFC & SOE-Forum**, Conference with Exhibition, www.efcf.com
- July 20th to 21th, 2016, in Ulm, Germany**, Ulm ElectroChemical Talks (UECT)**, Lifetime & Safety of Electrochemical Energy Technologies, www.uect.de
- October 4th to 5th, 2016, **California Hydrogen and Fuel Cell Summit**, in Sacramento, CA, USA, www.californiahydrogensummit.com
- October 15th to 17th, 2016, **World of Energy Solutions**, on the Stuttgart Fair Ground, www.world-of-energy-solutions.de

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- **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-(0)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
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- **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

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

Event Organizers

- **23rd Group Exhibit Hydrogen + Fuel Cells + Batteries**, HANNOVER MESSE 2017, April 24 – 28, Tobias Renz FAIR, Tobias Renz, 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

- **Peter Sauber Agentur Messen und Kongresse GmbH**, World of Energy Solutions, Wankelstr. 1, 70563 Stuttgart, Germany, Phone +49-(0)711-656960-55, Fax -9055, www.world-of-energy-solutions.de

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- **FuelCell Energy Solutions GmbH**, Winterbergstr. 28, 01277 Dresden, Germany, Phone +49-(0)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

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Gas Diffusion Layers (GDL)

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

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

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

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- **Borit NV**, Bipolar plates and interconnects, Lammerdries 18e, 2440 Geel, Belgium, Phone +32-(0)14-25090-0, Fax -9, contact@borit.be, www.borit.be
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- **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
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- **SMART Testsolutions GmbH**, Rötestrasse 17, 70197 Stuttgart, Germeny, Phone +49-(0)711-25521-10, Fax -12, sales@smart-ts.de, www.smart-testsolutions.de
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- **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

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Ten Years of HZwei News

Ten years ago, Hydrogeit Verlag printed its first issue of the

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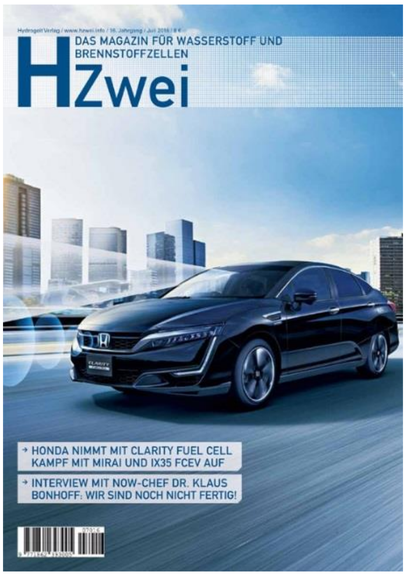

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