INTERNATIONAL NEWSLETTER FOR HYDROGEN AND FUEL CELLS

H2 international

H2-international – e-Journal

November 2015

This is the second official issue of the new H2-international e-journal.

All registered subscribers receive this pdf-file of this e-journal (31 pages).

Because of the interest the 25 % early-bird-discount is extended until the end of the year. This means new subscribers only have to pay USD 148.50 (135 Euro).

Content

- News & Articles – Published in November 2015
- Events – Timetable for Trade Shows and Conferences worldwide
- Companies – List of Global Manufacturer, Suppliers, Sellers, etc.
- Specials – Free Tickets & Discounts
- Imprint & Social Media – Stay in Contact

FC on board – MFC & SOFC in maritime applications

The SOFC system from sunfire©

Fuel cells are considered to be all-round talents. That is why their use in the maritime sector is being continuously tested out. Until now, however, a successful breakthrough is yet to have occurred in this field. Nonetheless, as before, a variety of companies are trying to gain a foothold in this challenging area of potential application with their systems. The company Siqens GmbH is currently testing its high temperature methanol fuel cell (HT-MFC) on board a sailing vessel, while sunfire would like to put its solid oxide fuel cell, which has thus far only been used on land, to use on water as well.

Siqens is still a young company. It was founded in 2012 and has set itself the goal of being able to offer market-ready fuel cell systems from 2017 onwards. The key focus of its work right now is on the *Ecoport 800* energy converter, a methanol-based fuel cell which delivers an output of 800 W for 48 hours with 20 liters of fuel. The system has been designed together with the Danish membranes manufacturer Danish Power Systems (DPS) for a wide variety of possible applications – from weather-independent APU systems in mobile homes, sailing boats and vacation chalets, to range extenders, through to independent power supply systems that are used in industry. For further development and market introduction in the scope of a two-year project Siquens has received 2.3 million Euros in financial support from the EU.

At the Sail 2015 trade show in August, together with ttz Bremerhaven, Siqens presented a sailing vessel, the *MHD Marleen*, on which a pre-series model has been installed along with a battery as a buffer storage unit. The vessel's owner, Hermann Behrens, told H2-international that in the future, his goal is to not only be able to use undiluted methanol for the fuel cell, but for the combustion engine as well. Behrens reported that the supply lines are now available and the diesel engine is also suitable for methanol. He is also working on the replenishment of the fuel at the same time. In this respect, he explains that he favors methanol filling stations such as those that now exist in China, because supply on this basis is far cheaper than refueling with methanol canisters. He has already discussed this topic with ship owners and yacht owners.

Behrens is confident that both the further conversion of his boat and the approaching discussions will proceed positively, so that the technology which is used can eventually go into use in HGVs, for instance. Since, as he explains, the use of fuel cells in shipping is “the toughest of applications,” other areas could also benefit from this development at a later day.

sunfire supplies SOFC stack

sunfire, in comparison, is setting sail with systems that offer a considerably higher performance. As planned, in August the Dresden-based company delivered one of its SOFC units to ThyssenKrupp Marine Systems. In the scope of the *SchiffsIntegration BrennstoffZelle (Ship Integration Fuel Cells / SchIBZ)* project, the high temperature fuel cell model, which now boasts 50 kW rather than the originally intended 40kW, will initially be used on land as part of the pioneering NIP *e4ships* project, before being tested at sea in 2016 on the freight vessel *MS Forester* owned by shipping firm Braren. Here, it will be responsible for 25 to 50 percent of the on-board power supply. Low sulfur diesel is to be used as the fuel.

The optimized use of HT-PEM fuel cells in CHP units

Reformer, developed by ICI-Caldaie Spa

Intelligent power networks and smart grid systems are demanding increasingly decentralized technologies that combine the storage and conversion of energy. Before this backdrop, in the scope of the EU’s *CISTEM* project (*Construction of Improved HT-PEM MEAs and Stacks for Long Term Stable Modular CHP Units*), a

combined heat and power technology (CHP) has been developed on the basis of high temperature polymer electrolyte membrane fuel cells (HT-PEM FCs), which is able to provide an electrical output of up to 100 kWel. In addition to electricity generation, the heat produced by the HT-PEM fuel cell is used locally and/or for the purpose of district heating. The system is also configured flexibly in terms of its fuel use, so that it can be operated with both hydrogen and oxygen which can be provided through electrolysis, as well as with natural gas.

The basic idea behind the project is a combined development of the fuel cells and a CHP system design. This combination offers the possibility of developing an optimized fuel cell technology for the specialist requirements of a CHP system as per the efficiency, costs and lifespan. Furthermore, the CHP system development is also able to incorporate the specialist advantages and disadvantages of this technology in order to ensure an optimized design of the fuel cell system.

The *CISTEM* project aims to demonstrate the practicality of the HT-PEM technology in medium sized CHP systems (5 to 100 kWel). For this purpose, a CHP system with an output of 100 kWel was installed in a HiL environment (hardware in the loop) for demonstration purposes. A CHP system of this scale is especially suitable for generating electricity and heat at the local level (for example, at a housing development with several family homes). The system under construction right now is of a modular configuration and is comprised of fuel cells, each of which has two stacks with 4 kWel and one reformer. This strategy of interconnecting smaller modules offers the option of being able to adapt the size of the CHP system to a wide range of applications with scalable performance requirements, for different sizes of building or the energy supply requirements of specialist peak power generating systems, for instance.
Within CISTEM at least two 4 kWel stacks are being used as hardware along with a reformer as a module. A further 14 modules are being used in tests as emulated modules in hardware in the loop (HiL).

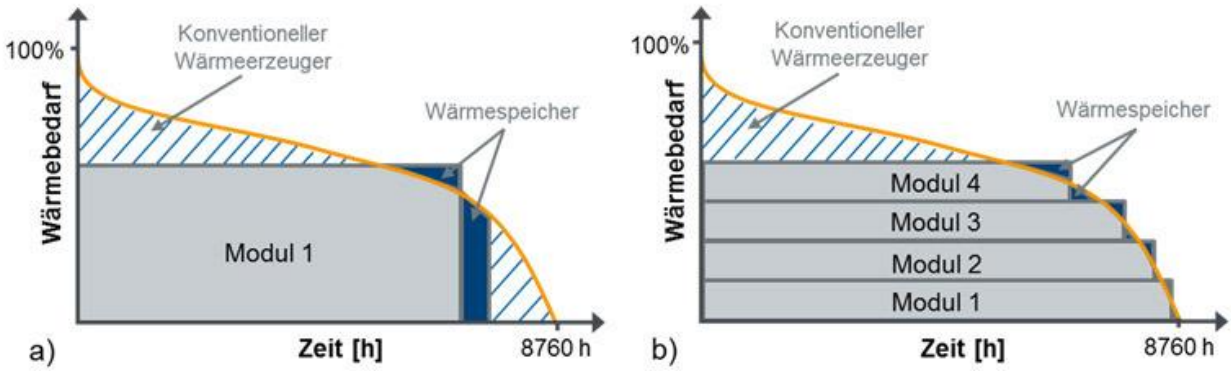
The advantages of this 8-kWel module are as follows:
- Lower manufacturing costs due to simplified production
- Higher system efficiency due to the targeted incorporation of the different modules
- Servicing and maintenance work possible during operations (“on the run”)
- Higher stability and reliability as well as higher utilization factor of the entire system

Combined with the upwards-scaling to a max. of 100 kWel, the HiL approach enables the simulation of different application and climate conditions which depict the differing load requirement profiles in northern, central and southern Europe. In this way, the control of the CHP system can be optimized in accordance with these load profiles.

