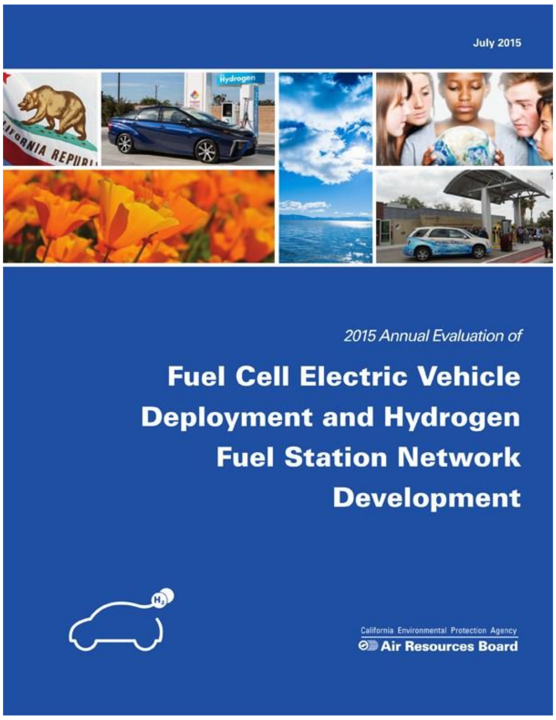
H2-international – e-Journal

January 2016

H2-international and Hydrogeit Verlag wish a happy new year!

Content

Refueling program may fall short of demand



The State of California is becoming more optimistic about early fuel cell vehicle sales, based on a survey of automakers. The fuel cell vehicle fleet is estimated to reach 34,300 by the end of 2021 (see chart). The estimate is high enough to raise concerns that California’s aggressive fueling station deployment program may fall short of demand.

The California legislature required an annual assessment of fuel cell vehicles, fueling stations and future needs, beginning in 2014, and gave the job to the California Air Resources Board (CARB). CARB has published its 2015 assessment, concluding:

- 179 FCEVs are on the road in California, up from 125 in 2014;
- 44 fueling stations are expected to be operational by the end of 2015, with another 6 coming on line in 2016.
- Deployment of fueling stations may fall short of the need sometime after 2018, despite the state’s pledge of funding of $20 million annually.
- The target remains 100 stations, but demand for operating expenses at existing stations means there will be less money available for new ones. Thus only 86 are expected to be on line by 2021

Direct comparisons of fleet size between the 2014 and 2015 reports are tricky since the 2014 report estimated the fleet size in 2020 while this year’s report estimates fleet size in 2021. Yet CARB felt safe in concluding “The 2015 auto manufacturer survey results suggest the FCEV market may grow faster than previously projected . . . ,“ with fleet size nearly doubling between 2020 and 2021.

The latest estimates are well short of projections made at the beginning of the decade by the California Fuel Cell Partnership, which surveyed its members for several years. Its 2012 report, for example, estimated more than 50,000 FCEVs would be on the road by 2017. This is higher than the current estimate by a factor of eight. The higher estimates were made Daimler Benz and General Motors were still committed, more or less, to commercialization in 2015.

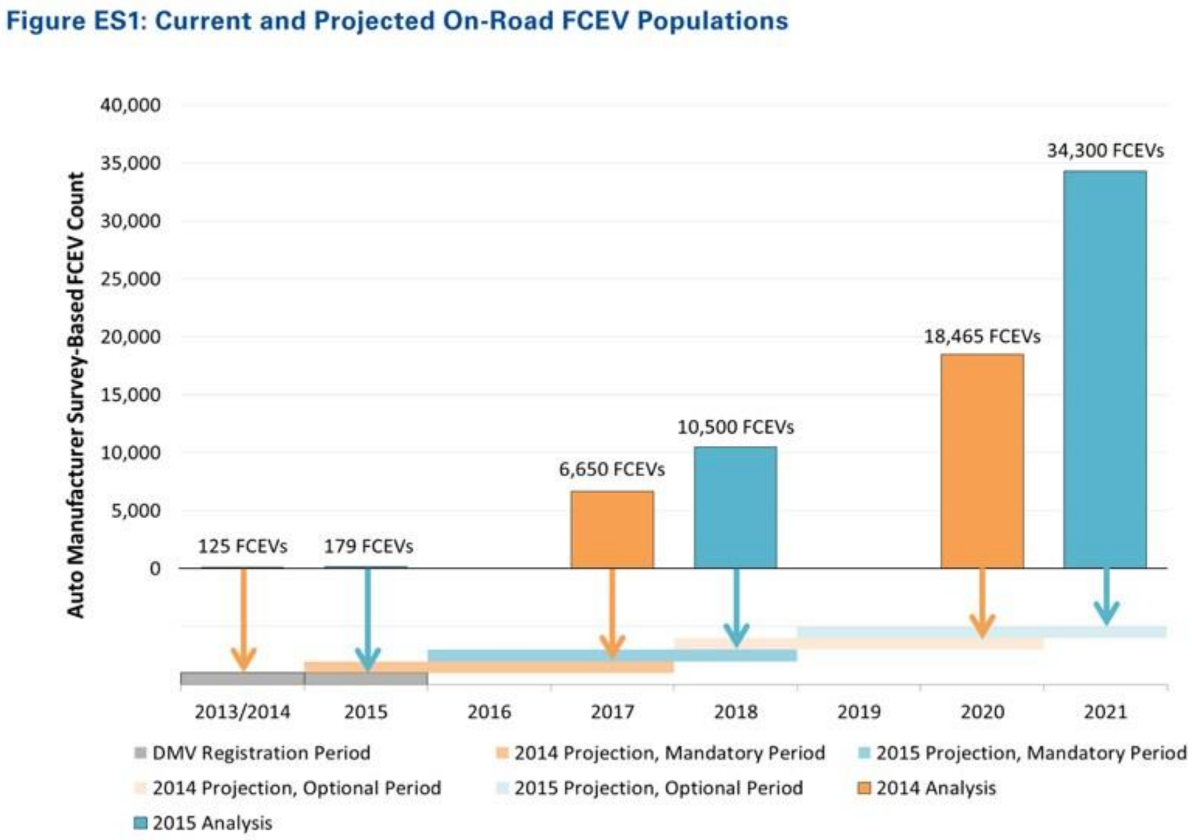


Chart: 2015 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development. California Air Resources Board, July 2015. P. 6

CARB expressed concern over several aspects of station development. “After 2018, the number of vehicles expected to be on the road may need more fuel than can be provided by the number of hydrogen stations that can be built with currently available public funding, assuming funding levels and station capacity remain unchanged,” the agency concluded.

But CARB stopped short of publicly advocating additional state subsidies: “Addressing the expected gaps in hydrogen capacity and coverage may require exploring innovative actions to maximize the utility of public investment and rapidly accelerate industry momentum to expand the fueling network.” This caution suggests that the question of state support for hydrogen stations remains a delicate one politically, and recent reports of problems at the existing stations will complicate matters further.

CARB concluded that “Station technical capabilities must continue to advance to satisfy customer expectations for a retail fueling experience, including meeting current fueling protocols and expanding capacity to fuel growing numbers of FCEVs.” The agency did note that some stations are fully commercial today, with approved hydrogen metering systems that allow fully transparent customer purchases. In most cases today the auto manufacturer is covering the cost of fuel while the metering technology is developed, deployed and tested.

http://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2015.pdf

Author: Robert Rose

Tesla: Another US$ 750 Mio. Capital Increase

Tesla Model X, © Tesla

A capital increase again: around US$ 750 million going to Tesla. Whether this will help provide the cash needed to build the Gigafactory for batteries – which is said to cost up to US$ 5 billion – seems doubtful. The increase also left a bitter aftertaste, as Morgan Stanley was the underwriter (placed the shares) of the “spontaneous” capital increase and, at the same time, a new study by an in-house analyst raised the target to US$ 445 per share. Besides, it is interesting to note how the shares fell in between from over US$ 280 to around US$ 195 (intraday) because of a generally weak stock exchange performance. It may be that the shares were sold short before the capital increase, so as to buy shares up again (only what I suspect, no guarantee that it is true).

