Hydrogeit / www.h2-international.com / Issue 4 / October 2019 / 10 $

H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

→ GERMAN ECONOMICS MINISTER ALTMAIER ANNOUNCES HYDROGEN STRATEGY

→ LIVELY DISCUSSION ABOUT CO_2 TAX OR CERTIFICATE TRADING

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H2-international

H2 international
E-JOURNAL ON HYDROGEN AND FUEL CELLS

ISSN 2367-3931
Issue/Years No. 4, October 2019

Publisher Hydrogeit Verlag
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16727 Oberkraemer, Germany

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Translation Übersetzungsbüro.Köln, Lana Boskovic, Cologne
Frequency 4 digital issues per year, 1 printed
Single issue (DE) USD 10 / EUR 8 (excl. VAT)
1-year sub (DE) USD 40 / EUR 35 (excl. VAT)
Shipping D: USD 2.50 / EUR 2.00, World: USD 5.00 / EUR 4.00
Students 50 % off standard prices
Termination At any time

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Cover image German Federal Minister Peter Altmaier announces H_2 strategy [Sources: BMWi / Susanne Eriksson; Freepik]

CHANGE IS IN THE AIR

Dear Readers!

The current interest in hydrogen is almost frightening. Too often we already had H_2 hypes, according to which the image of hydrogen was worse than ever before. A number of industry representatives with whom I have talked these days are therefore sceptical and fear that the hope for sustainable change that is just emerging will immediately be destroyed again.

At the same time, however, something is currently being felt that did not previously exist. Something is different from the previous hypes, as if the premonition of something new was already in the air.

At the time of the first hype, some developers had first emphasised the advantages of H_2 and FC technology and – as we later discovered – made unfounded promises about how quickly first products could get to market. A few years later, the media then celebrated fuel cells as an innovative technology of the future, but then quickly wrote them off again.

In contrast, we now have a completely different starting position: While these earlier hypes were driven solely by technology, today there is an acute need for action. At that time there were discussions about global warming and sustainability, but hardly anyone really wanted to change anything. Today – after the diesel scandal, driving bans, Fridays-for-Future, climate refugees, drought summers etc. – there are many more people who don't want to go on like this.

Another important point is that this is happening not only in Germany, but worldwide. In addition, it is becoming increasingly clear that Germany is no longer a pioneer when it comes to climate protection or renewable energies. The solar and wind industry in Germany is on the ground, while in Asia in particular the government is clearly pointing the way towards greater sustainability. While we are hesitant to start with battery cars here, China is already reducing subsidies for them again and is focusing entirely on hydrogen instead.

But the biggest difference between the hypes of that time and the situation I perceive today is the mood of the population. I'm not talking about the Fridays-for-Future kids, about whom there are very different opinions. I mean the consciousness of the average consumer, who has been telling me more and more recently: Battery cars are all well and good, but the future is hydrogen!

In recent months – almost unnoticed by sociologists or the media – an opinion-forming process seems to have taken place in society. The collected intelligence of the citizens anticipates a development for which many of the so-called experts and politicians needed much longer.

In line with this, however, all sorts of politicians are now suddenly daring to take to the microphones and announce hydrogen strategies – whether at local, state or federal level.

After "little Austria" first advanced and announced that it wanted to become the number one hydrogen nation (see p. 12), it took just eight days for the German Federal Environment Minister to present a PtX action programme, and further eight days for the German Federal Economics Minister to claim that it "wanted to become the number one in the world for hydrogen technologies" (see p. 8).

Even the Greens seem to finally give up their decades-long rejection of H_2 and FC technology: On 10 July 2019, six members of the Bundestag presented a position paper in which it was stated: "Hydrogen can and should make our country cleaner." We will probably never know why this long overdue step was so difficult for an ecoparty.

