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Content

Electrolyzer Manufacturers Stake Their Claims

New Alliances in Energy Storage Industry

Energy Storage

Fig. 1: M Series by Proton OnSite

Source: Proton OnSite

There has been quite an interest in energy storage recently. And as ever more power-to-gas systems have been popping up all over Germany, project planners are increasingly turning their attention to the key elements found on-site: electrolyzers. These electrochemical units to create hydrogen have been around for a long time. But ever since this energy source was put back into the spotlight of the storage debate, it has sparked a contest for devices that best respond to load fluctuations and ensure greatest possible efficiency.

The German Energy Agency, or dena for short, launched its Power to Gas Strategy Platform in late 2011 and organized its first P2G conference in 2012. These events were followed by breaking ground on the plant in Falkenhagen, Germany, and an increasing number of other projects (see HZwei issues from January 2012 and January 2013). The idea to use hydrogen as a chemical storage medium to help with eco-power reserves has meanwhile taken hold in people's minds. It goes even beyond that, actually. The buzzword "sector integration" as a term for combining the power, heat and transportation industry has been making the rounds over the past one or two years. Today, it has become clear that hydrogen can be a defining link between these markets.

Such integration requires components that can convert one type of energy into another in the most efficient way possible. This is where electrolyzers come in. Depending on the model, their efficiency of converting electrical into chemical energy ranges from 70 to 80 percent.

The rising interest in the technology has led to the creation of a whole new industry: Whereas previously, many stakeholders from various, sometimes very different, markets had worked on their own electrolyzer solutions, the past years have brought about some new alliances. Numerous businesses have joined forces to explore new markets.

Fig. 2: ELYTE 30 by Areva H2Gen

Source: Areva H2Gen

Global market players

For example, Areva – a corporation owned by the French government – founded its own subsidiary for hydrogen, Areva H2Gen, a merger of the electrolysis divisions of Areva Energy Storage and French-based CETH2, and ultimately relocated to Cologne, Germany. From there, it has been planning to install a 2 MW plant in Leuna. This system is one of eight to be installed during the second HYPOS project run. The MegaLyseur project has a budget of EUR 11.5 million and had originally been scheduled to start in the fall of 2016, but grant approval has not been given yet. Carsten Krause, managing director of Areva H2Gen, said: “Unfortunately, the size of the project, the many partners involved and the requested alterations mean that the process is taking longer than expected.”

Another large global player with extensive experience was Norwegian-based Statoil, which had acquired its hydrogen expertise after merging its oil and gas operations with the ones of Norsk Hydro years ago. In 2006 at Hannover Messe, the business unveiled its Inergon® (see [HZwei issue from August 2006]), a PEM electrolyzer designed for decentralized hydrogen production in the medium output range (around 10 Nm^3 H_2 per hour). The H_2 division of Statoil, however, has meanwhile been renamed to Nel Hydrogen. In 2015, Norwegian-based Nel took over H2 Logic, which is based in neighboring Denmark and had already installed some refueling stations in Germany. Nel Hydrogen is now in the process of setting up production facilities in Herning, Denmark, to manufacture 300 H_2 filling stations each year. The most recent move was the takeover of Proton OnSite (see box) this February. It has not been clear yet whether another name change will be in order soon. Nel celebrated its 90th year of company history in Hanover.

Fig. 3: Drawing of Nel Hydrogen's C Series

Source: Nel Hydrogen

Across the Atlantic, the market leader has been Proton OnSite, formerly Proton Energy Systems. The 90-staff business was founded in 1996 in Wallingford, Connecticut, and has since installed more than 2,600 units. It partly owes its success to its engineers, who were able to limit high pressures to the hydrogen side of the system, so that oxygen generation does not require them. The main business integrating these devices in Europe is Swiss-based Diamond Lite. Another sales partner, at which Hans-Jörg Vock has a management position just as at Diamond, is BeBa Energie based in the German state of Schleswig-Holstein.

Nel acquires Proton OnSite

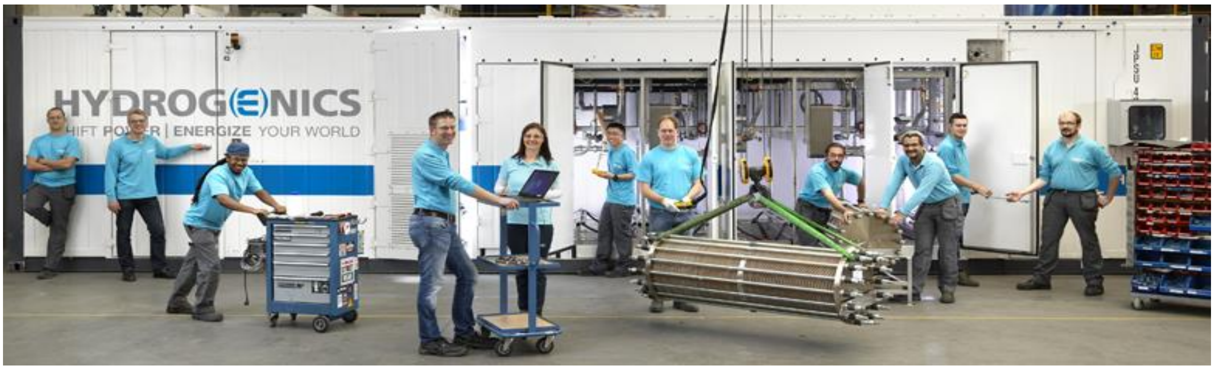
On Feb. 27, 2017, Nel announced that it intended to buy Proton OnSite. It said that there was a non-binding agreement between both partners. The price of the acquisition, which could be completed during the second quarter of 2017, is reported to match the current market value of Proton Energy Systems of USD 70 million, of which USD 20 million were to be paid out in cash. Additionally, Nel shares were to be transferred in two tranches after 12 and 24 months.

Jon André Løkke, CEO of Nel, explained: "We are proud to announce our intention of merging Nel and Proton OnSite and turn the company into the world's largest supplier of hydrogen electrolyzers." The Oslo-based energy corporation, which itself has had a production business for alkaline systems (see fig. 1), views Proton OnSite as "the number one provider of PEM electrolysis systems." The acquisition would mean both technologies can be covered by the new business. Said Løkke: “The combined entity will be able to offer the entire range of electrolyzer technologies and capacities.”

“We have always maintained that both technologies would keep their usefulness over the medium term and that there would not be a sole ‘winner’.” Franz Lehner, e4tech

Hydrogenics is another manufacturer of electrolyzers based on both alkaline and PEM fuel cells (see fig. 4). Headquartered in Canada, it also has locations in Belgium and Germany and more than 60 years’ experience in hydrogen technology. It has so far installed 500 electrolyzer systems worldwide, for example, an off-grid system with a 350-kW electrolyzer and a 120-kW fuel cell at Glencore’s Raglan nickel mine in northern Canada (see Hydrogenics – Record-High Order Figures).