In the meantime, UBS analyst Colin Laghan downgraded the shares to *Sell* – and the stock price to US$ 210. As I, he finds it curious that requests for information on the batteries are called “reservations.” Quote: “Misleading.” And: Many analysts would often project their very positive assessment onto 2020 – but who knows what will happen then.

Additionally, the marketplace is getting more competitive. Plus: Daimler ended its battery supply contract and is now buying directly from Tesla’s partner Panasonic.

New products such as the *SUV X* model (priced at between US$ 132,000 and 144,000) are intended to accelerate growth. The first sales could be expected for the fourth quarter, so that one can be curious how great the losses for the third quarter and the cash reserves (at the end of June 2015, at around US$ 1.15 billion after around US$ 1.9 billion at the beginning of last year) will be at the end of the quarter. Conclusion: I believe that with Tesla’s market cap of over US$ 32 billion, any – even a greatly positive – development will already be included in the current evaluation. Vehicle sales, especially of new electric car models (2016 will also make the US$ 35,000 version available on the market), should less be referenced by quantity but by loss per vehicle unit. Until now, analysts have placed their rating focus more on quantities than losses (second quarter: around 500 more units sold than expected, but at the same time a market cap increase of US$ 4 billion!?). And: A recent very positive consumer report suddenly upped the stock price by over US$ 4 billion, which shows how easily it can be “influenced” and how even analysts can neglect fundamental factors. I do not think that is healthy for business.

The relevance to fuel cells and hydrogen is there, since the efforts by Toyota, Honda und Hyundai have led an increasing number of manufacturers (Daimler in 2017) to work on fuel-cell hybrid vehicles based on hydrogen. They are becoming serious competition for Tesla, and various announcements (as Audi’s one in recent times) of direct e-car competition could make it hard for the company to achieve its growth targets.

My assessment: Sell/sell options with the expectation that the stock price will continue to be at a high risk of a downhill slide over the coming years – especially when there are more of the bizarre capital increases like the one mentioned above.

This post was written in September 2015 by Sven Jösting.

Note on risk

When investing in shares, every investor must make their own risk assessment, and ensure an appropriate spreading of the risk. The FC companies and/or shares stated here come from the area of small and mid-caps, which means that they do not constitute standard values and their volatility is far higher. This report does not provide purchasing recommendations – and no guarantees are made. All of the details are based on publicly accessible sources, and in terms of the forecasts they only represent the personal opinion of the author.

Munich's Two Ways of H2 Refueling

Thick hose for cryogenic hydrogen fuel, © BMW

The work on developing ultra-cold hydrogen was abandoned together with the H2 combustion engine in 2006 – at least, that is what everyone believed. After years of uncertainty, it is now clear that BMW is still holding on to cryogenic technology. Proof of that is the inauguration of a new pump at the multi-energy refueling station in Munich, at which drivers can fill up both their compressed gas and their ultra-cold H2 tanks.

On June 16, 2015, the Bavarian carmaker inaugurated the new refueling station together with Total and Linde in the Detmoldstraße in Munich, Germany. The station is part of the "axis of hydrogen" between Stuttgart, Munich, Innsbruck and Bozen within the southern cluster of the European *HyFIVE* project (see Interview). According to the companies' statements, the refueling technology deployed here is new territory for both the businesses and the *Clean Energy Partnership (CEP)* involved, because the station directly opposite to the Research and Innovation Center of the BMW Group offers a pump for cryo-compressed H2 filling in addition to a 700-bar one.

The station uses a cryogenic H2 high-pressure pump by Linde. It directs the ultra-cold hydrogen gas, which is stored in a liquid state at -253°C on-site, into the car tank that has a pressure of up to 350 bar. According to BMW, the storage temperature inside the vehicle is between -210 and -240°C. The cryogenic pump connected to the ionic compressor also enables the supply of the second pump station, at which one can refuel hydrogen gas compressed in the conventional way (GH2, 700 bar, -40°C).

Reduced boil-off losses

The difficulty with this technology is still the heat that enters despite good insulation, which increases the pressure in the tank. It, however, has been possible to reduce the boil-off, meaning the escape of H2 gas. Asked about it, the BMW Group replied: "We strongly believe that we can achieve breakthroughs in the long term." The Bavarian carmaker, however, did not want to divulge the name of its development partner. In the past, the group had collaborated with both Linde and Magna regarding

cryogenic tanks.
The project partners hope to increase the range of fuel-cell cars, since ultra-cold hydrogen has a higher storage density than gas compressed in the usual way. According to company information, the cryo-compression tank technology had a 50% higher H2 tank capacity compared to the 700-bar version.

The tests are being conducted with new BMW cars (*5 Series Gran Turismo*), which have so far been the only vehicles that possess this kind of cryogenic tank. Matthias Klietz, Head of Powertrain Research at the BMW Group, explained: "With this new hydrogen range, cars of private, commercial and industrial owners could be on the road for a long time when running on electric power only and produce no emissions locally while users won't have to downgrade in comfort, space and refueling periods."

When asked by *H2-international* why BMW was the only carmaker which still holds on to cryogenic hydrogen, a company spokesperson replied that it was an option for the long run in a pre-development stage. He said: "Over the medium term, the 700-bar standard is right, but for the long-term, we will continue work on the cryogenic pressure tank technology."

18 of 50 H2 stations
The refueling station in the Detmoldstraße, which was subsidized with EUR 1.4 million under the German National Hydrogen and Fuel Cell Technology Innovation Program (NIP), is the 18th of a total of 50 hydrogen filling stations originally planned to be installed until the end of 2015 in Germany.