But if even in the CSU it is now true that "hydrogen is increasingly establishing itself as a storage technology for the national and global energy turnaround of energy systems" (quote: Sandro Kirchner, parliamentary party leader of CSU Bavaria), and Federal Transport Minister Andreas Scheuer states that "hydrogen is good for the climate" (see p. 10), an environmental party must of course no longer lag behind.

At state level, Olaf Lies, Environment Minister in Lower Saxony, has long wanted to establish his state as an H_2 region. In return, he recently pledged 40 million euros in investment funds, for 2020 alone. Brandenburg would also like to move in this direction and become a "model state for the use of H_2 technology", said Economics Minister Jörg Steinbach. Even the Saarland is to be developed into a model region for hydrogen research in the opinion of its Economics Minister Anke Rehlinger.

That's why, because of all these developments, I have the feeling that this time it's not just a hype, but there's a certainty in the air that something fundamental must and will change. And we cannot only be witnesses of it, but we can actively participate in shaping it. Finally!

However, it is still questionable how strong the resistance of the established actors will be. The direction of the Federal Ministry of Economics and Technology to temporarily (until 2040/50) rely on so-called "blue" hydrogen from fossil energy sources and on CCS technology suggests that by no means everything is clear. Instead, it looks as if there are still many people who would like to stretch the actually necessary short-term energy turnaround over many years – for whatever reason. ||

Sincerely

Sven Geitmann
H2-international editor

BONHOFF SWITCHES TO POLITICS

Dr. Klaus Bonhoff

The Managing Director of the National Organisation for Hydrogen and Fuel Cell Technology GmbH, Dr. Klaus Bonhoff, will leave NOW and will in future be head of the Policy Department at the Federal Ministry of Transport and Digital Infrastructure (BMVI). He will thus occupy a central position within the ministry and, according to Minister of Transport Andreas Scheuer, will focus in particular on the "mobility of the future". Bonhoff has been active as a NOW spokesman since the company was founded in 2008, after working for Daimler on fuel cell cars for many years.

At the end of July 2019, several personnel changes in the BMVI went hand in hand with this change of personnel. Among others, Dr. Norbert Salomon, who was head of the basic principles department for 16 months, became the new head of the department Waterways, Shipping.

A successor for Bonhoff at NOW will probably only be named after a lengthy tender procedure. This is how long the second managing director, Wolfgang Axthammer, will probably take over his duties with the support of Thorsten Herbert, NOW's Head of Transport and Infrastructure. ||

CHEMNITZ BECOMES H_2-CENTRE

The Saxon city of Chemnitz is increasingly developing into a Mecca for hydrogen enthusiasts. On July 17, 2019, the Technical University there and the company Continental Powertrain will open a new hydrogen laboratory equipped with a test rig for researching modern fuel cell vehicle systems. Vladimír Buday, responsible for the test bench, reported to H2-international: "It is a Greenlight test stand with 150 kW power, which already has some features that are second to none." (The test bench can be extended to 300 kW.)

On the occasion of the inauguration on the university campus, in addition to Martin Dulig, the Saxon Minister

> "The fact that Chemnitz University of Technology is a leader in the field of hydrogen fuel cell technology is demonstrated not least by the commissioning of a test bench that is unparalleled in the university sector throughout Europe."
>
> *Prof. Gerd Strohmeier, Rector of the TU Chemnitz*

Prof. von Unwerth explains the new test bench [Source: TU Chemnitz, Jacob Müller]

of State for Economics, Labour and Transport, Miko Runkel, the mayor of the city, and Prof. Thomas von Unwerth, holder of the Chair for Alternative Vehicle Propulsion Systems at the TU, also attended. Prof. von Unwerth, who also heads the innovation cluster H2, said: "As the largest industrial partner in the innovation cluster H2 grid, Continental brings extensive knowledge of vehicle applications, control technology and components for fuel cells. Combined with our expert knowledge, this creates an ideal basis for developing efficient fuel cell solutions and preparing the ground for economic industrialisation". ||