An increase in the electrical efficiency of the fuel cells is achieved with both the use of the oxygen from the electrolysis, which is not normally used, and through general improvement to the fuel cells which are used. In addition to this, the overall energy efficiency can also be increased in district heating systems through the additional use of the generated heat. The latter is possible due to the higher working temperatures of the HT-PEM fuel cells of between 140 and 180 °C.

A key point of CISTEM is the optimization of the membrane electrodes units (MEA) in relation to the lifespan and the performance development. For this purpose, the PBI based membranes, the catalyst and the design of the MEAs have been developed further and modified. These individual cells boast a high lifespan and also stand out with degradation rates of less than -4 µV/h during long term tests under constant loads as well as with hydrogen and air as the operating gases. The especially low degradation rates mean that well over 20,000 operational hours can be expected. These new MEAs are used in small test fuel cell stacks as well as in the complete stacks which have been installed in the final modules. Materials for bipolar plates and gaskets from the project partner, Eisenhuth, have also been tested and developed further.

With these beyond state-of-the-art MEAs, as well as ones which are state of the art, a wide range of experiments have been carried out in the project, such as long term tests and accelerated ageing tests for individual cells and small stacks of fuel cell test stands. The characterization of these cells has taken place on an electrochemical basis with the help of current/voltage characteristic curves, impendence spectroscopy and different voltammeter methods. These electrochemical processes are complimented with product water analyses in order to determine the platinum and/or phosphoric acid discharge. With the help of ante- and post-mortem imaging methods such as scanning electron microscopy and micro computer tomography, it is possible for mechanical and structural defects and/or the thermal relaxation behavior within an MEA to be highlighted.



Process description of the annual load curve, a) conventional configuration; b) modular,

© CISTEM

A further method in the area of degradation research is mathematical modeling. With the help of this approach, among others, the influence of flux field geometries or different operational strategies on the degradation of the individual cells and stacks can be calculated and forecast. For this purpose, the results of the laboratory tests are applied to fuel cell test stands. In an initial step, a two dimensional mathematical model of an HT-PEM fuel cell stack consisting of 100 individual cells was calculated and transferred into a three dimensional model.

In the following step, the stationary model was adapted to a dynamic model. During the generation of the fuel cell stack model, the data of the components developed in the project (for example, bipolar plates including flow fields) were used in addition to the test results. With the help of the dynamic 3D models, it is also possible to

determine parameters such as the level of materials use and the flow resistance, and to adapt them accordingly.

During the planning and development of the CHP system, the lifespan, the costs of the individual components, and ensuring the highest possible electrical effectiveness of the overall system were all taken into account. Furthermore, during the configuration of the system it was also necessary for the legal and safety-related technical requirements to be considered. In addition to the development of the individual system components (the reformer and processor, for example), these were also tested, adapted and integrated in the overall system. In the scope of the CISTEM project, all of the components for two 4-kWel stacks and the module were constructed and tested. This includes both the design of two complete fuel cell stacks as well as a reformer (see image 1).

To guarantee an appropriate configuration of the CHP system, a concept was developed which takes both the system factors into account (module size, system parameters, operating strategy) as well as the regional requirements in Europe (north European countries like Norway/Finland, central Europe with Germany, or southern Europe with Italy and Spain) On this basis, an optimized operational strategy was confirmed.

Eight partners from the fields of industry and research from five European countries are cooperating in the *CISTEM* project:

- Next Energy EWE-Forschungszentrum für Energietechnologie (Research Center for Energy Technology) e. V., Germany
- Danish Power Systems APS, DPS, Denmark
- inhouse engineering GmbH, Germany
- Eisenhuth GmbH & Co. KG, Germany
- Universidad de Castilla – La Mancha, UCLM, Spain
- Vysoka Skola Chemicko-Technologicka v Praze, UCTP, Czech Republic
- ICI Caldaie Spa, Italy
- Öl-Wärme-Institut (Oil Heat Institute) GmbH, OWI, Germany

The authors wish to thank the European Commission, which is supporting the CISTEM project as part of the Seventh Framework Programme (GA number: 325262, duration 01.06.2013 – 31.05.2016).

Authors:
Dr. Alexander Dyck, alexander.dyck@next-energy.de
Peter Wagner, peter.wagner@next-energy.de
both Next Energy · EWE-Forschungszentrum für Energietechnologie e.V., Oldenburg, Germany

116 radio masts are equipped with FC systems

BOS in Brandenburg, © CPN

The area of USV systems – along with the mobility sector and the supply of domestic energy – offers a wide range of possible applications to fuel cells. Since 2010, the *Clean Power Net (CPN)* sector network has been focusing on companies which work in the areas of the uninterrupted and off-grid supply of electricity, or Smart Grids. One of the most important projects in this field is the large-scale order to the value of 6.6 m. Euros for equipping more than 100 radio masts in Brandenburg, Germany, with fuel cell systems for the purpose of emergency power supply.

In the course of modernization measures, in recent years, the radio operations of authorities and organizations with security tasks in Germany (police departments, the fire department, technical relief, etc. – in Germany aka BOS) have been changing over from analog to digital radio technology. With 500,000 users, the new BOS digital radio network in Germany is the biggest of its kind in the world. As part of the changeover measures, in the federal state of Brandenburg, a total of 116 fuel cells are going into use as emergency power systems at the base stations of the BOS digital radio network to ensure reliable electricity supplies. The fuel cells are set to function as USV systems and replace the diesel generators that have been used in most cases.

In the field of German digital radio communications, the widely used TETRA standard (terrestrial trunked radio) is used. Fourteen European countries already have a network of this kind, and along with Germany, eight countries are currently building one and another two are planning to. For Henrik Colell, the spokesman of CPN and managing director of the Berlin-based fuel cell manufacturers Heliocentris, this widespread use is a key advantage. He believes there to be great potential in equipping numerous new locations with fuel cell technology if the current field test is

a success. Then, the potential market would not only encompass the 4,500 base stations which are currently available in the German BOS digital radio network, but thousands more – throughout Europe and the world.