Audi Q6 as Fuel-Cell Crossover Car

Audi A7 Sportback h-tron quattro

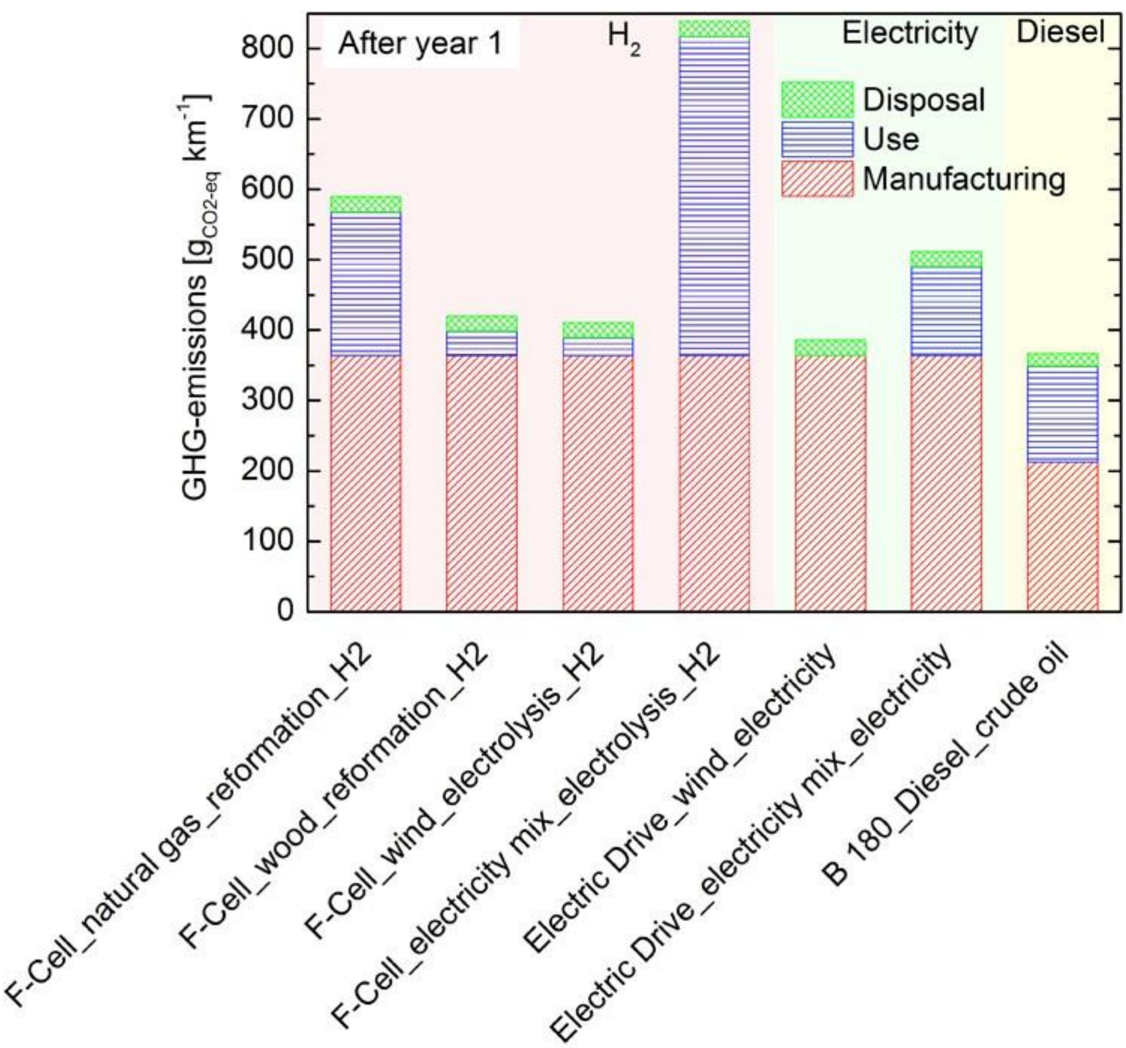
At the end of June 2015, Audi signaled that it also wanted to develop its *Q6* as a fuel-cell version. The VW subsidiary had already announced the new crossover car with an internal combustion engine at the beginning of last year, after it presented the *A7 Sportback h-tron Quattro* (see figure) in Los Angeles at the end of 2014 as another hydrogen prototype (see HZwei issue from January 2015). During 2015, the announcement by the carmaker based in Ingolstadt, Germany, became more specific: The aim was to design two purely electric cars as a plug-in and a fuel-cell version. Additionally, Volkswagen stated at the beginning of 2015 that Audi acquired a package of fuel-cell patents from Canadian Ballard Power Systems for EUR 44 million and made it available across the entire Wolfsburg-based corporation, which has meanwhile surpassed Toyota as the world's largest car manufacturer. Despite all of the above, Audi has still no intentions of commercializing fuel-cell cars this decade.

Fuel-Cell Cars and Their GHG Emissions

In 2012, the transport sector's share in overall greenhouse gas emissions was 19.7% across the 28 member states of the European Union, making it the second-largest producer of greenhouse gases after the energy sector. To achieve the EU Commission's climate protection targets for the transport industry, these emissions need to be lowered by 70% compared to 2008 values. The following will give an overview of how fuel-cell cars can mitigate greenhouse gas emissions in the EU up to 2050 and help achieve EU goals. The carbon footprint is the means by which to determine the potential for reducing those emissions. It describes the greenhouse gas emissions in CO2 equivalents across the entire product life cycle.

The calculation of greenhouse gas emissions by application is based on profiles of driving styles taken from the REM 2030 database created by the Fraunhofer Institute for Systems and Innovation Research [1]. The database contains profiles of 522 vehicles owned by commercial and industrial businesses. It puts the examined Mercedes B-Class in the Mid-Size Car category, which is why the study only includes driving style data of mid-size vehicles. With 55%, the mid-size car segment made up the biggest group of newly registered cars with commercial and industrial owners in 2012 [2], so the car category data used provides a good reference point for a company fleet.

To interpret the results and determine the potential reduction in emissions, the carbon footprint was also calculated for the Mercedes *B-Class Electric Drive* (a battery-driven electric car) as well as for the Mercedes *B 180 CDI BlueEFFICIENCY Edition* (a diesel version). Regarding the fuel-cell vehicle, there were three ways considered in the study to provide H2 supply: hydrogen separation from natural gas or wood and electrolysis through wind power as well as power from the EU electricity mix. The latter two supply the power for the electric car examined in the study. The amount of GHG emitted by using the different vehicles was calculated as shown in figure 1.

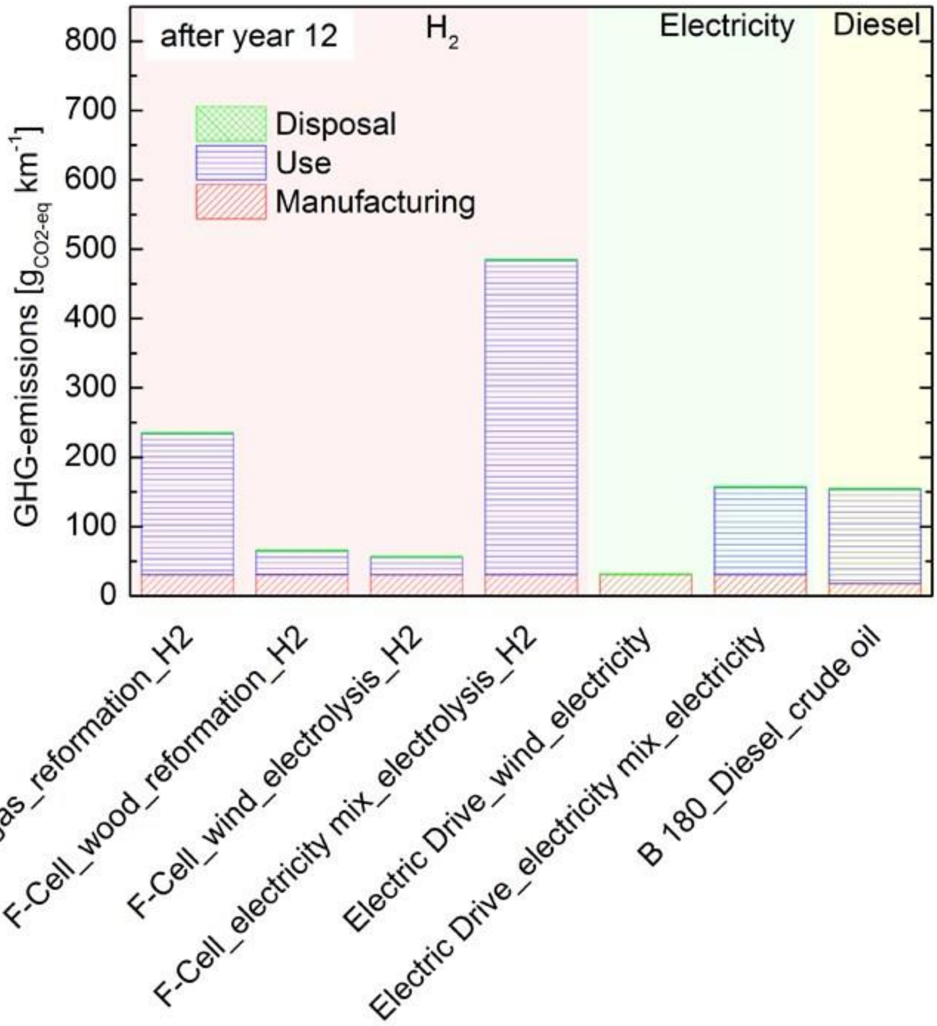


Greenhouse gas emissions caused by production, use and disposal after one year

The calculation results in a profile-based amount of greenhouse gas emissions per kilometer of driving. It includes 203 profiles of driving styles for mid-size vehicles taken from the *REM 2030* database in order to calculate GHG emissions under various conditions. The data was used to determine the power required and based on this value, the total work generated. This makes it possible to estimate fuel consumption and, based on the type of car design and energy supply, the amount of greenhouse gas emissions.