HYDROGEN-INNOVATIONS-CAMPUS IN GÖRLITZ

Joe Kaeser [Source: Siemens]

Hydrogen technology and steam turbines – this is the motto in Görlitz from now on. After the planned closure of the Siemens plant on the Polish border, announced two years ago, had caused a great deal of displeasure, the major corporation gave in and signed a declaration of intent in mid-July 2019 together with the Free State of Saxony and the Fraunhofer-Gesellschaft in order to strengthen the location in the long term and support structural change in Lausitz. To this end, an innovation campus is to be set up on the plant site, where technology and industrial companies, start-ups and research institutes as well as a laboratory for hydrogen research will be located. The partners intend to invest a total of 30 million euros in this project.

Minister president Michael Kretschmer was very pleased about this development: "Together with Fraunhofer, the universities and companies in the region, we are developing a research platform for innovative storage and hydrogen technologies for the energy turnaround But how many of the former 800 Siemens employees will continue to work there in the future remains to be seen. Chancellor Angela Merkel, who also visited the plant on this occasion, explained: "It is important for this energy region to become an innovation region, and the foundation stone for this has been laid today with the hydrogen future. The Confederation will try to accompany this." Joe Kaeser, Chairman of the Siemens Board of Management, added: "In addition to the worldwide headquarters for industrial steam turbines, we also want to build an innovation campus here in Görlitz, where products and solutions in hydrogen technology are to be developed together with partners and start-ups. ||

Hydrogen boiler without CO_2 from Remeha [Source: BDR Thermea]

BDR WANTS TO INSTALL 400 H_2 BOILERS

The BDR Thermea Group commissioned a hydrogen-powered boiler at the end of June 2019. The pilot plant, which was developed at the BDR Thermea competence centre for research and development in Italy, is located in Rozenburg, the Netherlands, and is supplied with sustainably produced hydrogen by the regional gas network operator Stedin, who also initiated the project. According to the manufacturer, this is "the first real situation in which pure hydrogen is used to fire a condensing boiler to heat the central heating system of a residential building". The device is operated by the Dutch BDR subsidiary Remeha. The next step is a larger field trial in Great Britain. The installation of 400 hydrogen boilers within two years is planned. ||

FIRE AT AN A HYDROGEN STATION IN NORWAY

On 10 June 2019, a hydrogen filling station in Norway caught fire. While several media talked about an explosion, the electrolyser manufacturer involved, Nel, stated that leaked hydrogen gas caught fire in the open air, causing a shock wave. According to police reports, two people were slightly injured in this incident in Sandvika, west of Oslo, when the airbags of their cars were triggered. After initial tests, it was said a few days later that hydrogen had escaped through a leak in the high-pressure storage system and had ignited. However, no tank had burst.

www.vg.no/nyheter/innenriks/i/zG9Bxw/eksplosjon-paa-hydrogenstasjon-i-sandvika-s

VG SPORTEN VG LIVE TV-GUIDE VG+ TIPS OSS

– Vi har ingen opplysninger om at det var noen på stasjonen da det eksploderte. To personer er sendt til legevakt med mindre skader.

Ifølge politiet ble de skadet da airbager ble utløst som følge av trykket etter eksplosjonen. Flere vitner har også fortalt om dette.

BRANN: Dette bildet ble tatt bare sekunder etter smellet. En bil (som er sladdet på bildet) sto da svært nær deler av hydrogenstasjonen, som ble blåst ut over. Foto: 2200-tipser

– Hydrogen er en av de mest eksplosive gassene vi har. Det er klart at det er alvorlig når en slik ulykke skjer. På den annen side har jeg aldri hørt om at at ulykke som dette har skjedd tidligere. Jeg er svært overrasket, og det er derfor viktig at myndigheten nå finner ut av årsaken.

Det sier Sindre Østby Stub, rådgiver for hydrogen i Zero til VG.