Fig. 4: Electrolyzer manufacturing



Source: Hydrogenics

German-speaking region

The know-how gained by project planner Enertrag through the construction of the hybrid power plant in Prenzlau, Germany – which broke ground in 2009 – has meanwhile ended up at McPhy (see fig. 5). While the former has begun to again focus on wind power, the knowledge about large-scale hydrogen production and the division’s staff have been transferred to McPhy Energy Germany, which used to deal primarily in solid-state hydrogen storage. Besides the German subsidiary, the French parent company, which shortened its name to McPhy in mid-February 2017, also owns Italian-based Piel, a manufacturer of electrolyzers it acquired in early 2013.

Fig. 5: Container solution by McPhy

Source: McPhy

Additionally, GP Joule acquired Lübeck-based H-Tec Systems together with its sister company H-Tec Education, a business dedicated exclusively to the education industry, at the beginning of this decade. The manufacturing division of H-Tec is primarily concerned with the production of electrolysis stacks and systems and sells them as “power gap fillers” through its parent company (see fig. 2 on p. 20).

Uwe Küter, formerly managing director of H-Tec, has since founded his own consulting business, h2agentur, and represents clients such as Giner, a U.S. manufacturer of electrolyzer stacks that are installed by German startup iGas energy.

At Siemens, people are preparing for the Silyzer 300, which is said to be available from 2018. The device will be tested during EU project H2Future in Linz, Austria. Once started, the project targets a total of 6 MW of installed electrolyzer capacity. So far, Siemens has been producing the Silyzer 200 (PEM, 1.25 MW, see fig. 6) in Erlangen, Germany. It is rated as a commercial product, but considering its price tag of EUR 1.5 to 2 million, the hundredth unit was just sold not too long ago.

Fig. 6:

Source: Siemens

ELT Elektrolyse Technik, a years-long leader in alkaline electrolyzers, hasn’t fared that well. Before the new hype even started, the business filed for bankruptcy in late 2010. However, a new investor was found and operations could continue from early 2011 under the name ELB Elektrolysetechnik. Mate Barisic, managing director of

ELB and previously of ELT, told H2-international: “We have concluded a purchase agreement with the bankruptcy trustee about the assets of ELT Elektrolyse Technik, acquiring all of ELT in the process.” Barisic added that this measure had made it possible to keep part of the staff and the expertise of Bamag and Lurgi, from which ELT was spun off in 1995.

Other business operating on the market include IHT Industrie Haute Technology, a small company based in Monthey, Switzerland, and Sunfire from Dresden (see fig. 4). Based in the German state of Saxony, the latter has collaborated with corporations such as Boeing, with which it is currently testing a joint prototype in Hawaii. Another unit is said to be delivered to Salzgitter this summer.

It was also interesting to see what HydrogenPro presented during Hannover Messe: Founded near Oslo, Norway, in 2013, it has an exclusive partnership agreement for Europe and the United States with Chinese-based Tianjin Mainland Hydrogen Equipment, by its own account, the global leader in alkaline electrolyzers. In January 2017, HydrogenPro also managed to get hydrogen expert Hans Jörg Fell as CTO on board. Fell, who worked for years first at Norsk Hydro, then Statoil and Nel Hydrogen, and had a brief stint in the CO_2 capture and storage segment from 2013, presented in Hanover his new employer and its products.

Competitive by 2030

Most systems, however, are still in the testing or demonstration stage, as there hardly have been any viable business plans for their use. Additionally, the investment in such systems is comparatively high – on average, EUR 1,000 to 1,700 per kilowatt for PEM and EUR 600 to 1,000 per kilowatt for alkaline units. [1] One can expect, however, that at the latest in 2030, fuel produced by electrolysis at H_2 refueling stations can be offered at a price competitive to steam-reformed hydrogen.

[1] Study on development of water electrolysis in the EU, E4tech, 2014

Electrolyzer Market Overview

Energy Storage

Last November, H2-international published a first market overview of residential fuel cell systems. In this issue, we will take a closer look at electrolyzers. To try and map the current situation on the electrolyzer market, we contacted 18 manufacturers, primarily from the German-speaking region, but also from across Europe and North America. Ten of them have sent us details on their electrolyzers. Nine of them have made it onto the product list (see pp. 20/21); Diamond Lite and Proton OnSite provided virtually identical information. The data shown in the table was not independently verified by H2-international; it comes directly from the business involved.

However, some manufacturers did not want to be included in the table. One reason for declining the offer was that not all information requested by H2-international could be provided, meaning that potential customers would get reliable data, but that the data was not meant to be publicized – even if it were part of an anonymized list.

Considering the above, the list shown here is neither exhaustive nor complete. Moreover, we were aware when creating the table that the devices could not be adequately compared, for example, because manufacturers may use diverging methods to calculate unit efficiency. Please keep this in mind when viewing the table. Still, it is our hope that this list can give you somewhat of an overview of dedicated stakeholders and improve market transparency.