Initially, however, as part of the BOS field test, the FC emergency power systems will be examined for around two years (approximately until March 2016) and run in parallel to the actual operations. If their use proves to be a success, a further roll-out can then be considered. Colell made the following statement when the order was awarded in February 2014: “This order clarifies the huge trust and potential that authorities can see in fuel cell technology, since if an outage or interruptions were to occur, they would result in supply shortages and a considerable impairment to public safety.”

During this field test in Brandenburg, PEM systems from two different manufacturers will go into use which will be installed by a total of three competing groups of companies. The then independent company FutureE Fuel Cell Solutions was awarded the contract to equip 53 base stations with *Jupiter* type USV systems together with its service partner, adKor GmbH. Every two units of this 48V fuel cells module provide an output of 4 kW, and as per the requirements, they are installed in a robust casing (resistance class 4) and sufficiently protected for outdoor use. Mark-Uwe Osswald, the founder of FutureE, explained: “We are convinced that in the future, fuel cell systems will play an increasingly important role in the field of emergency power systems as an environmentally friendly alternative to conventional solutions. We are planning more projects across Germany with adkor.”

A further 25 locations have been awarded to Heliocentris and FutureE along with their service provider telent. With this second project, their fuel cell solution has been extended with the energy management system from Heliocentris and integrated in a container together with the hydrogen unit in order to ensure a straightforward installation. Ayad Abul-Ella, CEO Heliocentris Energy Solutions AG, explained: “By using one of our modular and flexible energy management systems, we can achieve the highest levels of transparency through the monitoring of the emergency power system, and enable smooth and above all uninterrupted operations at the locations.”

In June 2014, Heliocentris Energy Solutions AG took over FutureE Fuel Cell Solutions GmbH, a move on which Ayad Abul-Ella had the following to say: “This means that we have established ourselves as a leading supplier of energy solutions that are based on fuel cells for the safeguarding of radio masts for radio communications between authorities in Germany.”

The third batch was awarded to the consortium of Mastbau Gärtner (MBG), Hoppecke/ReliOn, Generex and AdPos. The Berlin-based company MBG is falling back on the *E-2500* and *E-1100* fuel cell modules from Plug Power. In addition to its FC units for low-floor vehicles (*GenDrive*), the American (USA) company also has its own brand for stationary back-up modules (*ReliOn*) which are going into use here. Short power outages that last less than 15 minutes are bridged by the accumulators which have also been installed at all three providers. In the event of longer power outages, the fuel cell then supplies the locations with electricity. The first systems entered test operations in the summer of 2014.

According to Prof. Siegfried Rolle from Wildau University of Applied Sciences, the emergency power systems have to be configured for a total bridging period of 72 hours. Rolle is the Director of the Laboratory for Regenerative Energy Technology at Wildau University of Applied Sciences (THWi) and is providing the project with scientific support. For his investigative work, a demonstration container was constructed at the THWi in which an FC emergency power system is installed that has a nominal output of 2.5 kW.

Prof. Rolle made the following comments on why fuel cells are superior to diesel generators: “Diesel generators are high maintenance, environmentally unfriendly, and over the long term, increases in the price of diesel can be expected due to limits in its global availability. The FC emergency power supply system constitutes an environmentally friendly alternative: along with its other attributes it is low maintenance, reliable, almost silent to operate, and through the straightforward extension of the fuel store, it is also flexible in terms of its bridging duration. Furthermore, if hydrogen is used, a major fuel leak would not cause any damage to the environment.”

A long run-up

After the German federal government decided to create the requirements for the step-by-step introduction of digital radio throughout Germany to replace the analog radio in 2003, the implementation took more than ten years. On December 31st 2014, the Digital Radio BOS Brandenburg project was completed. On January 1st 2015, the Authorized Agency for *Digital Radio in the Federal State of Brandenburg (AS DF)* began operating, since when it has served as the operational control center for all of the authorities and organizations with security tasks in the state.
The presentation of the government grant in total of 3.17 m. Euros for the “Hydrogen emergency power systems for authorities and organizations with security tasks in the federal state of Brandenburg” project took place on November 26th 2012.

H2 production under way in Dormagen

Reformer in Dormagen (Source: Air Liquide)

Over a construction period lasting two years, Air Liquide has constructed a new natural gas reformer in Dormagen. The French gases company has invested

approximately 100 million Euros in the facility which is situated at the Chempark industrial park near Leverkusen, Germany, with the goal of producing hydrogen and carbon monoxide there which are required by the local industrial firms. As detailed by the company, the facility will be one of the most modern steam reformers in the world. The facility, which is 54 m in height, is able to produce 22,000 tonnes of hydrogen (= 25.000 Nm3 per hour) and 120,000 tonnes of carbon monoxide per year from natural gas and water vapor. The lead buyer of these gases is Covestro AG (until August 31st 2015 Bayer MaterialScience AG), which requires large volumes of H2 and CO for its TDI system (toluenen-diisocyanate), in which polyurethane is manufactured for use in mattresses and polyester. To enable other companies to be supplied, the facility is also connected to the 600 km long Rhine-Ruhr pipeline for H2, N2, and O2 owned by Air Liquide.

In comparison with *HyCO4*, the natural gas reformer of competitor Air Products, which entered operation in Rotterdam in 2012, the facility's production capacity is five times lower. Totaling 16,000 m2, the surface area is also smaller (compared with 25,000 m2 at HyCO4), although the constructed steel volume (2,500 tonnes) is two and a half times the size of that at the plant in the Netherlands.

Plug Power takes over HyPulsion

The HyPulsion joint venture has now been owned in full by Plug Power since August 2015. As announced by the American (USA) company on July 27th 2015, it has acquired all of the shares in its former partner Axane, a subsidiary of the gases company Air Liquide. The New York-based manufacturer of fuel cells paid US-$ 11.5 m. for 80 % of the shares. In 2012, Plug Power and Axane joined forces to form HyPulsion, primarily with the goal of kick-starting the market for fuel cell forklift trucks. Andy Marsh, managing director of Plug Power, made the following comments: "We are now moving ahead with optimism to extend our presence in the European materials handling market. […] I am pleased that our collaboration with Air Liquide for the further development of the hydrogen sector in Europe is continuing."

Power-to-gas is now en vogue in Europe

ITM-system in Ibbenbueren (Source: ITM-Power)

The political statements are now being trotted out on an almost weekly basis. This should come as no surprise, since more power-to-gas projects are now starting than ever before. We repeatedly hear things like “PtG technology has the potential to lead the energy transition to success.” Such statements were to be heard most recently, for example, at the commissioning of the facility in Ibbenbüren and in Mainz, and also at the initialization of the project in Solothurn, Switzerland.

On some occasions the speakers sound keen to outclass each other with extravagant statements. They usually say the same kind of things, however: sometimes something like: “The production of hydrogen using environmentally friendly electricity is a major step forwards on our path to protecting the climate,” or sometimes: “The process has the potential to play a key role in the energy transition (Energiewende).” The words “innovation”, “key technology” and “power network stability” are also frequently to be heard.