– Hydrogen er lagret under svært høyt trykk. Men på grunn av at hydrogen er mye lettere enn luft vil en hver lekkasje og flamme gå rett til værs. Og et hvert slikt lager er jo designet med tanke på uønskede

Fig. 1: Seconds after ignition, it can be seen how pure hydrogen burns with only a weakly visible flame [Source: VG]

For safety reasons, several hydrogen stations in some countries were closed as a precaution to avoid further incidents of this type until the cause of the leakage and ignition could be identified. In addition, Toyota and Hyundai temporarily stopped the delivery of their fuel cell cars. However, Espen Olsen of Toyota Norway stated that the incident did not change "our attitude towards hydrogen, and it is important for us to stress that H_2 cars are at least as safe as conventional vehicles".

On 27 June, Nel reported that Gexcon AS, one of the world's leading companies in safety management and explosion and fire modelling, had identified a fault in the assembly of a connector in a high-pressure hydrogen tank as the cause. As a result, hydrogen had escaped which had mixed with air and ignited. However, it is still unclear what the ignition source was, which is why further investigations are being carried out.

The hydrogen filling station is a Uno-X site (see photo), where the Nel ASA electrolysers, located directly next to the filling station, generates H_2 gas with the aid of solar energy. ||

F-CELL WITH 24-HOUR RALLY

During this year's f-cell, which took place on 10 and 11 September 2019 in Stuttgart, a look into the future was taken and the question of how hydrogen can make the transport sector more climate-friendly was answered. In the House of Economy studies were discussed which had just been published and which had already provided a lot of material for discussion when they were published. For example, the life cycle analysis of the Fraunhofer Institute for Solar Energy Systems ISE, in which battery and fuel cell cars were compared on behalf of H_2 Mobility, was presented. It states that FC cars are more economical than battery cars for vehicles with a range of several hundred kilometres from the point of view of climate protection.

The discussion with presenter Jürgen Pfeiffer (see p. 8), who discussed the best mix of alternative drive technologies with H_2 Mobility boss Nikolas Iwan, among others, was also interesting again. In the context of this panel discussion, the infrastructure study of the Ludwig Boelkow Foundation by Dr. Ulrich Bünger, which was carried out with the help of the ADAC Foundation (see p. 32), was also mentioned.

Valuable input from abroad came from the French bus manufacturer Safra, which presented its bus concept based on hybrid technology. His model Businova is an electric bus whose battery is powered by a 30 kW fuel cell so that it can cover about 300 km. A ten-member delegation from China was arriving this year to exchange ideas with local exhibitors and participants. A workshop entitled "Doing Business in China" was also offered. Hans-Werner Kulenkampff traveled from Chile to explain why this South American country is traded as an insider tip in the PtX sector.

New this year was the 24-Hour-Hydrogen-Challenge, which was held in the run-up to f-cell. This 24-hour rally started on Monday, 9 September, in which various teams in Stuttgart had to head for various checkpoints on a self-chosen route across Germany within one day. Although this was the first German hydrogen challenge, it was also the 5th hydrogen challenge organised by the Dutch organisers. The winners were announced at the evening event on 10 September, at which the f-cell awards were also presented. ||

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Category: Politik | **Authors:** Sven Geitmann, Sven Jösting

POLITICIANS RECOGNISE HYDROGEN POTENTIAL

A master plan for a hydrogen economy

Source: PFEIFFER - Fragt/Oliver Reetz

Something is happening in politics. After decades of niche existence, hydrogen now seems to have become socially acceptable – at least in some circles. In any case, more and more political representatives are openly talking about the fact that this gaseous energy storage system has potential. Even some Bavarians now admit that hydrogen can significantly advance the energy turnaround. After Federal Education Minister Anja Karliczek announced that her budget for hydrogen research would be increased, Federal Transport Minister Andreas Scheuer also ventured into the public eye at the end of June 2019 with completely new tones and presented a complete package with over 50 measures for a more sustainable transport policy. To top it all off, Economics Minister Peter Altmaier announced an H_2 strategy for autumn this year (see p. 10), after his cabinet colleague, Federal Environment Minister Svenja Schulze, had already presented a PtX action programme a week earlier.