Tab.: Manufacturer overview

			dimensions (mm)				main application[1]				capacity range (% of nominal output)		Electricity			Feedwater		Hydrogen output	
Company	product	Type	height	width	depth	market status	chemical /industrial sector	fueling station	Power-to-Gas[2]	nominal hydrogen output (Nm^3/h)	min	max	kWh/Nm^3	AC or DC	Voltage	l/Nm^3	conditions	purity	pressure
AREVA H2Gen	ELYTE	PEM				comm (serial)		x	x	5 - 4000	20	120	5.7 - 4.7	AC	400	< 2	tap water	99,999	35
H-TEC SYSTEMS GmbH	EL 450 Electrolyzer	PEM	2591	2438	6058	field test	x		x	100	2	100	4,5	DC	500	1	ISO 3696 Grade 1	99,99	30
iGas energy GmbH	iEL 90-300 PEM MD 5.0 "Outdoor"	PEM	2926	2500	7500	comm (spec)	x		x	90	10	100	5,19	AC	400V, 3Ph	< 2	tap water	99,999	
	iEl 120-1250 PEM MD 5.0 "Outdoor"	PEM	2926	2500	9000	comm (spec)	x		x	120	10	100	5,4	AC	400V, 3Ph	< 2	tap water	99,999	40
	iEL 30-300 PEM MD 5.0 "Outdoor"	PEM	2926	2500	6000	comm (spec)	x		x	60	10	100	5,21	AC	400V 3Ph	< 2	tap water	99,999 Vol% H2	40
Inabata Europe GmbH	ELS1000	AEM	1910	800	800	comm (serial)	x		x	1	30	100	4,5	AC and DC		0,8		99,999	35
ITM Power	Hgas	PEM	2590	2440	6100	comm (spec)		x	x	3.5 - 2000	0	100	4.5 -5.0	AC	400	1.6	tap water, 2 bar	99.9999	20
McPhy Energy	McLyzer	alcaline				comm (serial)		x	x	Up to 400 per module	20	130	4,9	AC				99,999	30
Nel Hydrogen	Nel C-300	alcaline				comm (serial)		x	x	300	15	100	4,4	DC	6-30 kV	0.9	< 5 µS/cm	99,999	200
	Nel A-485	alcaline				comm (serial)	x		x	300-485	15	100	4,4	DC	6-30 kV	0.9	< 5 µS/cm	99,999	Flexible
	Nel C-300	alcaline				comm (serial)		x	x	150	15	100	4,4	DC	6 - 30 kV	0.9	< 5 µS/cm	99,999	200
Proton OnSite (Vertrieb über Diamond Lite S.A./AG	M Series	PEM	2410	12192	8737	comm (serial)	x		x	50 to 400 ; multiple units for higher outputs	0%	100%	5,3	AC, 50 or 60 Hz	Low (380 to 480V) or Medium (10 to 20 kV)	0,9	ISO 3696 Grade 2 acceptable, Grade 1 preferred	99.9995%	30 [3]
Proton OnSite (Vertrieb über Diamond Lite S.A./AG	H Series	PEM	1910	1800	810	comm (serial)	x	x		2; 4; 6	0%	100%	6,8	AC, 3-phase	380 to 480V, 50 or 60 Hz	0,9	ISO 3696 Grade 2 acceptable, Grade 1 preferred	99.9995%	15 or 30 [3]
Proton OnSite (Vertrieb über Diamond Lite S.A./AG	C Series	PEM	2007	5739	1159	comm (serial)	x	x		10; 20; or 30	0%	100%	5,8	AC, 3-phase	380/400/415V, 50 Hz or 480V, 60 Hz	0,9	ISO 3696 Grade 2 acceptable, Grade 1 preferred	99.9995%	30 [3]
Sunfire GmbH	SF 150/30 Hydrogen Generator	SOEC	650	1525	625	field test	x		x	40	30	125	3,6	AC	400 V	1.25	< 2 µS/cm	99,999	10
abbr.: comm (serial) = commercial status, serial product; comm (spec) = commercial status, customer specific product																			
remarks: 1 maximum to answers possible; 2 includes energy storage; 3 bar Ü																			

enlarge

The information compiled in this month's edition will be followed by data on products and components in the next issues of H2-international. And, of course, we will update these tables if the market situation changes, so that manufacturers not yet shown on this list will be included in the next.

H_2 Producers Show Confidence

Survey Among Electrolyzer Manufacturers

Energy Storage

When we compiled our list of currently available electrolyzers, we also asked manufacturers for their opinion on the market outlook of hydrogen technologies in Europe. Their assessment tended toward the positive; all ten businesses participating in the survey at least somewhat agreed that hydrogen technologies were developing at a satisfactory rate across the continent. They also expect a notable increase in demand for electrolyzers even before 2020.

However, optimism took a dive when the question came to EU policy on hydrogen. At least three of the ten businesses participating in the survey voiced their skepticism or even outright caution about current targets and methods. One point was electricity use, which is not referred to as storage in the context of electrolysis but as consumption in Germany and leads to a high tax burden.

All of them would wish for a better EU framework to support deployment on large markets, for example, as “green” hydrogen in refineries. One survey respondent suggested that it would be helpful to have the backing of the EC Legal Service. This could make it possible for member states to consider emissions at the start of the production chain when drafting national legislation. Another participant, who mainly favored the use of hydrogen in vehicles, had the wish that politicians would create incentives for operators of gas stations and vehicle owners. Direct distribution of renewable electricity from producers to operators of electrolyzers should be made possible as well.

Container solution by Sunfire

Source: Sunfire

In response to questions about financial support, most participants, in principle, favored better support of research and development. Considering that these are businesses operating on the market, it would be a surprise if they didn’t. However, since many of the manufacturers have, for the most part, passed the research stage, the priority is on incentives for real-life applications. Eight of the ten survey respondents would find it useful to expand renewable energy generation to produce more “green” hydrogen.

Author: Eva Augsten

H_2 Production by Water Electrolysis

Technology Trends and List of Manufacturers

Energy Storage

Fig. 1: Alkaline NEL electrolyzer at Akzo Nobel

Source: Nel Hydrogen

Splitting water into hydrogen and oxygen with the help of electrical energy is commonly known as water electrolysis. This process matches the oxyhydrogen experiments one may remember from the classroom, albeit in reverse. If the anode and cathode in an electrolyzer cell are separated by a semipermeable membrane or a diaphragm, the gases produced by the process can be directed out of the cell individually.

Due to the rising share of electricity generated from renewable sources and the subsequent transformation of energy supply, hydrogen production has gradually assumed a much more prominent role. As an electrochemical process, water electrolysis makes it possible to couple power generation with other energy-relevant industries (power-to-X concept).

Hydrogen or its derivatives produced from renewably sourced electricity can be used as storage media for renewable energy. They are not limited to being chemical substances, but can be found as a secondary energy carrier in stationary and mobile applications in several industries and markets.

The successful increase of the renewable share in Germany over the last 15 years and stronger government support have led to several German stakeholders becoming (co-)leaders in researching, developing and demonstrating the benefits of water electrolysis around the globe. They have launched many power-to-gas – and since recently, power-to-liquid – projects (P2G and P2L; see fig. 2). [1]

Fig. 2: Power gap filler in Reußenköge, Germany

Source: GP Joule

Technology trends

There are three relevant water electrolysis methods today: AEL, alkaline electrolysis using a liquid base electrolyte; PEMEL, acid-based electrolysis with a proton exchange membrane and a solid polymer electrolyte; and SOEL, high-temperature electrolysis with solid oxide as the electrolyte.

Particularly alkaline electrolyzers with liquid electrolytes, operated at around 80 °C, have been in commercial use for over 100 years (see fig. 1). In the mid-twentieth century, there were some electrolyzer systems with up to 140 MW and the hydrogen they generated was primarily used as a chemical element in fertilizer production. These modules are still available today. They are offered at below 10 MW, a cell surface area of up to 3 m² and can often be operated at ambient pressure. Modified versions of these modules are increasingly used for P2G applications.

More recent developments in alkaline electrolysis often come in compact size and integrated into standard containers (see fig. 2). They are mostly operated at between 10 and 20 bars of pressure. Current advancements put less of a focus on cell surface area, operating pressure or temperature, but on increasing the current density from today's around 0.2 to 0.4 A/cm² to about 1 A/cm² in order to lower specific capital costs. This increase is said to be achieved through using electrochemically more active electrodes, optimizing combinations of bipolar plates and electrodes (see fig. 3) and improved electrolyte management. One challenge of development is to retain a lifetime equal to conventional cell materials in alkaline electrolysis despite more complex catalyst systems and greater current density.