The people who speak such words, and where, are of less importance. What is important is the core message, which is that both in Germany and now across Europe, most of those responsible for energy policy have made a clear commitment to power-to-gas technology, which they see to be an important component in the energy supply systems of the future.

Mainz Energy Park officially opened

One place that has also made a major contribution to raising the profile of PtG technology is the recently opened Mainz Energy Park, the ground-breaking ceremony of which was also attended by Vice Chancellor of Germany and Federal Minister of Economic Affairs Sigmar Gabriel. After a period of construction lasting one year, on July 2nd 2015, the Energy Park celebrated its official opening with a major fanfare. In the presence of numerous big names from the worlds of politics and business, the chairmen of the participating partners pressed the button together (see image 1), getting the research project to the value of 17 million Euros under way. The chairman

of Siemens, Prof. Siegfried Russwurm, somewhat loftily described the project as being a “bridge from the initial vision to the industrially-appropriate reality.”

Opening of Energy Park Mainz (Source: Stadtwerke-Mainz)

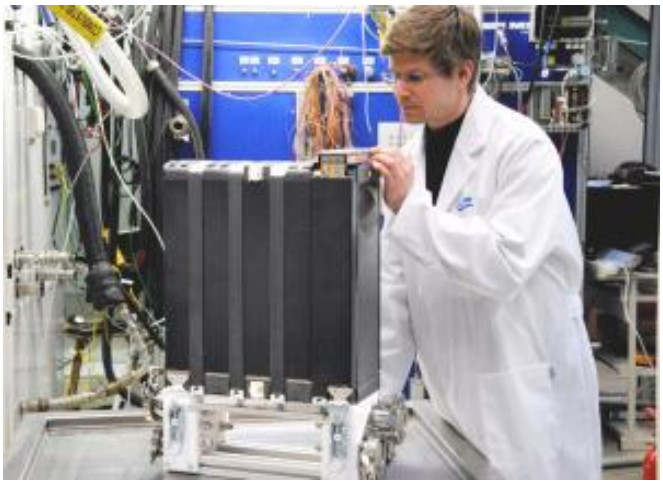
PtG facility in Ibbenbüren now up and running

Six weeks later, a similar button was also pushed in Ibbenbüren (the one there was green, however, and a lot bigger). On August 17th 2015, a new power-to-gas facility was also officially opened there which, according to a press release “combines the local supply of electricity, natural gas and district heating in an efficient way”. The opening event for the facility was also attended by numerous representatives from the worlds of politics, business and the energy and science sectors. In use at the site is a PEM electrolyzer from British manufacturer ITM Power, which has a power input of 150 kW and produces hydrogen gas at 14 bars (30 m3/h). Since its excess heat is used in the neighboring pressure regulator station, where it preheats the gas, the facility has a comparatively high level of effectiveness of 86%.

Hybrid power for Solothurn

At the end of June 2015, the hybrid Aarmatt facility entered operation in Solothurn, Switzerland, which combines all four of the supply media of gas, electricity, heat and water. The connecting element in this pioneering project is a PEM electrolyzer from Proton Onsite (*Hogen C30*, input power: 350 kW), which is operated with excess electricity from renewable sources of energy. This facility, which was installed by the Swiss company Diamond Lite, is situated on the site of the Solothurn public utilities, on which a 6-MW cogeneration plant with a district heat connection has also been built. The second construction phase saw the recent completion of three 1MW cogeneration units as well as the electrolyzer, which has a hydrogen storage unit. A methanization system is set to follow later, to enable pure hydrogen or methane gas to be directly fed into the natural gas network, and for the optional use of the methanized H2 gas at the CHP facility.

Development of a European FC Stack at ZSW



Stack installation in a test stand

The *Auto Stack Core* (Automotive Fuel Cell Stack Cluster Initiative for Europe II) cooperation project is a merger between 14 European auto manufacturers, suppliers, system integrators and research institutes. Working together, their goal is to develop a fuel cell stack (FC stack) for vehicle applications which satisfies the most advanced international aspirations in terms of performance, performance density, lifespan and effectiveness. On the basis of cooperation between these differing participants, the most optimum possible combination of the existing know-how should be achieved and the critical development interfaces coordinated efficiently.

The *Autostack* precursor project, which was completed from 2010 until 2012 (FCH-JU GA 245142), served the purpose of developing shared specification requirements for the participating OEMs and a technical concept for their realization. The goal of this concept was to enable the installation in different vehicles and vehicle categories of differing manufacturers, and on this basis, to enable the achievement of far superior economies of scale during the initial marketing phase. The basis for this was provided by a detailed installation study, in which the available installation space in the different vehicles from the participating manufacturers was investigated in order to determine the volume and geometry of the target design as the basis for the shared platform concept.

The additional framework conditions for the project constitute the use of components that can only be manufactured on an industrial basis with the necessary degree of maturity for the development of the stack, to enable a rapid transfer of the results into the industrial manufacturing subsequent to the completion of the development. In combination with an exceptionally high output density, the platform concept also aims to create the requirements for ensuring that the target costs for the use in vehicles can be realized as quickly as possible. The scalability of the stack output of 10 to 95 kW also aims to create the requirements for the flexible use of the stack in other applications.

3D view of stack

In the scope of the project, the stack development progressed through the three following development phases, which are based on the development cycle in the field of automotive design: Prototype = Evolution 1, A-sample = Evolution 2 and B-sample = Evolution 3.

The first two phases were accompanied by a complete test program which consisted of all of the standard functional-, performance-based, duration-based and environmental tests in order to demonstrate the technical realization of the goals and the potential optimization. Accompanying benchmark- and manufacturing cost analyses should also ensure that the specification is compared with the international development status and adapted accordingly, and that the design is suitable for attaining the target costs.