Shortly before the summer break there was movement in politics: The moderator Jürgen Pfeiffer first discussed the "hydrogen miracle weapon" in Kiel on 21 June 2019 and asked questions there: "Will Northern Germany save the energy turnaround?" Invited to this political talk were high-ranking representatives from politics and economy, among others Dr. Bernd Buchholz, Minister for Economy, Transport, Labour, Technology and Tourism of Schleswig-Holstein, and Jorgo Chatzimarkakis, Secretary General Hydrogen Europe from Brussels.

NOW Managing Director Dr. Klaus Bonhoff reported that hydrogen is taking up more and more space in the global energy system. Already today, hydrogen is being produced in a Chinese province for US$ 1.60 per kilogram. In his opinion, Germany should finally "step on the gas" and exploit the potential. DWV Chairman Werner Diwald demanded that Germany must prove that it works for itself in order to be a role model for the world. Otherwise, China will explain to us how the energy turnaround is going, says the head of the association.

Jürgen Wollschläger, Managing Director of Raffinerie Heide GmbH, sees great opportunities especially for synthetic fuels based on hydrogen, from which, in his opinion, Hamburg Airport would also benefit. And Economics Minister Buchholz stressed the industrial-political opportunity offered to the North. However, it was viewed critically that other countries such as Denmark, England, France and the Netherlands already have a defined hydrogen strategy, whereas Germany has not yet done so.

All in all, this was a round that left nothing to be desired in terms of dynamics and flow of information, also thanks to moderator Jürgen Pfeiffer. It was agreed that hydrogen is a very important – if not the most important – medium for creating the energy turnaround. Most important point: The politicians of the Grand Coalition, as well as some car manufacturers, could be very wrong about the timeline. They do not see the breakthrough until 2025/30 – possibly a misjudgement if one considers the rapid developments in Japan and now also in China (new subsidy programmes for fuel cells, subsidy stop for batteries). However, parts of German industry and many local regions are in the starting blocks, even if the major rethink is still missing. Germany could be a Hydrogen-Front-Runner, but – unfortunately – it would rather become a follower. But it is not too late yet, according to the tenor of the panellists.

BAVARIA AS LEAD MARKET Almost at the same time, interesting speeches with unusual content were also heard from southern Germany. CSU leader Markus Söder had initially announced a climate offensive to the party executive, whereupon Bavaria was called upon to become a pioneer in hydrogen technologies. As the Süddeutsche Zeitung reported, the CDU's sister party is currently increasingly focusing on hydrogen as an energy carrier. Not only could new industries and jobs be created with hydrogen, CSU state parliament member Martin Huber was quoted as saying that Bavaria also had the opportunity to take on a pioneering role worldwide in innovation, value creation and sustainability. The potential is gigantic, says Huber.

It was also said that a "Master Plan Hydrogen Economy for Bavaria" was in

"All those present were motivated, and it could have been the impression that we are on the right track with the hydrogen economy. But if you have listened well 'between the lines', you can see the problem: Minister Dr. Buchholz is very committed, but so liberal that he does not want to consider designing the policy guidelines in such a way that there will be a reward and punishment system to promote hydrogen (for the economy/industry and private individuals). Dr. Bonhoff, on the other hand, has almost prayed like a madman for the NOW strategy (station construction in metropolises and magistrates), without considering the possibility of adapting to accelerate the H_2 expansion. That's why I went home with rather subdued expectations for the future after this event."