Fig. 3: Novel, flexible and production-optimized electrode package for current densities of up to 1 A/cm²

Source: ZSW

In the last 20 years, PEM electrolysis has become an established means of energy production primarily for industrial or niche applications requiring up to around 10 Nm³ per hour, high operating pressure and an operating temperature of around 60 °C. In principle, they can be combined with renewable energies (fast startup and shutdown, can be operated at intermediate load or absorb excess energy, able to handle high pressures while sporting a compact design, option to operate at differential pressure, etc.), which has led to considerable R&D efforts in almost all countries over the last ten years, both in industry and research institutions. One activity that was and still is the focus of development is the scale-up of cell surface area and, consequently, an increase in stack power.

Whereas the niche applications mentioned above typically had up to 200 cm² of cell surface, current modules in the low-megawatt category use cells with an active surface area of 600 to 1,500 cm² (see fig. 5).

The next generation of PEM cell stacks with 2,000 to 5,000 cm² of surface area are already under development. However, there does not seem to be a marked tendency toward higher operating pressures and temperatures. It is true that during the last years, there have been several presentations of stack prototypes with pressures below 100 bars, but from a user's point of view and because of the costs involved, the standard is gradually becoming 30 to, at most, 50 bars. A notable exception is the work at Honda and Proton OnSite, which develop cell stacks with 350 bars of pressure and above.

In contrast, current density is viewed as having much untapped potential. Cells available today typically operate at densities of 1 to 2 A/cm². The latest prototypes achieve up to 4 A/cm², whereas laboratories are experimenting with membrane electrode units above 10 A/cm². The latter number is thought to be achieved particularly through improved and thinner membranes and the use of more active electrocatalysts. Technically, the implementation of these cell designs poses no difficulties, but the question remains whether the new membrane electrode unit can also increase the lifespan of the system.

Table 1: List of selected electrolyzer manufacturers; see also pp. 16/17; data from 2017

Manufacturer	Country	Model	Type	H_2 pressure [bar(g)]	H_2 rate [Nm³/h]	Stage
EM Korea	KO	EHG EHP	AEL AEL	9.9 1 - 8	20 - 80 20 - 300	Commercial Commercial
Honda	JP	SHS	PEMEL	350	0.7	Pre-series
Hydrogenics	CA	Hylyzer	PEMEL	8	1 - 2	Commercial
Hydrogenics	BE	HySTAT (outdoors)	AEL	10	10 - 60	Commercial
Siemens	DE	SILYZER 100 SILYZER 200	PEMEL PEMEL	50 35	22 - 44 225	Prototype (field test) Commercial
Teledyne Energy Systems	US	Titan HMXT Titan EC Titan EL Titan EL-N	AEL AEL AEL AEL	11.3 7.9 – 11.3 7.9 – 11.3 10	2.8 – 11.2 28 - 42 56 - 78 100 - 500	Commercial Commercial Commercial
Tianjin Mainland Hydrogen Equipment	CN	FDQ FDQ	AEL AEL	50 30	2 - 60 80 - 400	Commercial Commercial

Source: Fraunhofer ISE, [2], [3]

High-temperature units

The current domain of high-temperature steam electrolysis continues to be the R&D stage. Individual cell stacks have a rating in the lower kilowatt range. The operating temperature typically is between 750 and 1,000 °C. The high working temperatures make it possible to operate the stacks in both fuel cell and electrolysis mode. This is also being touted as a benefit by the few suppliers and developers of solid oxide electrolysis cells. Consequently, nearly all SOEC developments are based on fuel cell materials from the SOFC and they may simply be adapted for electrolysis operation. Flat cell designs are clearly favored over tubular ones (see also fig. 6).

Recent R&D activities have focused on the materials themselves, for example, on how to reduce the internal resistance of the anode and increase the lifetime of this oxygen electrode or how to improve the porous properties of the cathode. In principle, lowering the operating temperature would be desirable for increasing system life, but is often dropped in favor of improved kinetic properties. A maximum pressure of around 10 bars is typically made possible by an additional outer pressure section. The use of ceramic materials has severely cut down the cell surface area of SOECs compared to PEMELs or AELs. This means that higher output ranges can only be achieved by adding ("numbering-up") stacks/modules.

Market overview and list of manufacturers

Despite the growing importance of electrolysis for intersectoral integration of the energy industry, there has only been a small, commercial market for water electrolyzers. Around the globe, one can find only few, mostly small businesses offering products in this segment. Besides established uses in industry, such as hydrogen production in power plants to cool generators, renewable storage remains a nascent market. Often, there is also a lack of sustainable business models to ensure commercial viability.

As seen in the table, many of the systems have indeed been commercially available around the globe. However, it should be noted that most manufacturers only produce them in small series or on demand.

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Got High Voltage?

Energy Storage

Jens Hanke

Source: Graforce Hydro

Graforce Hydro based in the Köpenick suburb of Berlin, Germany, is currently developing a high-frequency electrolysis solution. It would use an electric and a magnetic field to split water, explained Jens Hanke, Graforce's founder. He has been working on the idea in the Technology Park Adlershof since 2010. By his own account, the high-voltage field directly above the water surface "creates plasma like on the sun." The released electrons would split water into hydrogen and oxygen, he said.

Solar-sourced electricity could be used to operate such a plasma electrolyzer, as he calls the unit. A suitable PV system could be installed on the Center for PV and Renewable Energies or ZPV, which Graforce moved into in 2013. Hanke said that around 18 employees on the building's fourth floor were currently implementing his ideas. The aim was to produce hydrogen at 89 percent efficiency (conventional electrolyzers have 70 percent) and a price of EUR 2.80 per kilogram. These figures date back to as early as 2010 when Hanke researched the technology in collaboration with his colleague Ramin Radmanesh in Wittenberg.

At first, it was said that a corresponding "garage-based hydrogen generator" could be ready for the market in fall of 2014. Then, the date for commercializing high-frequency electrolysis was postponed to late 2016. Now, there has been another pushback to late 2017. Due to patent protection, there are no details on how the process works, for example, how hydrogen and oxygen are separate during the process. The announcement that hydrogen could be produced from water in an eco-friendly way at below three euros per kilogram should be taken with a grain of a salt, at least for the time being. Robowatch, which was headed by Hanke for 10 years before he founded Graforce, filed for bankruptcy in 2010.

Still, Berlin's water utility BWB intends to support the implementation of Hanke's H_2 plans, although it will first be mainly about testing out a "new" fuel. A BWB spokesperson confirmed that two Opel Combo were planned to be converted for running on hythane, a mixture of 30 percent hydrogen and 70 percent natural gas. It remains unclear whether the required hydrogen will be produced by plasma electrolysis.