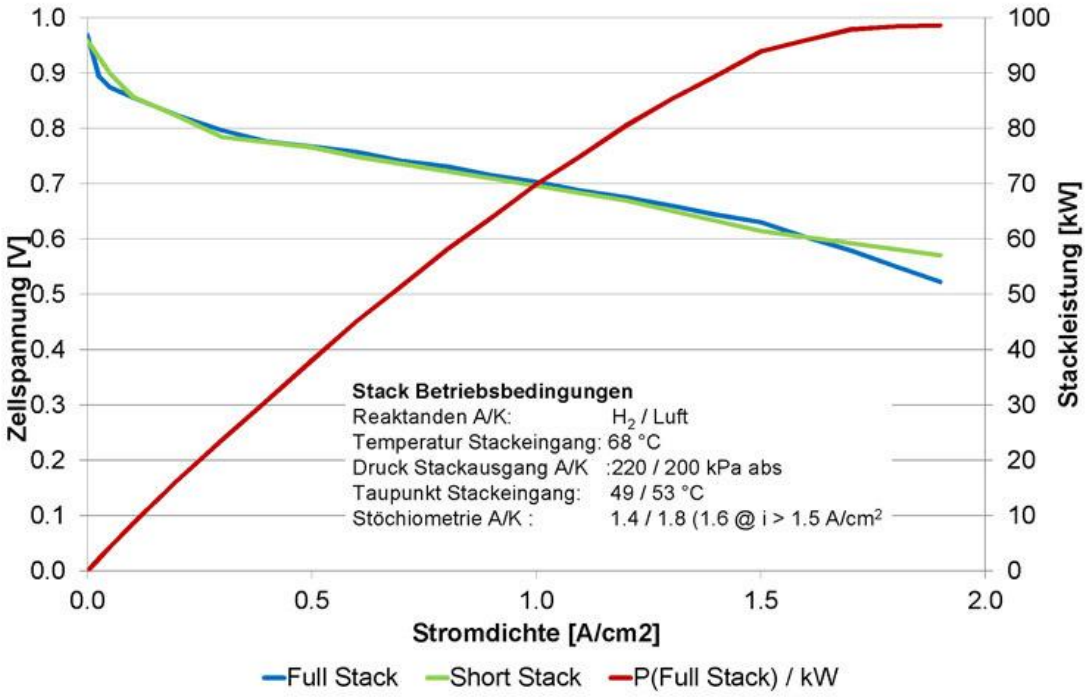
At the end of 2014, following a development period lasting one and a half years, a total of 20 short stacks, each of which had ten and/or 20 cells, as well as a full stack with 331 cells, were available for the validation of the results.

In March of this year, the test program for the prototype (Evolution 1) was successfully completed. The proven technical attributes correspond to the development goals for this phase in terms of all the key parameters (see tab. 1) and confirm the design concept. The stack stays robust within the specified operating conditions, is cold-start-capable at -20 °C and already has a very high output density with even more potential for improvement. The fact that the costs which are to be expected for the subsequent series manufacturing, and which have also been analyzed by external experts, are very close to the target level even in this early developmental phase, is especially pleasing. The tests also demonstrated an excellent concordance of the output data in the operation of short stacks and full stacks.

Tab 1: Degree to which key design goals in Evolution 1 have been achieved

Goal	Specification	Achieved in Evolution 1
Output	95 kW (continuously), 118 kW (peak load for 30 sec)	94 kW (continuously), 99 kW (peak load for 30 sec)
Stack output density	2,8 kW/l (continuously), 3,4 kW/l (peak load)	2,7 kW/l (continuously), 2,9 kW/l (peak load)
Operating point	1 W·cm^{-2} @ 1,5 A·cm^{-2}	0,947 W·cm^{-2} @ 1,5 A·cm^{-2}
Maximum operating temperature	95 °C	95 °C
Cathode humidification	< 50 % RH	50 % RH
Operating pressure	2,2 … 2,4 bars (continuously) 2,7 bars (peak load)	2,2 bars (continuously) 3 bars (peak load)
Degradation rate	< 12 µV·h^{-1}	50 µV·h^{-1}
Frost starting capability	of -25 °C	demonstrated -20 °C
Specific stack costs aggregated according to the DoE study [1]	< 40,00 €/kW	47,83 €/kW

The approach taken in the project, which consisted of an intensive cooperation between vehicle manufacturers, component suppliers, system integrators and research institutes, proved to be a success. The direct exchange of information and the shared analysis of the critical development tasks enabled an optimization of the cell and stack design as well as the faster and more efficient realization of the technical and commercial goals. The ongoing consultation with the vehicle manufacturers enabled the provision of direct feedback on the construction-based requirements. In comparison with the conventional development programs used in the automotive industry, it was therefore possible for the development results to be achieved with a comparatively modest budget.



Comparison of the electricity current and output curves of the short stack and full stack in hydrogen/air operation under pressure determined across all cells (Sources: ZSW)

The consortium completed an analysis of the achieved level of development at the start of April 2015, and agreed to specific steps for the next phase of the

development. Following the conclusion of the design phase for Evolution 2 (A-sample) and the completion of a comprehensive test program, a further design review is scheduled to take place. The development level that has been achieved and the considerable potential for improvement already allow the conclusion to be drawn that all of the key project goals can be achieved.

The project has a total duration of 46 months and is forecast to be completed by the end of 2016. The expected level of development will then enable a transfer into industrial series manufacturing within approximately two and a half years. The series manufacturing of FC stacks for automotive use originating from European development and manufacturing will thus be a realistic option from around 2018/2019 onwards. The project will therefore close a critical gap in the German and European value added chain and also provide a substantial contribution to increasing the level of European competitiveness with an important technology of the future.

The market launch of FC vehicles by Toyota and Hyundai was recently initiated. With these vehicles, some initial experiences have been gathered in the area of customer business, and the market response has also been tested. Other manufacturers are set to follow over the years to come. At the same time, the development of the H2 refueling infrastructure is being driven forwards in the leading key markets, although some time is required before large volumes of FC vehicles can be sold marketed appropriately.

The developmental status and a sample construction of the stack prototype were presented at the 2015 Hanover trade show, and as hoped, elicited considerable interest with vehicle manufacturers and system integrators. Follow-up discussions have already been scheduled with some players. From the start of next year, it will be possible for A-samples to be supplied to vehicle manufacturers or system integrators for the purpose of testing and demonstration. AutoStack-Core therefore slots in very well in the wider context of the general technological developments. The consortium is ready to drive the future development of fuel cell propulsion systems forwards, and to support potentially interested parties with their development.

AutoStack-Core is receiving support in the scope of the European Fuel Cell and Hydrogen Joint Undertaking program (FCH-JU GA 325335). The participants include the auto manufacturers BMW, Volkswagen and Volvo as well as the supply firms Belenos, Dana, Freudenberg, PowerCell and Solvicore. CEA, Fraunhofer ISE, PSI and ZSW are also accompanying the project as research institutes.

Literatur: B. D. James, J. M. Moton, W. G. Colella, Mass Production Cost Estimation of Direct H2 PEM Fuel Cell Systems for Transport Applications 2013 Update; Strategic Analysis Inc., Arlington VA (2014)

Authors:
André Martin, André Martin Consulting, Idstein, andre.martin-nc@t-online.de
Dr. Ludwig Jörissen, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Ulm, ludwig.joerissen@zsw-bw.de

Japan is leading in building H2-stations

(Source: JX Nippon Oil & Energy, Kyodo)

In the good-natured international race to deploy hydrogen fueling stations for fuel cell electric vehicles (FCEV), Japan has taken a clear lead, with 74 stations approved to date, a dramatic jump from the 45 stations operating or under construction at the end of 2014. By comparison, California and Germany have about 50 stations in operation or under development.