The calculation of the required power considers rolling resistance as well as auxiliary power consumers, such as air conditioning and heating. Not included in the calculation was the resistance experienced through road inclination and acceleration, as well as the ambient air temperature. To determine the power one needs to apply, the required power is divided by vehicle efficiency, which is different for each vehicle. For the sake of simplicity, the efficiency value is viewed as being a constant in this scenario.

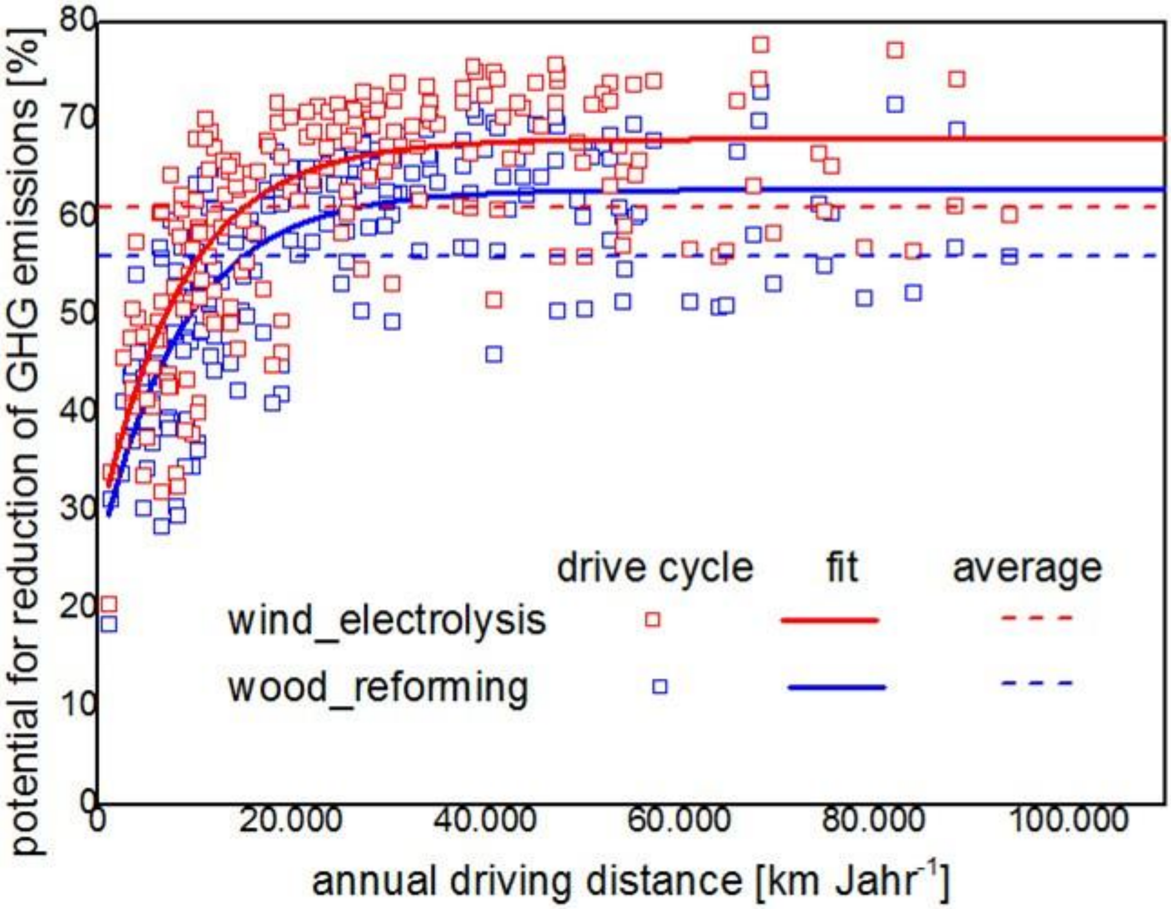
Influencing factors, such as road gradient, acceleration, temperature and variable efficiencies were greyed out, since they influence the calculated values but are not considered. To determine fuel consumption, the total work is divided by current vehicle speed. The result is multiplied by the greenhouse gas amount specific to this kind of energy supply.



Greenhouse gas emissions caused by production, use and disposal after twelve years

The method described above can be used to show the carbon footprints of different driving styles. This requires extrapolating the available data to one or twelve years. As the average examined profile restricts the life cycle to 8.000 hours in operation, based on the 2015 target described in publication [3], it is possible to use a Mercedes *B-Class F-CELL* for around twelve years. Figure 2 shows the GHG emissions across the product life cycle of different vehicles and means of supply after one and twelve years, broken down by production, use and disposal. The calculation assumes that the same amount of greenhouse gas emissions was produced to manufacture an *F-CELL* model and a Mercedes *B-Class Electric Drive*, since the UMBReLA study conducted by the Institute for Energy and Environmental Research Heidelberg (IFEU) showed the emissions for the manufacture of fuel-cell and battery-driven electric cars to be virtually identical. Another assumption is that there is a sufficiently large network of H2 refueling stations as well as enough fast-fill pumps to allow the inclusion of all driving styles considered in the study.

The GHG emissions produced are one part of the carbon footprint. The other concerns the emissions caused by the manufacture and disposal of vehicles and will be included in the balance across the entire product life cycle. The results are always based on the supposition that the lifetime is the same for the fuel-cell car and the two reference cars, independent of powertrain and storage technology.



Emission reduction potential of Mercedes B-Class F-CELL with hydrogen from regenerative sources wood (blue) and wind (red) compared to a diesel reference car among 203 examined driving styles

With 5.9 tons of CO2 equivalent, the greenhouse gas emissions for the production and use of the diesel car are substantially lower than for the other two cars with 10.1 t CO2 equivalent [4]. The emissions caused by driving the car are determined through averaging the GHG emissions calculated per kilometer of the 203 mid-size car profiles. After one year, production still accounts for a large share of overall greenhouse gas emissions. After twelve years, the GHG share of production makes up only a twelfth of what it was after one. The longer the car is in use, the lower will be the share of greenhouse gas emissions from manufacture and disposal and the higher the importance of car utilization. The large influence of emissions from manufacturing means that the diesel car will have an advantage regarding its carbon footprint after one year because of the lower GHG output during production and disposal. After twelve years, car use has become the dominating factor regarding the carbon footprint, which shifts the advantage toward designs with fuels from regenerative sources. GHG emissions from fuel-cell car use are higher than from a battery-driven electric one because the fuel-cell car needs to convert electricity into hydrogen and because it has a lower vehicle efficiency.

Conclusion
The regenerative potential of hydrogen production to lower emissions for the 203 examined driving styles is shown based on the mileage per year (see figure 3). For each profile, there is the assumption that the maximum lifetime is reached after 8,000 hours in operation or after 27,200 stop-start cycles.

Assumptions regarding lifetime restriction were the same for the diesel reference car as for the Mercedes B-Class F-CELL. Vehicle life based on a certain driving style results in the maximum mileage over the vehicle's service life. The comparison of reduction potential contains each of the 203 driving styles and refers to the yearly mileage of the examined profiles. Average reduction potential is exceeded at around 20,000 kilometers for both variants of H2 supply. Additionally, the dotted lines in the diagram show the average potential reduction of the 203 driving styles for both variants of H2 generation.