Fuel Cells for Car Use

Energy Storage

Stijn van Els

This March, Shell presented a new study carried out in collaboration with the Wuppertal Institute for Climate, Environment and Energy. Focusing on transportation, the authors compared several different production pathways for hydrogen and took a closer look at the three regions spearheading global development: Germany, Japan and the United States. Jörg Adolf, who headed the project at Shell, said that hydrogen technology had made big advances over the past years, “not just in car use.” He added: “The fuel cell is, in principle, suited for all means of transport beyond their application in passenger vehicles.” Stijn van Els, chair of the German Shell companies, said in Berlin: “Battery and fuel cell complement each other. Fuel cell vehicles are also electric vehicles, and battery-driven ones require hydrogen technology, for example, to increase mileage.”

At the same time, it was stressed that the hydrogen technologies would need further support and incentives from the government. Another two areas needing improvement were social and consumer acceptance. “The current decisions made by the federal government based on the National Innovation Program Hydrogen and Fuel Cell Technology [NIP 2] are an important first step in the right direction,” the authors said.

Shell, Energie der Zukunft? Nachhaltige Mobilität durch Brennstoffzelle und H_2, March 2017

BMVI Approves EUR 250 Million Budget

Electric Transportation

Nationales Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie

As announced previously, the German federal transport ministry BMVI has launched its subsidy program to start up the market for hydrogen and fuel cell products in transportation. The first stage of the National Innovation Program Hydrogen and Fuel Cell Technology, or NIP for short, supported research and development activities as well as demonstration projects and came to an end last year. NIP 2 is now following in its footsteps. From 2016 through 2026, it is said to guarantee the continuation of R&D activities and assist with the introduction of the first products that have reached market maturity but are not yet competitive.

The grant guideline titled Measures for Market Activation was implemented on March 1, 2017, and has been the second BMVI measure based on NIP 2. The first one, Measures for Research, Development and Innovation, had already been published on Sept. 29, 2016. The BMVI has allocated EUR 250 million to both programs. During the NIP general assembly in 2015, EUR 161 million were expected to be put aside for program activities from 2016 through 2018. As planning has now been extended to include 2019, the budget was raised accordingly. Applications can already be submitted.

The program is aimed particularly at operators of fuel cell vehicles in public mass transport and commercial fleets of cities, towns and private-sector investors. It funds vehicles used on roads, rails, on water and for special purposes in logistics as well as the associated infrastructure, but also electrolysis systems to produce H_2. Additionally, support will be provided for non-stationary CHP systems and off-grid power supply.

The German federal economy ministry, BMWi, likewise continues its support of hydrogen and fuel cells in applied research and development as part of its sixth Energy Research Program with EUR 25 million annually – EUR 5 million more each year than originally stated. Additionally, the BMWi has been incentivizing purchases of residential fuel cells as part of MAP since last year. Overall, the current federal agenda includes pledges of EUR 1.4 billion in hydrogen and fuel cell support from 2016 through 2026.

H_2 Kit to Upgrade Combustion Engines

Interview with Thomas Korn, CEO of Keyou

Electric Transportation

Fifteen years ago, BMW had still been industriously working on hydrogen-based internal combustion engines. Over the course of eight vehicle generations, the carmaker based in the German state of Bavaria had tried to adapt conventional gasoline engines for efficient, low-emission operation with hydrogen. In 2009, however, BMW halted its efforts. Now, former employees of the corporation are planning to bring about the renaissance of the H_2 ICE and develop an upgrade kit, if only for the commercial vehicle segment. H2-international spoke with the manager of Keyou, a young business based in Unterschleißheim near Munich, Germany.

H2-international: Mr. Korn, you used to work on the H_2 ICE at BMW. What went through your head when it became clear that the hydrogen engine won't have a future at your former employer?

Korn: At that point, I had already been involved for over a decade in BMW's R&D activities and evaluation of different alternative types of engines. There had already been reliable data on battery-electric vehicles, cars with fuel cell engines and ones with hydrogen ICEs that are again being discussed today. Considering these results, I was certainly surprised to learn that development of the engine with the biggest customer ROI would no longer be pursued.

H2-international: What exactly were the reasons for halting development?

Korn: The Hydrogen 7 was developed with the intent to have hydrogen combustion engines approved by the California Air Resources Board as a third zero-emission vehicle technology besides electric and fuel cell engines. I should add that big carmakers are only allowed to sell conventional cars in California if they put a minimum number of zero-emission vehicles or ZEVs on the market as well.

I can clearly remember the immense effort that was invested in the testing stand at the Argonne National Laboratory in Chicago, the independent testing facility, to even be able to detect the already marginal Hydrogen 7 emissions found in 2008. They measured a NO_X value of 1 percent of today's Euro 6 threshold limit. All carboncontaining emissions were at the detection threshold. Despite these impressive results – the vehicle was indeed a good method to clean the air in inner cities – CARB decided not to accept vehicles with hydrogen engines as a third ZEV category. This decision made electric vehicles the go-to technology. Development resources were channeled into electric transportation and the hydrogen ICE was no longer an R&D goal at BMW.

Thomas Korn

Source: Keyou H2-international: Please give us a quick insight into the extent of your work at BMW. The Hydrogen 7 had already been equipped with a bivalent 12-cylinder internal combustion engine adapted for hydrogen use, correct?

Korn: The Hydrogen 7 was only a small step away from becoming a commercially viable product. Long lifetime and reliability are key characteristics of vehicles with hydrogen ICEs. However, a vast part of the potential of hydrogen combustion with respect to power density and fuel consumption had not been tapped yet.