Political talk guest Udo Wagner, Neumünster

the works. The aim is to bring more vehicles with fuel cells onto the market, which is why the infrastructure must be expanded, for example by gradually increasing the number of hydrogen filling stations. In this context, environmental politician Huber spoke of a pioneering role for public transport, for example through the increased use of hydrogen-powered buses and taxis. His target is: "We want to make Bavaria the lead market for clean economy."

> "Today we have to make hydrogen technologies, fuel cells, synthetic fuels cost competitive."
> *Thomas Kreuzer, head of the CSU state parliamentary group, in Munich Merkur*

MORE MONEY FOR HYDROGEN RESEARCH FROM THE BMBF In the same week, the Federal Minister of Education and Research, Anja Karliczek, also tried to set new accents by particularly advocating the intensification of research activities in the hydrogen sector. She declared on the occasion of the new budget just passed by the federal cabinet: "In the current legislative period, we will spend EUR 2.3 billion on promoting projects in the areas of sustainability, climate and energy according to the current budget planning. That's about 50 percent more than in the previous parliamentary term."

She pointed out that the Federal Government was currently preparing a climate protection law for which it had founded a science platform together with Federal Environment Minister Svenja Schulze, in which climate protection-relevant topics were to be developed. In addition, a research and innovation programme on climate protection had been launched. In addition, research into the use of green hydrogen should be intensified.

Using concrete examples, she first mentioned the commercialisation of Power-to-X plants for the production of green hydrogen, for which 30 million euros have been earmarked over the next three years. Secondly, Africa is to be made a partner of Germany's energy turnaround. To this end, a "Potential Atlas on Green Hydrogen and Synthetic Fuels" is to be published, which will contribute to the analysis, together with German industry and research partners, of possible locations in Africa, their production and export potentials and their development, so that climate protection can become a global business model. And thirdly, hydrogen is to be brought into everyday life through "Franco-German research cooperation" (budget for the stationary sector): 4.5 million euros).

In total, the BMBF intends to provide around 180 million euros within three years for projects in hydrogen research – twice as much as before.

BMVI WANTS TO SUCCESSIVELY EXPAND HYDROGEN INFRASTRUCTURE One highlight was the initiative of Andreas Scheuer, Federal Minister of Transport and Digital Infrastructure, who still does not want to prohibit or regulate anything, but instead focuses on "allowing, facilitating and enabling". He explained "Climate protection is a task for society as a whole. The only way we'll be able to handle them is for everyone to join in. That is why we must not take measures that are dependent on sections of society. We want everyone to make good progress – in the city and in the country."

Scheuer, who has been said to be very close to the automotive industry so far, seemed both to accommodate the Fridays-for-Future students and to want to improve his battered image again as a result of the toll disaster.

From the BMVI it was said in addition: "According to the German government's climate protection plan, greenhouse gas emissions from transport must be reduced by 68 million tonnes in 2030. The measures already adopted will reduce greenhouse gas emissions by 13 million tonnes. Through our climate protection strategy, we are reducing emissions by a further 55 million tonnes and thus achieving our target."

This strategy includes more than 50 actions in different categories. In the field of alternative fuels, for example, a concept "hydrogen/renewable fuels" is to be developed "in order to advance hydrogen and liquid renewable fuels from production through composition to the end customer". Within this framework, Scheuer also wants, among other things, to "promote generation plants". In the area of commercial vehicles, the Minister of Transport wants to "ensure sufficient H_2 filling stations". Specifically, he said: "We're gradually expanding the hydrogen filling station infrastructure."

> "In the German chemical industry and refineries alone, we can avoid up to 15 million tons of CO_2 a year by replacing 'grey' hydrogen from natural gas and oil with climate-friendly 'green' hydrogen. For comparison: the entire German industry emits around 190 million tons of CO_2 per year."
> *Federal Minister of Education Anja Karliczek*

ONE-SIDED CAR SUMMIT In contrast, the German automotive industry and Chancellor Angela Merkel still did not give in. The car summit at the Chancellor's Office, to which the bosses of German car manufacturers were once again invited at the end of June 2019, was primarily about battery cars and charging infrastructure, but hardly about fuel cells, which according to the Handelsblatt was expressly criticized by the Association of Engineers (VDI) and the Association of Electrical Engineers (VDE). They called for a technology-open discussion and a rapid expansion of the hydrogen infrastructure.