Japan's acceleration seems clearly the result of pressure from the Japanese federal government, which has made hydrogen the centerpiece of its post-Fukushima energy policy and which promised, very publicly, that 100 stations would be on line by the end of 2015. The government expressed its disappointment about the shortfall but also took steps to improve support for station owners.

Now the government is promising 100 stations "prior to market introduction," meaning 2016 (Honda's commercialization target) or 2017 (Nissan's). Toyota is already selling its *Mirai* fuel cell vehicle in Japan. Meanwhile the three auto makers have stepped up to a fresh commitment to support station deployment by contributing to operating expense subsidies until about 2020.

In a joint statement July 1, they also committed to helping station owners "deliver the best possible customer service and create a convenient, hassle free refueling network." This help will come in the form of sharing customer survey data and technical information, conducting public education activities and improving access by supporting longer hours of operation, and providing station location information to customers.

The government's has committed to finance about half of station construction costs, and a commitment to pay two-thirds of station operating costs, but station operators must step up with their own cost share. Since the stations will not be profitable, that is substantial commitment. The government has budgeted $80 million in FY 2015, implying a private sector commitment of at least as much. Discussions are under way about financing another round of stations in FY 2016.

The stations are located in four major metropolitan areas in populous southern Japan, with half in Tokyo and stations in Chukyo, Kansai and north Kyushu. About half the stations are being built by Japan Oil.

Nissan's public statement that it planned a commercial FCEV "as early as 2017" was something of an advance on earlier announcements though the company left itself plenty of wiggle room.

Author: Robert Rose

A pauper's oath for the automotive industry

Toyota Mirai during IAA 2015

Seldom before was it evident just how big the gap between theory and practice can get than it was at the *66th International Motor Show (IAA)*. Indeed, in the run up to the *IAA 2015*, the show organizers, the German Association of the Automotive Industry (VDA) had said clearly and repeatedly that electric mobility would be a key topic again at this year's event. In reality, things were very different, however: neither fuel cells nor battery powered vehicles proved to be a major topic at any of the auto manufacturers. Of those present, only Toyota made a clear focus on hybrid vehicles, presenting the new *Mirai* at the show.

At all of the other large trade show stands, other topics were covered, primarily connectivity and digitalization. Once again, it was sports utility vehicles (SUVs) and large, expensive limousines which took center stage. The word "electric mobility" was only used when the topic of discussion was fuel consumption; thanks to hybrid

technology, the CO2 emissions of even the biggest limousines can be reduced considerably in purely mathematical terms.

And it is on this basis that we're getting closer to the crux of the matter: for the VDA, the definition of electric mobility is any vehicle that is equipped with some kind of an electrical motor, whether it is a Mercedes *GLC 350 e 4MATIC* or a BMW *740e*. It is of no importance how often the charging cable is actually connected during the everyday operations of the plug-in hybrid in question. It appears to be far more important that the fuel consumption can be downscaled drastically on a completely legal basis, so that it is then comparatively easier to comply with the CO2 threshold limits of the new vehicle fleets.

In this respect, it is no longer surprising that Daimler recently stopped production of its Smart Electric Drive models. As German TV channel *ARD* reported, for a few months, there have been supply problems with the e-Smart, since combustion engines for foreign export have been manufactured on the production lines of the Stuttgart-based auto manufacturer instead of electric cars for Germany. A company spokesman reported that new e-models would first be introduced in the second half of 2016. Right now, this means that it is only the electric *B Class* which is available to buy through Daimler, although the director of Smart, Annette Winkler, had the following to say about the electric *Smart* in the spring of this year: "It is popular and is being purchased."

If it is possible to achieve the specified CO2 threshold values with hybrid limousines which are also more profitable and the emissions values of which have been "dressed up", however, sales of compact cars can be held back – notwithstanding the demand for them, but to the pleasure of the shareholders.

Similar to the Smart Electric Drive, fuel cell cars are also being treated rather shabbily in the auto industry right now. As explained by the director of Daimler, Dieter Zetsche, in an interview in August 2015: "The benefits offered by the fuel cell can now be seen to be lower than they were five years ago." At the same time that this statement was made, the south German firm decided against being the main sponsor of the *World of Energy Solutions (WES)* at their home town of Stuttgart again this year.

News items of this kind do not provide the impression of a technology that is being driven forwards. Numerous additional occasions are available right now, however, to consider the setting of priorities in the worlds of politics and business, as well as the appropriate use of the available support funding: in its documentary on "The fairytale of electric mobility", *ARD* revealed that it has been consciously accepted that the statistics are sometimes being interpreted incorrectly. In this context, of the 8,463 electric vehicles registered in 2014, almost half were registered to the auto manufacturers themselves. Just 4,814 E-cars were sold to "real" customers, which is why the report talks of "massaged" sales figures.

The number of charging stations in Germany also raises questions: almost everywhere else in Europe it is the number of charging stations which are installed that are counted, and rightly so, but in Germany, it is the "charging points" that are counted. Since most of the charging stations have two connections, this means that

in terms of the figures alone, there are assumed to be double the number of stations in Germany than there actually are: we only have 2,500 stations here in Germany.

At the beginning of the year, German TV channel *ZDF* also reported about the aberrations in the field of electric mobility: the consumer magazine *WISO* revealed that the charging current for electric cars is sometimes far more expensive than that of the electricity used by households. A test revealed that depending on use, the prices were sometimes three or four times higher at RWE, EnBW and E.On, which is why the report talked of “profiteering”.

The *IAA 2015* ultimately confirmed the initial trend: today’s policy of financial support has resulted in some questionable developments. Despite many millions of Euros in taxpayers’ money having been invested in both the battery and fuel cell technology, there remains a lack of suitable framework conditions (incentives or threshold values) to drive the contemporary marketing of the appropriate products. Rather than proceeding on a targeted basis from the field of R&D towards the market, industry and lobbyists alike are repeatedly abusing the trust of the consumers by consciously playing for time and publishing misleading statistics.