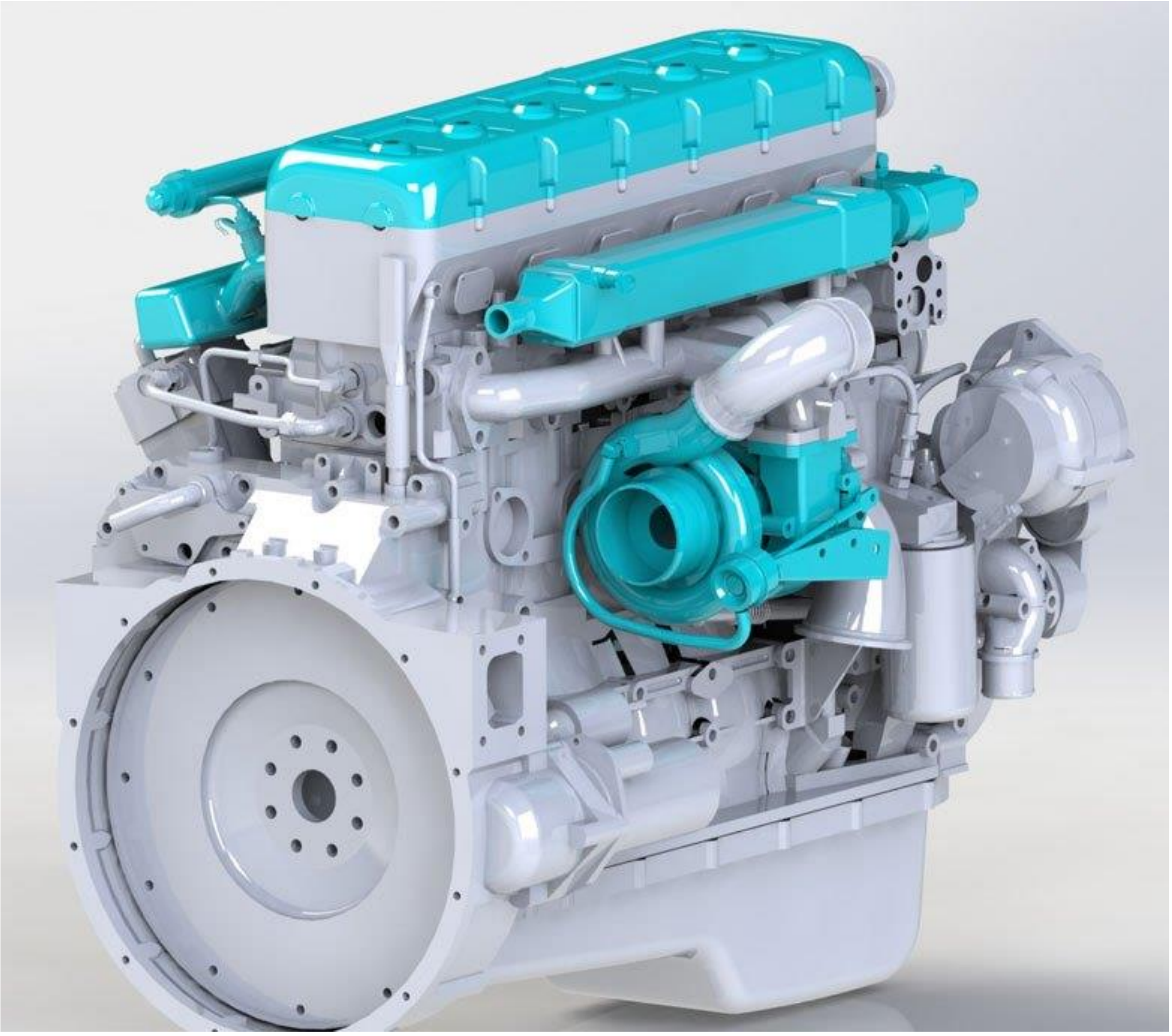
H2-international: How did you feel personally at that time? Why did you leave?

Korn: BMW’s decision was understandable considering it is an OEM and its core business is to meet the demands of the mass market. Because of the huge potential of hydrogen combustion, which we’ve just touched upon, the situation was disappointing for us engineers. Later, I realized the great potential offered by the technology and founded a startup to develop it further.

H2-international: I can still remember when we ran into each other ten years ago at Hannover Messe and started talking about adapting gasoline engines for hydrogen use. Sometime thereafter, you founded your own business, Alset Global, with the aim of developing an upgrade kit. What were you plans back then?

Korn: Alset was a startup in Austria, a country that had given serious consideration to hydrogen dual-fuel use. It’s an interesting approach to reduce the effort of upgrading conventional ICEs.

Fig. 2: Engine block with upgrade components



Source: Keyou

H2-international: On May 19, 2013, you presented your technology as part of an Aston Martin Rapide S during the 24-hour race on the Nürburgring (see [HZwei issue from July 2013](#)). After that, Alset disappeared from the headlines. What happened?

Korn: Adapting the Aston Martin for hydrogen use was a great challenge and a really fun project. Back then, I was in charge of development, but not involved in other business areas. This makes it difficult for me to determine what went wrong.

H2-international: What did you learn from that experience?

Korn: A startup offers an excellent platform for developing innovative engine technology and putting a successful product on the market by using an approach typical for these types of businesses. And that you should always keep an eye on all business areas.

H2-international: Now, you're starting all over again. What are your goals this time?

Korn: To develop a mass-market, zero-emission engine that offers customers benefits comparable to conventional vehicles at competitive pricing – meaning a real alternative to gasoline and diesel vehicles and an opportunity for the rapid deployment of many emission-free vehicles.

H2-international: You've said that Keyou had expertise on catalysts, H_2 injection systems and hydrogen storage. It would seem as if you were able to save a lot of the know-how gained during Alset times.

Korn: You learn new things with every new job. I worked at BMW for 13 years and four years at Alset. Our current technical design, however, has no longer anything to do with the previous ones at both businesses, but represents a new and innovative approach.

H2-international: Then could you please explain a bit what this innovative approach based on your patented H_2 SCR catalyst technology entails?

Korn: The multipoint injection easily integrated in a first step was replaced during development by mid-pressure direct injection. The combination of M-DI and turbocharger and the switch from stoichiometric combustion used at BMW and MAN to a low-temperature design have resulted in high specific output and excellent efficiency. The typical conflict between reduction in NOx and particles in a diesel engine when using a vapor recovery system is entirely resolved by using zero-carbon hydrogen. The rapid combustion of hydrogen makes it possible to utilize vapor recovery in an effective manner without cutting down on efficiency. Thanks to our special H_2 SCR catalyst, you have an even better guarantee that typical commercial vehicle operations will produce no emissions.

H2-international: Is it otherwise comparable to a CNG upgrade kit?

Korn: The switch from conventional to turbocharged low-temperature combustion significantly reduces the number of alterations that must be made to the base engine and closely matches the number of changes for past CNG upgrades. The effort to retrofit the vehicle is indeed identical.

H2-international: This time, your focus is on commercial vehicles. Any particular reason?

Korn: Current hydrogen storage units have an enormous advantage over the latest high-performance batteries, which becomes even more visible in the commercial vehicle segment. It translates into crucial benefits in terms of costs and maximum load or range. There won't be a real alternative to our design in this segment in the foreseeable future.

H2-international: And you can, in fact, use this kit to upgrade gasoline and diesel engines?

Korn: Our technologies allow us to adapt diesel engines for hydrogen gas use. We are currently focused on developing units for vehicles with 200 kW and more. Upgrading natural gas engines is less troublesome; gasoline ones don't play a role on the commercial vehicle market. However, the design is scalable and could be applied to them in time. A different output range, however, would require a redesign of upgrade components.

H2-international: Is it all but wishful thinking that a prototype could already be available in late 2017, or are there any binding agreements?

Korn: We will test the first engine this May. In late 2017, we will unveil the first prototype of a bus equipped with Keyou Inside technology. The bus that is going to be used is parked outside.

H2-international: Do you intend to develop these "conversion kits" entirely on your own or are you still looking for business partners to develop the technology?

Korn: We are collaborating with many partners, but see to it that the specific hydrogen know-how stays with the company.

H2-international: Whose backing do you have? Who is providing financial support?

Korn: The Nagel Group, a successful German-based machinery and equipment manufacturer, took over the entire first financing round. We are currently in talks with other interested investors.