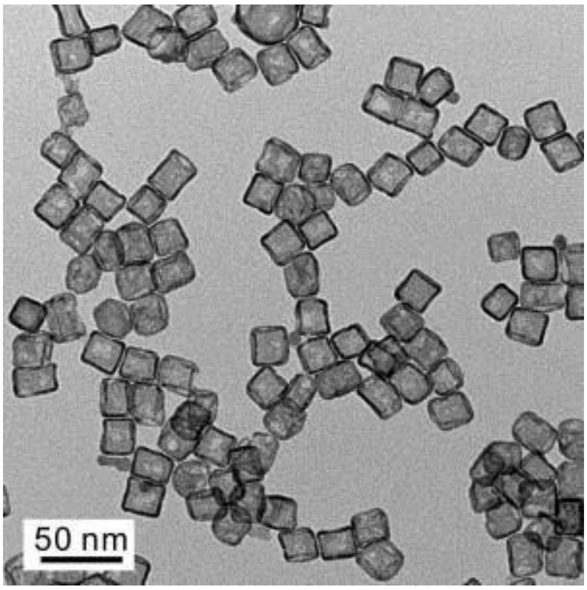
The reduction potential of the Mercedes *B-Class F-CELL* with hydrogen from wind energy is a bit higher than for hydrogen based on biogas. Some driving styles can achieve a reduction of nearly 80%. The difference in potential for the various profiles at the same yearly mileage can be explained by the difference in how the car is being driven.

As a conclusion, it can be said that hydrogen production from regenerative energy sources, primarily through the means of hydrogen generation examined here – electrolysis through wind power and hydrogen separation based on wood – shows great potential to significantly reduce GHG emissions by using fuel-cell cars. Especially since more than half of all commercially and industrially used vehicles have a mileage of over 20,000 km per year [5] and a considerable share of 62% of all new vehicles is registered by commercial and industrial owners [6], the potential of reducing GHG emissions is comparably high when using hydrogen to power vehicle fleets of businesses.

[1] REM 2030 Fahrprofile Datenbank, ed: Fraunhofer ISI, 2014
[2] Kraftfahrt-Bundesamt, Fahrzeugzulassungen 2013 nach Wirtschaftszweigen und Untergruppen und Fahrzeuggrößen, Kraftfahrt-Bundesamt, Flensburg, 2013
[3] B. Pollet, et al., Current status of hybrid, battery and fuel cell electric vehicles: From electrochemistry to market prospects, Electrochimica Acta, vol. 84, pp. 235-249, 2012
[4] Mercedes-Benz, Umweltzertifikat Mercedes-Benz B-Klasse Electric Drive, ed, 2014
[5] T. Gnann, et al., Elektromobilität im Personenwirtschaftsverkehr – eine Potenzialanalyse, Fraunhofer ISI, Karlsruhe, 2012
[6] Kraftfahrt-Bundesamt, Privat und gewerblich zugelassene Personenkraftwagen (Pkw) – der kleine Unterschied, 2012

All authors are working at Fraunhofer ISE, Freiburg:
Laura Sutor, laura.sutor@ise.fraunhofer.de
Nada Zamel, Ph.D., nada.zamel@ise.fraunhofer.de
Ulf Groos, ulf.groos@ise.fraunhofer.de

The Long Search for Platinum Replacements



Hollow platinum cubes, © Xia Laboratory/UW

Regarding fuel cells, a challenging and important issue are still the catalysts. To a considerable degree, they determine both the performance of stacks and their price. Currently, the most different nanoparticles are being examined in the most different structural combinations. This is also true for the field of water splitting, where catalysts are employed in electrolysis systems. The jury is still out on which materials could ultimately replace platinum in both cases, so work on the required catalyst quantity continues.

One of the potential contenders to replace platinum used in oxygen reduction is a nanoparticle mixture that is said to be less expensive but just as efficient as the original. The compound consists of a palladium-wolfram mixture at a ratio of one to eight, into which palladium islands of around one nanometer in size have been embedded. Thomas Wågberg from Sweden’s Umeå University explained that the mixture was similar in efficiency to a platinum catalyst because of its unique morphology, “but costs around 1/40,” as the palladium islands serve as high-efficiency catalytic hot spots. Together with his Swedish-Chinese team of researchers, Wågberg created the compound by employing a simple synthesis method that could also be used in a common microwave oven. He explained: “If we hadn’t used our argon as a protective inert gas, we could have created this great catalyst in our own kitchens.”

Meanwhile, American scientists have developed a new non-metallic catalyst system whose efficiency is almost as high during O2 reduction as the platinum one. The team of chemical engineers from the Wisconsin-Madison University said in the scientific research journal *ACS Central Science* that they had used a combination of nitroxyl and nitrogen-oxide mediators. Professor Shannon Stahl explained: “Despite the catalytic coupling having being used for aerobic oxidation previously, we did not know whether it would be a good fuel-cell catalyst. As it turns out, it is the most efficient molecular catalytic system ever to be reported." [1]

The scientists at the Peter Grünberg Institute at the Research Center Jülich, on the other hand, have been trying to substitute part of the platinum with more inexpensive metals. Together with colleagues from TU Berlin, the researchers from the PGI had already had success in 2013 with creating particles that do not consist exclusively of platinum but of nickel or cobalt on the inside. These nanocrystals in the shape of octahedrons are said to require only a tenth of the usual platinum amount. They are created by first setting up a cross-shaped frame with six tips made of pure platinum. Then, the nickel or cobalt atoms bond with it until the gaps are filled and crystal growth stops on its own.

Ruhr University Bochum bets on carbon
In summer 2014, chemical engineers from the Ruhr University Bochum had already found a bifunctional catalytic material that can promote two opposite reactions: the cold combustion of hydrogen through oxygen in a fuel cell and the splitting of water by electrolysis. The material is carbon-based and incorporates manganese-oxide or cobalt-oxide nanoparticles. Professor Dr. Wolfgang Schuhmann and his team as well as Professor Dr. Martin Muhler "cut" the carbon nanotubes by using heat and oxygen in order to make use of the catalytic particles enclosed in them.

Gold nanoparticles
A*STAR in Singapore is yet another institute researching catalysts for electrolysis systems. While experimenting with water-resistant lanthanum-strontium-titanium-oxide, Andy Hor and his team discovered that nanoparticles made of gold can increase catalytic activity. The researchers added gold nanoparticles enriched with electrons to the compound. This resulted in better light concentration, which in turn accelerated catalytic reactions. The porous structure of the catalyst also increased overall surface area (one gram has a surface area of 100 m2). Hor explained: "The large surface area plays an important role in increasing photo-catalytic activity."

Slow synthesis
In Germany, researchers are more focused on considerably cheaper materials, namely an iron-nickel-oxide compound. It was reported that the compound was used to synthesize nanoparticles that were ten times as efficient as everything described in the literature about attempts with comparable nickel-iron-based bonds. As stated by the Ludwig Maximilian University of Munich in May 2015, the team of Professor Thomas Bein and Professor Dina Fattakhova-Rohlfing relied on an intentionally slow synthesis. Ksenia Fominykh: "Common synthesis methods always create particles in the state with the greatest thermo-dynamical stability. Our method places the importance on an intentionally slow reaction time. It enables the establishment of less stable, so-called metastable states, with one of the results being the formation of distinct mixture ratios of nickel and iron in our nanoparticles."

Together with colleagues from the MPI Düsseldorf and the Free University of Berlin, the scientists from Munich were successful in fully deciphering the extraordinarily small crystalline structure of the particle (1.5 nanometers). The discovered coupling of a very highly catalytically active surface area and a high crystallinity of the nanoparticles was one of the factors responsible for the structure staying intact even after sustained electrolysis under electric currents at high voltage. Additionally, it was said that the nanoparticles were easy to create and inexpensive to use for various applications.