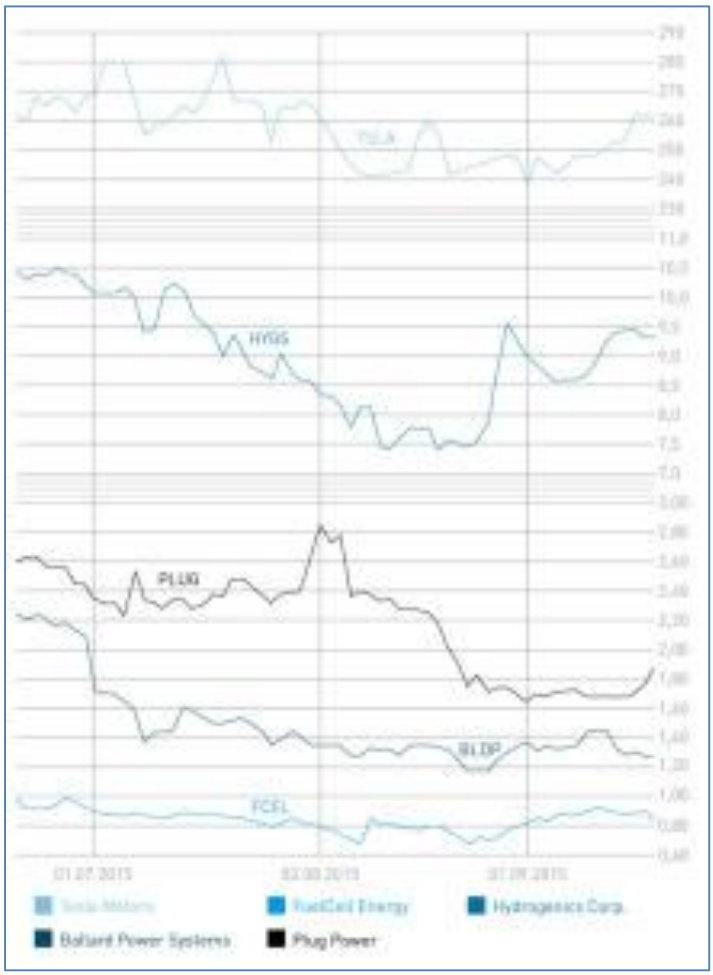
In this respect, a greater awareness of responsibility is required from all of the participants, so that firstly, Germany does not completely lose its links with the E-mobility market, and secondly, the support funding that has already been paid out can turn out to be a sensible investment.

Plug Power: Home-made price weaknesses?

It may well be the case that Plug Power has itself triggered the fall in the price of its shares that occurred in recent weeks, as described in detail and substantiated by a report (*Seeking Alpha* dating from 2.9.2015). In detail: 1. The takeover of HyPulsion, the European joint venture with Air Liquide for US-$ 11.5 m. was settled in shares (6.4 m. units due to the fall in the share price instead of the originally planned 4.8 m. shares), whereby it had already been made clear that the Air Liquide subsidiary, Axane SA, would register these shares and sell them on the stock exchange. Plug would have been better off paying the US-$ 11.5 m. in cash – with more than US-$ 100 m. in the bank this wouldn’t have been a problem – than issuing shares which put pressure on the share price. This was a perfect argument of the short sellers, or the investors, who made the most of the falling prices at Plug: more than 34 million shares were sold short. Air Liquide continues to hold around 5.6 m. shares in Plug, and wants to hold onto them as a “strategic partner”, according to the prevailing opinion. Also interesting to note: they are now working with Jungheinrich in Europe.

2. Cash holdings: the most recent quarterly result showed a cash outflow of around US-$ 22 m. to approx.US-$ 109 m. This includes more than US-$ 10 m., however, that are required as security deposits for financing operations (including leasing transactions). This means that purely in accounting terms, Plug has set aside around US-$ 120 m. for a “rainy day”. US-$ 10 m. are considered to be a realistic quarterly

outflow of cash, to finance the growth of the company from its own resources (development of the production systems, personnel, etc.). The raising of capital via so-called secondaries/offerings is not necessary in the foreseeable future. Here, the short sellers have taken the quarterly outflow of capital as the basis for their line of argumentation that Plug could run out of money and another weakening would then occur through the issuing of new shares – which should be taken with a pinch of salt!



Courses of the share prices of four listed companies

3. Major orders, including Walmart & Home Depot: both of these companies have more than 100 logistics centers which are being upgraded from battery operation to fuel cell operation on a step-by-step basis. The stock exchange expected the announcement of major orders and oversaw/has overseen the fact that both companies are converting all of their logistics centers on a step-by-step basis, and have therefore taken the basic decision to focus fully on fuel cells, since operations using hydrogen pay off after just one year (conversion), enabling appreciable cost reductions and allowing environmental commitments to be achieved. It can thus be assumed that with these two major companies alone (with many others set to follow, for some of which initial orders already exist), Plug has the potential to secure orders to the value of hundreds of millions of dollars. At the moment, according to its own announcements, this year, Plug has received (existing) orders to the value of US-$ 206 m. of which US-$ 100 m. will be implemented. Plug is converting the logistics centers of a range of major customers, but has also apportioned them so as to avoid being overly dependent on a single customer. Its commitment is therefore

proportional: x centers for customer X, y centers for customer Y (meaning, for instance, 6 logistics centers p.a. for Walmart, 4 for Home Depot, 3 for Kroger etc.). This means they are growing with different customers at different places without focusing all of their capacity on a single address. This approach will be taken into account with its value on the stock exchange.

The bottom line: everything is okay. Plug will continue to focus on achieving a growth rate of 40 % plus p. a. and on consistently increasing its profit margin. It is expected to break even and to thus become profitable in 2016. In the short or long term, the shares that were sold short, numbering more than 34 million, could eventually be the turbo for significantly higher quotations (squeeze in the event of good news).

This analysis was written in September 2015 by Sven Joesting.

Tipping Point is Reached in the Development of FCs

PEM-electrolyzer in a container (Source: Hydrogenics)

Looking at the share prices for fuel cell companies that are being traded on the stock exchange right now, one could be forgiven for thinking that a crash had just taken place. It is as if the technical breakthroughs in the further development of the fuel cells had never taken place, and as though the production, storage and use of hydrogen had zero chance of achieving any success. Yet in fact, the opposite is the case. Right now we are at the start of a new mega trend, and in 2015, many FC products are market-ready. It has been possible for a wide range of long standing test series to be completed to great success, and following the servicing of the test markets, the focus now is on their widespread use for the generation of clean energy (heat & electricity) worldwide.

As with every new trend, there have been some big initial reservations – as shown by the persistently insufficient geographical coverage on hydrogen filling stations, for example. Toyota has refused to be put off by any of this, however, as “the journey is its own reward”, and has forecast that the more vehicles powered by hydrogen there

are on the market, including FC hybrids, the more H2-filling stations there will be. And the FC car is exactly what will dispel the “imaginary” fears surrounding hydrogen.

The fact that the share prices of the FC companies presented here are so low is also due to the low price of oil, which has naturally had an impact on alternative methods of propulsion, at least on the psychological level, even if no direct link is evident. The companies monitored here have healthy financials (debt-free/few debts/high liquidity), key know-how (IP/patents), long standing experience, high order balances and strong partnerships and collaborations.

In short: crisis – what crisis? It is more of a productive state of affairs. Those prepared to wait should be able to earn some high yields here if the market – with rising prices – begins to recognize and/or take the actual potential and prospects into account. And then the falls in prices will be a thing of the past and commitment will eventually lead to profit – but it will take time.