H2-international: What makes you so confident that it will work out better this time than before?

Korn: All good things come in threes! In all seriousness, I think we're talking about a combination of several factors: First, this is a business of BMW and MAN employees who have come together and learned a great deal about the technology, the product and the market over the years. Their knowledge has gone into the innovative technical design, the business model and the market deployment strategy. And times have changed. Demand for clean and sustainable technologies is on the rise, but currently offered products are not able to compete with conventional vehicles. We believe that we can offer the right product at the right time in the right segment of the market.

In fact, we believe in a renaissance of the hydrogen internal combustion engine over the next years and hope that many OEMs will come to rely on our expertise and technologies.

Back to the End of the Line?

ISH in Frankfurt

Fair News

Source: E. Augsten

The most important trade show of the heating and sanitation industry, the ISH in Frankfurt, Germany, showed from March 14 through 18 this year what kind of heating systems are in demand these days. Fuel cells did not seem to play much of a role at the event. Only one of the big manufacturers of heating systems made news in this segment, and what for news: Vaillant is on its way out (see Vaillant Puts Fuel Cell Heating on Ice). Spokesperson Martin Schellhorn explained: "Technologically, everything's great, but the market isn't becoming sustainable. So far, the benefits of economies of scale have not materialized." Still, Vaillant would complete currently running projects (e.g., ene.field) and continue to maintain all installed systems thereafter.

The other exhibitors did not seem any more optimistic about the fuel cell's outlook than Vaillant. The only thing Buderus and Junkers had to announce was that "more than a hundred" systems of both brands had been installed, as estimated by spokesperson Jörg Bonkowski.

Vaillant's competitor Viessmann presented its fuel cell heating system Vitovalor together with a battery storage unit called Vitocharge. The combination of both devices is intended to provide more independence from the grid in residential buildings. Anyone who also buys a PV system can produce electricity during summer when the fuel cell operated based on heat demand shuts down due to a fully heated tank.

Elcore, based in the German state of Bavaria, painted a bit of a different picture. It was planning to create new sales channels, for which it had just established a partnership with Solvis, a manufacturer of heating systems from the solar industry. Several hundred installers are said to first undergo a one-day training course to install a combination of Elcore 2400 and SolvisMax, a system to be marketed through Solvis. The energy management system SolvisMax is a fully integrated heating device consisting of a 750-liter (or 198-gallon) stratified storage unit, a condensing boiler for peak loads and controls. Not a single watt will be lost, as the boiler is basically located inside the storage unit. Elcore's fuel cell device is placed next to it as a backup heater.

About a week before the ISH started, Elcore announced that German energy corporation E.ON had become a strategic investor in the business through a VC stake of below 10 percent. Philipp Ulbrich, who is in charge of E.ON's investment in startups, explained: "The fuel cell is the most efficient choice for system upgrades to generate heat and power." The first synergy attempts in sales are showing as well: Anyone intending to operate fuel cells completely CO_2-neutral can order eco-gas or eco-power from E.ON to meet remaining electricity demand. The eco-friendly natural gas is around one-tenth of a euro cent per kilowatt-hour more expensive than its standard counterpart, money that will go into TÜV-certified environmental projects. Other joint sales activities, however, remained mere speculation, said Manfred Stefener, managing director and founder of Elcore.

Elcore also showcased its own compact-size heating system, which focuses on space requirements rather than on technical integration. The device with a 390-liter (or 103-gallon) storage unit is said to be available in the second half of this year. That even the compact unit has a large storage tank compared to most other fuel cell devices was intentional, so that the 305-watt high-temperature PEM cell could possibly be run without having to modulate power output. This power could then be used almost completely as part of the baseload of a building.

Even pellet boilers and solar systems were seemingly not as ubiquitous as they had been just a few years ago. In the minds of heating system suppliers, "environmental protection" and "innovation" seem to be inextricably linked with "heat pumps" and "internet connection" today.

HPS presents: Picea

HPS Home Power Solutions – a spin-off from Heliocentris, which had filed for bankruptcy (see also: The Break-Up of Heliocentris) – unveiled at the ISH a novel and comprehensive approach to supply nearly all of a building with electricity from solar energy and hydrogen. This system called Picea entails a fuel cell, a battery storage unit, an electrolyzer and a hydrogen tank. The actual energy source is a PV system, which is not sold by HPS. Any solar power (10 kW for a four-people household) not used immediately will be stored in the battery. Once the battery is fully charged (at 25 kWh), the electrolyzer starts producing hydrogen. The H_2 tank outside the house has a capacity from 350 to 1,000 kWh and requires four to six square meters (43 to 65 square feet) to set up. (more information will be available in the July issue of h2-international).

Author: Eva Augsten

Rethinking Energy Policy

Energy Industry Warns of Barriers to Innovation

Energy Storage

The who's who of the energy industry met in Berlin, Germany, between Jan. 24 and 26, 2017, for the 24th annual assembly of German business magazine Handelsblatt in order to discuss developments in energy policy, assess risks and opportunities and develop scenarios for the path ahead.

Germany has so far invested more than EUR 200 billion in the transformation of its energy market. The share of renewables, however, is at a mere 13 percent of energy demand when looking at overall consumption (annual average of energy demand, baseload). But batteries are severely limited in storing renewable power. Conversely, “green” hydrogen and power-to-X are being redefined and are considered to have much potential.

Electricity (price, amount, availability) is not the only, nor the most important piece to the puzzle – especially for a country such as Germany that has a large manufacturing base; it’s “heat.” The latter is often neglected when discussing Germany’s EEG, as the renewable energy law focused exclusively on a power and heat market. But what about sector integration? How does power come from producer to consumer? What is the impact of advancing digitization on a changing energy market? What innovations, new technologies and business plans should you rely on?

Must the federal government rethink its strategy and rewrite the EEG? Do some taxes hinder the development and expansion of power production? Does politics provide the right answers to the energy challenge? The transformation on the electricity market needs to turn into one affecting the entire energy industry, was the agreed-upon notion by all speakers during the assembly meeting bearing the telling name “Energy Industry 2017 – Rethinking Energy.”

Energy transformation: digitized and European

The basic message of the event was that energy was to be thought of in pragmatic terms and be unburdened from government regulations. The incorporation of free-market principles, for example, when determining energy prices, was necessary to enable fair competition among suppliers of different energy sources, it was said. The CO_2 footprint (climate targets) was just as important as energy efficiency, decentralized energy generation, transport and prices.

Digitizing energy flows (smart metering, smart grid) through data analysis would allow for a successful implementation of energy market changes. Sector integration was as essential as it was necessary to put energy into a broader perspective (Europe and the world). Instead of serving special interests, attention should shift toward implementing the entire system (and away from micro-management issues) – always based on “digital” and “decentralized” means. The renewable energy law and the various costs associated with it (e.g., grid charges) have grown into a barrier to innovation, and politics has set targets that cannot be met.