Reduced platinum quantity

Another way to save costs is to reduce the platinum quantity required. Younan Xia from the American Georgia Institute of Technology has just recently made a breakthrough here: As reported in the magazine *Science*, Xia developed miniature platinum cubes whose nanostructure promises an up to seven times more efficient catalytic reaction at the same material cost. The cubes, which are only 20 nanometers in size (see figure 1), are hollow and possess ultra-thin walls of few atomic layers, providing a large surface area despite the small quantity of material.

The researcher created the nanocubes by letting individual atomic layers of platinum grow on the palladium nanocrystals and etch them away thereafter. The good controllability of the process enables the creation of one, two or three atomic layers. Until now, similar cubes had around 20 layers, which required much more platinum. Xia explained his motivation to create hollow platinum cubes as follows: “We did not want to waste material that takes up space inside but does not contribute to catalytic activity.”

[1] Gerken, J. B., Stahl, S. S., High-Potential Electrocatalytic O2 Reduction with Nitroxyl/NOx Mediators: Implications for Fuel Cells and Aerobic Oxidation Catalysis, ACS Central Science, DOI: 10.1021/acscentsci.5b00163 (2015)

Local Design to Enhance Regenerative Energy Use

© *Energiepark Ewald*

The biggest challenge of the energy sector transformation will be the spatial and temporal separation of production and consumption. Such a global issue may seem to require global or at least national solutions. The Energiepark Ewald study for the Hydrogen City Herten in Germany shows that regional concepts can make an important contribution as well.

The object of the study was the industrial zone Ewald in Herten. Until 2000, it was an active mining site and has meanwhile been turned into an industrial zone with a focus on services and logistics. This has resulted in the creation of 1,300 jobs, making the zone a prime example of successful structural changes in an area.

An important part of this zone is the Hydrogen Center of Excellence, h2herten. The technology center for the hydrogen and fuel-cell industry offers a unique system to test 100%-regenerative power supply. The storage medium used is a hybrid system consisting of hydrogen and battery storage.

The aim was to put the inspirational ideas into practice by providing energy supply to the entire industrial zone. The basis for realizing the project was an already existing 1.5-MW wind power plant set up in 1997 at the adjacent hill as well as a total of 680 kWpeak of installed PV power.

How to meet high demand

Tapping the full potential of the location would mean installing PV systems with a power of 3.5 MWpeak as well as a 3-MW wind power plant. This would directly meet 70% of the electricity demand; if the full economic potential of the location were realized, coverage would be between 65 and 70%. The balance sheet would even show a 30% surplus generated if the full potential were tapped. Thus, it is entirely possible to supply the industrial zone mainly by renewable energies without using much of the land available. Large-scale industrial consumers, however, could not be supplied like this.

How to use the local surplus

The high renewable share in power generation also results in a considerable surplus. Around half of the electricity generated in this scenario cannot be used on-site. Should it soon no longer be possible to feed the created surplus into the grid, it will have to be used otherwise. This opens up several possibilities.

Since power in an industrial zone is mainly consumed during the day, battery storage combined with solar systems is not a feasible option. The load fluctuations of the wind power plant do not allow for an efficient use of battery storage either. From a technical point of view, hydrogen-based storage systems are the much better alternative. They make it possible to even out seasonal fluctuations, further reducing the amount of power needed from the grid. This way, a renewable share of above 80% in power supply is quite a realistic target. The drawback is the economic feasibility of such a system.

A more economical way to use the surplus power generated is its application in the transportation sector. One option would be the use of excess energy during working hours, in order to charge employees' electric cars. The high level of efficiency turns this method into a big advantage. However, any surplus generated at night will not be utilized. To make the most out of the excess potential, hydrogen for fuel-cell cars will be the right avenue to pursue. Additionally, energy suppliers will not have to depend on the needs of industrial zone employees alone. Such flexibility, however, takes its toll in the form of greater energy losses; the optimal solution would be a combination of hydrogen and electric vehicle usage.

The last option would be to use the excess energy to generate heat. Because of the high exergy losses, this is an intensely disputed method, but none of the systems mentioned above are designed for power peak loads in order to reach an acceptable number of operational hours. These peak loads could be well served by Power-to-Heat, especially because the industrial zone is connected to the district heating network that makes for a year-round consumer.

Organizational hurdles
All scenarios described above were developed by considering their economic feasibility. They, however, paint a simplified picture of reality: The industrial zone as only a single consumer. Such a scenario can rarely be found in reality. Besides the challenge of getting several companies to collaborate on the issue, it is mainly the legislator setting limits. Collaborative energy supply projects have very narrow confines in which they can operate, which will ultimately fail feasibility. It will be necessary to develop business models which circumvent these barriers or hope for a change in legislation.

The Energiepark Ewald study is a master thesis in Energy Systems studies at the Westphalian University of Applied Sciences in Gelsenkirchen. It is a part of the *Herten Climate Concept 2020+* project. In June 2015, the paper's authors were awarded the Innovation Prize 2015 by the German Hydrogen and Fuel Cell Association (DWV).

Author: Thorben Müller, h2herten Anwender-Zentrum GmbH, Herten, Germany, t.mueller@herten.de

---

Fuel-Cell iPhone Nothing but Hot Air

H2-international has long since refrained from spreading any rumors or participating in any speculation about fuel cells for mobile devices, even if it was about an *iPhone* which allegedly could be powered by Intelligent Energy modules. It is precisely for this reason that we will do no more than quote *roby111*, who posted a pretty accurate assessment of the situation on the web at *Elektronikpraxis*: "Yes, since 1998 this topic has been making the rounds through the news outlets after c‘t once reported about a market-ready solution for Toshiba (or was it IBM *Thinkpad*) notebooks. I've tried to get such batteries through the distribution channels, but unfortunately they have never been available for shipment! So, the classic faux story during a summer's lack of news!" That says it all.

Power-to-Gas – Microbes to Cut Costs

Micro-organisms, © Schmack Biogas

Micro-organisms provide more flexibility than common catalysts, and the methane produced by them is relatively pure. Additionally, the investment costs for Power-to-Gas systems can be lowered by using transformers and power as well as gas network connections of already existing biogas and wastewater treatment plants. This field of study, however, still requires more research to be done, even for the newly built Power-to-Gas plant by Viessmann, which has been feeding into the public gas grid in Allendorf since the middle of last March.

The placid Allendorf community at the Eder in Germany's federal state of Hesse has its own airfield, although no regular or charter flights make their landing here. The airfield had neither been set up for the around 5,600 inhabitants of Allendorf: It is a private company airfield of the Viessmann Group, so that the family business stays linked to the world despite the headquarters' rural setting.

Visitors of those headquarters will immediately notice the large biogas plants directly at the Viessmannstraße next to the airstrip. The three boxes as big as shipping containers beside those plants seem kind of unremarkable at first. They contain the technology of the Power-to-Gas plant (see figure 2). The longer grey container houses the instrumentation and control equipment. The smaller container behind it houses the pump as well as the gas and temperature monitoring devices. The PEM electrolysis system is found to the right in the third container. The actual secret, however, is in the silver pressure container with the many pipes protruding from it. This fermenter employs a new technology for producing methane: Through their cell membranes, micro-organisms take in the hydrogen dissolved in a liquid as well as the CO2 and convert it into methane (CH4). This process only leaves water as a residue.

New Power-to-Gas plant in Allendorf
"Since 2012, we have been researching micro-organisms in our laboratory and have started to screen them," says Ulrich Schmack. As President, he heads Viessmann's

subsidiary Microbenergy, a spin-off of Schmack Biogas, which Viessmann acquired in 2010. The biochemical and process engineers of his enterprise further developed Schmack's screening process and have now set up a semi-commercial plant in Allendorf.