Global market for electrolyzers sees dramatic growth

With more than 60 years of experience, Hydrogenics is one of the pioneers in this technology, which uses electrolyzers to split water up into H2 and O2. It also manufactures the highest performing equipment (throughput). Boston Consulting has forecast that by the year 2030, over 150 bn. Euros will be invested in large scale industrial storage systems such as electrolyzers – and only approx. 70 bn. Euros in battery technology. Hydrogenics is now on the same level as Siemens, which primarily uses PEM electrolysis (among others, for power-to-gas systems). On this basis, regenerative electricity (wind and solar) can go into rapid use as a storage medium for the transformation into H2, and can then be fed into the gas grid through the addition of CO2 (methanization).

Its share price is very low – like all of the other prices in the sector. Its figures for the most recent quarter were not good (recording a loss) despite considerable quarterly changes (billing of orders). One should consider the share to be an FC admixture, since if the fuel cell is discovered, all of the companies which are viewed as being technological leaders will become the focus of the stock exchange. The companies’ financials will then move into the background, with high growth taking them to the profit zone.

This analysis was written in September 2015 by Sven Joesting.

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.

Events

- November 16th to 19th 2015, **Fuel Cell Seminar & Energy Exposition**, in Los Angeles, California, at the Westin Bonaventure, www.fuelcellseminar.com
- November 17th to 19th 2015, **8th FCH JU Stakeholder Forum**, Program Review Days (17th to 18th), in Brussels, Belgium, www.fch.europa.eu
- November 17th to 20th 2015, **Zing Hydrogen & Fuel Cells Conference**, in Cancun, Mexico, www.zingconferences.com
- December 1st to 4th 2015, **European Battery, Hybrid and Fuel Cell Electric Vehicle Congress**, in Brussels, Belgium, www.eevc.eu
- December 6th to 8th 2015, **International Hydrogen & Fuel Cell Conference**, in Agra, India, www.hai.org.in
- December 16th to 18th 2015, **European Fuel Cell Conference & Exhibition**, in Naples, Italy, www.europeanfuelcell.it
- February 4th to 5th 2016, **HyVolution**, in Paris, France, www.hyvolution.fr
- March 15th to 17th 2016, **International Renewable Energy Storage Conference (IRES 2016)**, Düsseldorf, Germany, www.eurosolar.de
- April 25th to 29th 2016, **Group Exhibit Hydrogen + Fuel Cells + Batteries**, in Hanover, 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, Germany – 50825 Cologne, Phone +49-(0)221-888244-88, Fax -67, www.arevah2gen.com

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

- **H-TEC SYSTEMS GmbH**, PEM-Electrolyzers, Maria-Goeppert-Str. 9a, Germany – 23562 Lübeck, Phone +49-(0)451-39941-0, Fax -799, info@h-tec-systems.com, www.h-tec.com

- **Heliocentris Industry GmbH**, Phone +49-(0)30-340601-500, Fax -599, sales@heliocentris.com, www.heliocentris.com

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

- **ITM Power GmbH**, Energy Storage – Clean Fuel, Hegewiese 4C, Germany – 61389 Schmitten, Phone +49-(0)6084-950012, www.itm-power.com

- **McPhy Energy Deutschland GmbH**, Oberer Mainkai 1, Germany – 97070 Würzburg, Tel. +49-(0)931-35987-244, www.mcphy.com

Energy Storage

- **GKN Powder Metallurgy**, GKN Sinter Metals, PO Box 55, Ipsley House, United Kingdom – Redditch B98 0TL, Worcestershire, www.gkn.com/sintermetals
- **Hydrogenious Technologies GmbH**, Weidenweg 13, Germany – 91058 Erlangen, Phone +49-(0)9131-12640-220, Fax -29, www.hydrogenious.net

Fuel Cells

- **Proton Motor Fuel Cell GmbH**, Benzstrasse 7, Germany – 82178 Puchheim, Phone +49-(0)89-1276265-0, Fax -99, www.proton-motor.de

Fueling-Recirculation and Air-Supply

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

Hydrogen Distribution

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

Membrane and Separator

- **FuMA-Tech Gesellschaft für funktionelle Membranen und Anlagentechnologie mbH**, Carl-Benz-Str. 4, Germany – 74321 Bietigheim-Bissingen, Phone +49-(0)7142-3737-900, Fax -999, www.fumatech.com
- **Plansee SE**, Bipolar Plates, Interconnects and Metal Supported Cells, Austria – 6600 Reutte, 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, Germany – 12203 Berlin, Phone +49-(0)30-398209946-0, Fax -9, www.dwv-info.de
- **hySOLUTIONS GmbH**, Steinstrasse 25, Germany – 20095 Hamburg, Phone +49-(0)40-3288353-2, Fax -8, hysolutions-hamburg.de
- **National Organisation Hydrogen and Fuel Cell Technology (NOW GmbH)**, Deutscher Wasserstoff- und Fasanenstr. 5, Germany – 10623 Berlin, Phone +49-(0)30-3116116-15, Fax -99, www.now-gmbh.de

Reformer

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

Research & Development

- **Fraunhofer ICT-IMM**, Reformer and Heat Exchanger, Carl-Zeiss-Str. 18-20, Germany – 55129 Mainz, Phone +49-(0)6131-9900, info@imm.fraunhofer.de, www.imm.fraunhofer.de

- Fraunhofer ISE
  Fraunhofer ISE, Heidenhofstrasse 2, Germany – 79110 Freiburg, Phone +49-(0)761-4588-5202, Fax -9202, www.h2-ise.de

Suppliers

- borit
  Borit NV, Bipolar Plates and Interconnects, Lammerdries 18d, Belgium – 2440 Geel, joachim.kroemer@borit.be, www.borit.be

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

- Heraeus
  Heraeus Precious Metals GmbH & Co. KG, Electronic Materials Division, Business Unit Circuits & Components, Heraeusstr. 12-14, Germany – 63450 Hanau, Phone +49-(0)6181-35-5466, Fax -7850, www.heraeus-circuits-components.com

- **HIAT gGmbH**, Schwerin, Germany, CCMs / MEAs / GDEs for PEFC, DMFC & PEM-Electrolysis, www.hiat.de

- **Theisen GmbH & Co. KG**, GH2 & LH2, info@theisen-gmbh.de, www.theisen-gmbh.de

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

System Integration

- **Deutsche Zentrum für Luft- und Raumfahrt (DLR) / German Aerospace Center** Institute of Engineering Thermodynamics Energy System Integration Pfaffenwaldring 38-40, Germany – 70569 Stuttgart, Phone +49-(0)711-6862-672, Fax -747, www.dlr.de/tt, www.dlr.de/tt

- **FLEXIVA automation & Robotik GmbH**, Power Electronics – Hybrid Energy System Solutions, Weißbacher Str. 3, Germany – 09439 Amtsberg, Phone +49-(0)37209-671-0, Fax -30, www.flexiva.eu

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

Such an entry on the website and also in the e-journal costs only USD 135 (120 Euro).

Please let us know and you will be part of every issue twelve times a year.

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

Specials

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

Please contact *H2-international* for more details.

Advert

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