Former economy minister Sigmar Gabriel plotted the course

Source: Handelsblatt

Battery technology is indeed advancing: ever-higher energy densities meet ever-lower prices. Hybrids (run by battery power or hydrogen) are thought to create big opportunities in the months and years ahead. However, it needs to be noted that today’s power grid would collapse if hundreds of thousands of electric cars were to draw electricity from it simultaneously. It needs new lines or grids.

Overall, the point is that renewable energies should become more prevalent in transportation and on the heat market. Current taxation has not lent a helping hand thus far. Participants of the conference said that charges and fees currently made up around 54 percent of the power price and the consumer paid the price (quite literally). Additionally, it was criticized that power consumers bore the brunt of the costs related to market transformation, paying a good EUR 25 billion per year.

The future belongs to fuel cells and H_2

Several presentations by representatives from well-known corporations, e.g. Siemens, ExxonMobil, Audi, pointed to the unique potential of hydrogen and methane as storage media through power-to-X (gas, heat, chemical) and their potential in combination with CO_2 (methanization) for carbon capture and in electric transportation. Batteries can only store large amounts of regenerative energy in a very limited fashion, but the energy can be stored in hydrogen through electrolysis and distributed via gas lines until power demand prompts a reconversion into electricity.

In short

The EEG should not only be revised, but entirely rewritten to make room for adjustable, inexpensive and environmentally friendly energy supply in the form of power and heat, and in transportation. Politicians, however, do not yet seem to fully appreciate the many intricacies of the development. In addition to batteries, it will be fuel cells and hydrogen that will grow in importance in their many fields. China – and apparently soon the United States – will put on the pressure, manufacturing more products based on these energy sources domestically and increasing their use in electric transportation. Support should be provided for innovations related to technologies, new business areas and all types of digitization of the energy industry.

Author: Sven Jösting

Charging Infrastructure Revisited

Electric Transportation

Inaugurating the 100th charging point at German freeways in January 2017

Source: BMVI

In mid-February 2017, the European Commission approved the federal government's incentive program for establishing a charging infrastructure in Germany. This EUR 300 million project has been open to applications since March 1. In late April last year, the German chancellor agreed with carmakers to provide a tax-funded budget for charging points on top of the incentive money for electric vehicles. It provides EUR 200 million for setting up 10,000 charging stations across the country and EUR 100 million for a minimum of 5,000 fast chargers (see HZwei issue from July 2016).

Incentives are granted for the grid connection of charging points, their construction and assembly. To receive funding, applicants must make the station accessible to the public and source electricity from renewable energies. A supplementary program is the one for electric charging stations themselves, with the objective of establishing a network at freeways. However, the Green Party's expert on transportation, Stephan Kühn, said that both programs would not guarantee an "extensive charging infrastructure without blind spots." He also thought that the expansion was moving along much too slowly.

Busy Association Schedule

News

Spring traditionally means a full calendar for members of the German Hydrogen and Fuel Cell Association, or DWV for short. It is the season in which industry stakeholders meet at Hannover Messe and the Energy Storage Europe, but it is also the time to prepare the annual member assembly, which was held in Erlangen on May 12 this year. Additionally, the DWV often organizes a so-called "parliamentary evening" in the first half of the year; in 2017, the topic that evening on March 30 in the French embassy in Berlin was sector integration. On top of that, the association's deputy chair, Johannes Töpler, has been busy this year trying to breathe new life into the hydrogen industry in the German state of Bavaria.

His efforts have led to the first Bavarian Hydrogen Forum, which took place in Energiepark Hirschaid on April 1. Together with Frank Seuling, the organizer of the fourth element-e energy trade show, Töpler is seeking to give hydrogen technologies again a more prominent role in the debate over the future energy supply of the region. Around 2000, Bavaria used to be a leader in H_2, but politics has seemingly all but abandoned the technology by now.

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read more: www.h2-international.com

Events

- June 19th to 22th, 2017, 17th Advanced Automotive Battery Conference, in San Francisco, CA, USA, www.advancedautobat.com
- June 27th to 28th, 2017, International Hydrail Conference, in Graz, Austria, www.hydrail.org
- July 4th to 7th, 2017, European PEFC & Electrolyser-Forum, in Lucerne, Switzerland, www.efcf.com
- August 28th to 30th, 2017, China International Hydrogen and Fuel Cell Exhibition (CHFCE 2017), in Beijing, China, http://en.chfce.com
- September 10th to 13th, 2017, Hydrogen + Fuel Cells NORTH AMERICA, in Las Vegas, USA, www.h2fc-fair.com/usa
- September 18th to 22th, 2017, European Summer School on Hydrogen Safety (ESSHS), in Athens, Greece, www.jes-school.eu
- September 20th to 22th, 2017, 2nd FC EXPO Osaka, Osaka, Japan, www.fcexpo-kansai.jp

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
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Energy Storage

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

- **HPS Home Power Solutions GmbH**, Carl-Scheele-Str. 16, 12489 Berlin, Germany, Phone +49-(0)30-5169-5810, mail@homepowersolutions.de, www.homepowersolutions.de

- hydrogenious TECHNOLOGIES

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

- VIESSMANN

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Event Organizers

- HANNOVER MESSE
  HYDROGEN FUEL CELLS BATTERIES GROUP EXHIBIT
  April 24-28 2017
  Hall 27, C66 Exhibition Grounds Hanover, Germany

  SOLARPOWER INTERNATIONAL
  HYDROGEN FUEL CELLS NORTH AMERICA
  September 10-13 2017
  Mandalay Bay Convention Center Las Vegas, NV, USA

  24rd Group Exhibit Hydrogen + Fuel Cells + Batteries, HANNOVER MESSE 2018, April 23 – 27, Tobias Renz FAIR, Tobias Renz, tobias@h2fc-fair.com, www.h2fc-fair.com

- EFCF.com EUROPEAN FUEL CELL FORUM
  PEFC & Electrolyser July 2017
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- WORLD OF ENERGY SOLUTIONS
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Hydrogen Distribution

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

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

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- **ElectroChem Inc.**, 400 W Cummings Park, Woburn, MA 01801, USA, Phone +1-781-9385300, www.fuelcell.com

- **HIAT gGmbH**, Schwerin, Germany, CCMs / MEAs / GDEs for PEFC, DMFC & PEM-Electrolysis, www.hiat.de
- **Kerafol Keramische Folien GmbH**, Koppe-Platz 1, 92676 Eschenbach, Germany, Phone +49-(0)9645-884-30, Fax -90, www.kerafol.com/sofc
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System Integration

- **Areva GmbH**, Paul-Gossen-Str. 100, 91052 Erlangen, Germany, Contact: Mrs. Gemmer-Berkbilek, Phone +49-(0)9131-90095221, www.areva.de
- **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

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

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