Power-to-Gas plant in Allendorf, © Viessmann

The current plant size is 200 kilowatts, which corresponds to a converted power of 100 kilowatts of methane gas. Performance is planned to be increased step by step to 400 kW, a move which has already been approved by the grid operator. "We are very satisfied with how the process has developed so far," says Schmack. The future would bring Power-to-Gas plants of between two and five megawatts, although plants with even more power would be quite rare.

The company had already run the plant that was now moved to Allendorf (see HZwei issue from April 2014) as a testing system in Schwandorf in Upper Palatinate. The demonstration plant had been set up in Schwandorf in the fall of 2014 and had been operated there until the end of the year. The result: The test run showed a gas quality with a methane content of 98% and a hydrogen share of less than two percent as well as a relatively stable gas production.

There is another plant still running in Schwandorf. It is supplied by a digester and creates a comparably high share of methane. Its electrolysis system has a power of 30 normal cubic meters of hydrogen per hour. Plans are to let the system continue in operation at Schwandorf until the end of 2015.

After the demonstration plant was now disassembled and reassembled at Viessmann's headquarters in Allendorf, the hydrogen produced on-site by microbial methanation is fed through the available biogas plant into the natural gas grid. The required CO2 is either taken from the gas processing plant or the raw biogas is used directly, including its inherent CO2. In this case, the Power-to-Gas also prepares the raw biogas.

Business flexibility

Based on current estimates, the costs of biological methanation will be EUR 400 per kilowatts of electric power in 2017. Another EUR 800 per kW will have to be added for the PEM electrolysis system, bringing the total up to EUR 1,200 per kW. A 2-MW plant could then cost around EUR 2.4 million, including electrolysis system and grid connection. At present, however, costs are twice as high. “Cost reductions result from upscaling to a plant accordingly larger in size,” explains Schmack.

Since 2012, the company has put much effort into researching micro-organisms, because the little helpers offer several advantages: Above all, they provide more flexibility than catalysts based on a chemical-catalytic process. A quick ramp-up and shut-down of methane production in seconds or mere minutes is be possible with common catalyst versions. The conversion process from hydrogen to methane can start up quickly or be shut down fast if micro-organisms are used at normal operating temperatures of 50 to 60°C. The microbes will just minimize their metabolic functions. The comparably low temperatures and pressures make this method an economically interesting one.

This is exactly what Power-to-Gas needs if it wants to be a partner technology for volatile power generation from sun and wind. The utility association Thüga estimates that the relevant storage demand will already be at around 17 terawatt-hours in 2020 and at 50 TWh in 2050.

The use of existing biogas and wastewater treatment plants could lower the costs for Power-to-Gas installations, because both the transformers and the power as well as gas grid connections will already be in place. Another advantage: The reaction only takes seconds and the produced methane is relatively pure. Common processes wash out the CO2 from biogas production. In the future, hydrogen will be added to the biogas or sewage gas, and the micro-organisms will get to work on converting the CO2 in it into CH4. This results in a synthesized gas that can be fed into the grid and a methane content that is almost doubled from a good 50 to between 95 and 100 percent.

Up to 80% efficiency

Plant efficiency is between 52 and 54 percent, according to Schmack. “However, we use the waste heat during conversion, which brings efficiency up to between 75 and 80 percent.” This is important especially for wastewater treatment facilities, because the waste heat from the electrolysis system heats the plant’s digester and saves energy. Another benefit of the technology: The waste heat temperature of 65 to 70°C is around 20°C higher than the one of conventional PEM electrolysis systems, which can increase the plant’s overall efficiency.

But PEM electrolysis still requires more research. “Both power density and response speed need to increase,” says Schmack. This will be paramount when supplying the energy imbalance market. When such system power is achieved for the grid, energy storage will already generate revenue.

“It needs the right environment to make the conversion of power to methane gas an economically viable option,” explains Schmack. It will require excess power from renewable energies, which one could get free of charge under the best circumstances. “Today, we are obligated to pay the EEG charge on the power used, whose feed-in would otherwise be restricted,” explains Schmack, and he adds: “This is unacceptable.”

Biogas and wastewater treatment plants could then supply power when needed. When there is excess power in the grid, it would make sense to save biogas or sewage gas and use the natural gas grid as intermittent storage. The entire system would become more responsive to actual demand if there was a Power-to-Gas plant set up next to the biogas or sewage gas one – similar to today’s installation of combined heat and power plants. When there is a power surplus, the Power-to-Gas plant would use the electricity to create hydrogen through electrolysis and bring the biogas or sewage gas up to natural gas quality as well as feed it into the gas network. This example also shows the growing link between the power and gas sector. For that to happen, additional investments will have to be made, according to Schmack. “On the other hand, our method does away with the process of having to prepare the gas.”

Since July 2015, the gas has been marketed as a biofuel after the successful completion of a one-month performance test. The contract party is a leading car manufacturer with a CNG vehicle fleet.

Responsive 1.2-gigawatt supply
In the opinion of the Biogas industry association, a responsive power market will attribute great importance to a flexible energy carrier such as biogas, as it can be stored and can always fill the gap that is created each time volatile suppliers like sun and wind cover energy demand. Even today, around 2,200 of the about 8,000 biogas plants in Germany are registered with the Federal Network Agency for responsive plant operation. This translates into 1.2 gigawatts of electric biogas plant power available when needed. In total, the German biogas plants produce 27.6 terawatt-hours of electric energy, enough to meet around 5 percent of Germany’s yearly demand.

“Methanation, however, is the last link in the chain,” explains Schmack and adds: “Before that, there are plans for the direct use of hydrogen and also Power-to-Heat.” The natural gas network is a “seemingly limitless large-capacity storage.” It can hold up to 200 terawatt-hours of gas. Whenever hydrogen can be used directly, it should be. One example: fuel-cell cars. Still, hydrogen can only be fed into the natural gas network in a limited fashion; the legal requirements stipulate that the feed-in be less than five percent in most cases, depending on the location.

Germany is not the only country in which Power-to-Gas is currently trending. The markets in Scandinavia and California are growing as well. Schmack has already received several requests for project specifications.

Ulrich Schmack founded Schmack Biogas in Schwandorf in Upper Palatinate as early as 1995. The company sold biogas systems ranging from compact units with a power of 50 kW to systems of 20 MW. In 2010, heating technology specialist Viessmann took over the biogas enterprise and all of its subsidiaries. Founded in 1917 and managed as a family business, Viessmann employs 11,500 people around the world. Group revenue amounted to EUR 2.1 million in 2013, with 55 percent having been generated abroad. The Bavarian Ministry of Economy subsidized the Microbial Methanation with around EUR 500,000.

Author: Niels Hendrik Petersen

ZBT Uses New PAFC to Create Air Low on O_2

QuattroGeneration, © ZBT

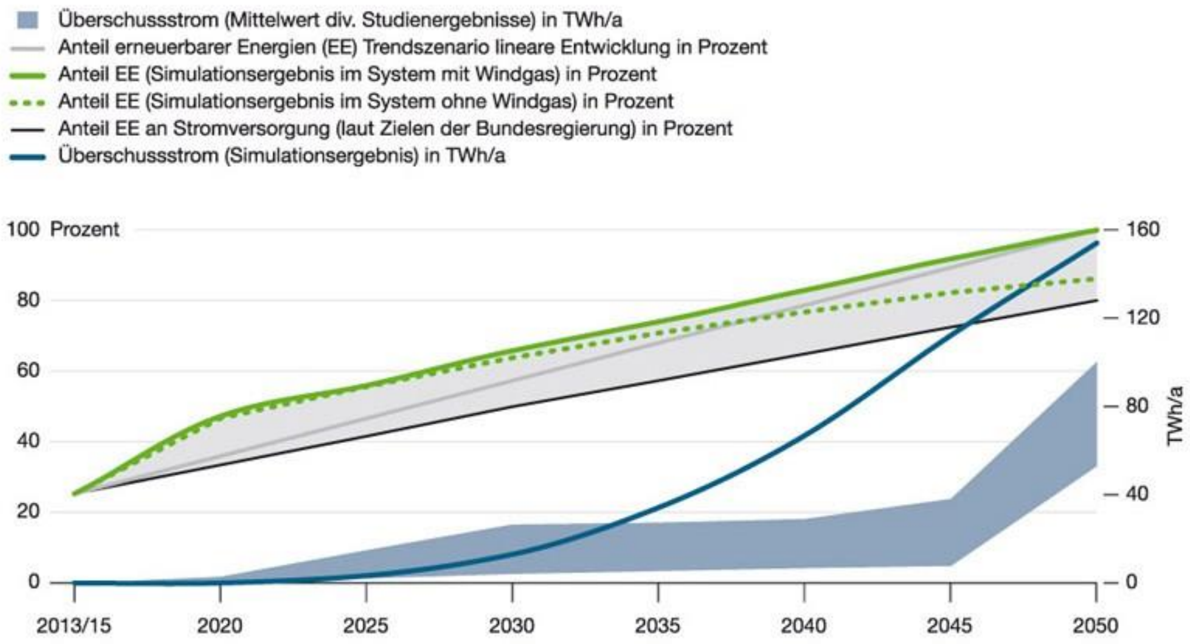
Since the end of last May, the Center for Fuel Cell Technology (ZBT) in Duisburg has had a phosphoric acid fuel cell (PAFC) in operation, which supplies the research institute with power and heat. The 100-kW unit even took on three additional tasks: It reduces energy costs, it serves as the basis for scientific studies in combined heat and power and it helps to produce air low on oxygen.

The ZBT had already worked on fuel-cell systems creating air with low oxygen content in 2008, together with the back then start-up N2telligence. At that time, both partners presented their design at the *World Hydrogen Energy Conference (WHEC)* in Essen, a design that produces power and heat at the same time while also creating air low on oxygen. This air could be used, basically as a side-effect, to simulate heights for training purposes. In the meantime, the initial idea has been turned into a commercial product: *QuattroGeneration* units have already been supplying electricity, heat, cooling and air low on oxygen at various locations, just as in Duisburg.

The “exhaust gases,” which originate at the cathode in Fuji Electric‘s PAFC unit driven by natural gas, have a lower oxygen content because part of the O2 molecules react with H2 ones, producing power and heat. For example, this exhaust air can be used for medical applications (hypoxia), for inert suppression or even for fire protection. To enable such usage, a second container was installed, about which Professor Dr. Joachim Fandrey from the Institute of Physiology at the University Hospital Essen said that the climate inside corresponded to a height of 2,500 meters above sea level.

The focus of the tests at the institute adjacent to the University of Duisburg-Essen (UDE), however, is combined heat and power. Here, it is about scientific analyses of the power-to-heat ratio as well as the exhaust and noise emissions. Moreover, the CHP waste heat is decoupled at different temperature levels and is being utilized, and just as it so happens, power costs go down as well. The ZBT saves around 115 tons of CO2 per year (combined efficiency: 90%). Reason enough to have the plant costing around EUR 1 million to become part of the EnergyLounge.NRW as a qualified project. The EnergyLounge.NRW is an initiative by the federal state government with the 2022 aim of having presented 1,000 North Rhine-Westphalian projects that advance the goal of climate protection.

Power-to-Gas for Cheaper Electricity



Greenpeace Energy presented a new study in August of 2015 according to which “wind gas” (gas produced with the help of excess power from renewable energy – hydrogen or methane) could contribute to strengthening the transformation of the energy sector. The 97-page comparison of future power supply with and without Power-to-Gas technology concluded that “from 2035 on, electricity supply would be cheaper with the help of wind gas technology than without it." Furthermore, "with the help of wind gas, it would be possible to have the entire power supply generated by renewable sources by 2050, instead of the 80% aim of the government – and at considerably lower costs." Without wind gas systems, there would be no electricity supply exclusively from renewable sources, no matter how many solar, wind or biogas systems were added (see picture).

The head of the project, Professor Dr. Michael Sterner from OTH Regensburg University of Applied Sciences, said: "Without a storage transformation, the energy one will not be achievable." Thorsten Lenck from Energy Brainpool, one of the study's authors, explained: "The initial investment into the expansion of wind gas systems may raise costs in the short-term […], but it will amortize in the long run, and it will be greatly overcompensated by 2050." Marcel Keiffenheim from Greenpeace Energy added: "To make the technology available when it will be needed, there must be a decrease in regulatory barriers, which often impede wind gas investments."

The study commissioned by Greenpeace Energy was conducted by the Research Center for Power Grids and Energy Storage of the OTH Regensburg and Energy Brainpool. The energy cooperative was founded in 1999 by Greenpeace Germany and has since worked based on the environmental organization's ecological standards.

Greenpeace Energy, Bedeutung und Notwendigkeit von Windgas für die Energiewende in Deutschland, Berlin, August 2015

---

read more: www.h2-international.com

Events

- February 4th to 5th 2016, **HyVolution**, in Paris, France, www.hyvolution.fr
- February 16th to 18th 2016, **E-world energy & water**, in Essen, Germany, www.e-world-essen.com
- March 2nd to 4th 2016, **International Hydrogen and Fuel Cell Expo**, at Tokyo Big Sight, Japan, www.fcexpo.jp
- March 15th to 17th 2016, **Energy Storage Europe**, Düsseldorf, Germany, www.energy-storage-online.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
- April 13th to 14th 2016, **Grove Conference Fuel Cells Science and Technology**, in Glasgow, United Kingdom, organised 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
- June 13th to 16th 2016, **World Hydrogen Energy Conference 2016**, in Zaragoza, Spain, www.whec2016.com

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

- **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

- **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

- **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

- **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

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

Hydrogen

- **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

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
- HIAT HYDROGEN AND INFORMATICS INSTITUTE OF APPLIED TECHNOLOGIES **HIAT gGmbH**, Schwerin, Germany, CCMs / MEAs / GDEs for PEFC, DMFC & PEM-Electrolysis, www.hiat.de
- WEKA CRYOGENICS Member of the ARCA FLOW Group **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

- DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center Institute of Engineering Thermodynamics
  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
  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

- **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


whec
2016
World Hydrogen
Energy Conference 2016
Zaragoza - Spain
13-16th June 2016
info@whec2016.com
Call for abstracts
Open April 2015
Deadline 31st October 2015
So mark your calendars now, we look forward to seeing you in Zaragoza
www.whec2016.com

Specials

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

- **Free tickets / Discount** for the trade show & conference:***Hyvolution***, from February 4th to 5th 2016, in Paris, France, www.hyvolution.fr

- **50% Discount** for the trade show:***E-world energy & water***, from February 16th to 18th 2016, in Essen, Germany, www.e-world-essen.com

- **10% Discount** for the conference:***Energy Storage Europe***, from March 15th to 17th 2016, in Düsseldorf, Germany, www.energy-storage-online.com

- **10% Discount** for the conference:***Power to Gas and Power-to-X for Europe's energy Transition***, March 16th 2016, in Düsseldorf, Germany, www.otti.eu

- **Special Discount** for the conference:***Electric Vehilces Europe***, from April 27th to 28th 2016, in Berlin, Germany, www.idtechex.com/electric-vehicles-europe/

Please contact *H2-international* for more details.

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