The study "Fuel cells and battery vehicles – significance for electro-mobility", which was presented on the occasion of this summit in Berlin, states this in concrete terms: "It is the opinion of VDI-GEU, VDI-FVT and VDE/ETG that fuel cell-based electric-mobility can also make an important contribution to reducing greenhouse gas emissions. This is also the assessment of the railway operators and, in addition to cost aspects, an important reason for their decision to invest not only in battery trains but also in fuel cell trains". It criticises the neglected treatment of FC technology and the strong focus of the discussion on car traffic: Truck and bus transport were not included, nor was rail transport (detailed report on page 34).

BMW boss Harald Krüger told the Handelsblatt newspaper after the car summit: "We believe in electric cars, we believe in hybrids, and we believe in fuel cells. That was the consensus of the Federal Chancellor." On the other hand, it was said from the other side: "In the coming years, cars with plugs will be favoured. Fuel cell technology is not suitable for mass production until 2030 at the earliest." ||

→ Political talk video: http://bit.ly/2Tr5ZPR

> "We need more hydrogen for clean mobility. It's good for the climate. We're all going for clean fuels. Germany must become champion here."
> *Andreas Scheuer, Federal Transport Minister*

Category: Policy | **Author:** Sven Geitmann

MINISTER OF ECONOMICS ANNOUNCES HYDROGEN STRATEGY

Altmaier announces the winners of the real laboratories

In the middle of the summer break, Federal Economics Minister Peter Altmaier announced what the hydrogen and fuel cell industry has been waiting for for many years: a hydrogen strategy for Germany. The announcement of a hydrogen roadmap to be presented in autumn is also likely to have been of particular interest to large parts of the entire German energy industry, as it could mark a turning point in energy supply. What is decisive now, however, is how concretely this hydrogen strategy will be developed. Not only the success of the energy turnaround will depend on this, but also social peace (see Fridays-for-Future, driving bans, etc.).

The official tag of the press conference, which Altmaier held in Berlin on 18 July 2019, was the presentation of the "Handbook Reallabore". The announcement of the winners of the "Reallabore der Energiewende" (Real laboratories of the energy turnaround) competition of ideas alone, which went hand in hand with this, provided sufficient publicity material, since a total of 90 consortia – "an enormous response", according to Altmaier – had applied, of which 20 locations were ultimately selected. In these real laboratories, hydrogen technologies in particular are now to be tested nationwide on an industrial scale and in a real environment in order to strengthen the value chains in Germany within the energy sector. The selected ones are now called upon to submit their applications for the funding provided (100 million euros annually on the part of the Federal Government plus the industry's own funds).

The new handbook contains tips and concrete practical examples with the aim of encouraging companies, research, politics and administrations to test and implement smart ideas in the future.

Altmaier had launched the real laboratory strategy in December 2018 (see H2-international issues Apr. and Jul. 2019). The ideas competition started in February 2019. On the occasion of the award ceremony, the Minister explained: "Hydrogen technologies offer enormous potential for energy turnaround and climate protection as well as for new jobs. With the real laboratories of the Energy Turnaround, we will test new hydrogen technologies not only in research, but also in application under real conditions and on an industrial scale. This is an important building block for the further implementation of the energy turnaround." The Federal Minister of Economics and Technology formulated clear objectives in line with this:

> As test spaces for innovation and regulation, real laboratories make it possible to test new technologies and business models under real conditions [...]. In the process, state rules and regulations are opened for testing purposes – also in order to learn which legal framework is the right one."
>
> *BMWi*

WINDRETTER SUCCESS

In April 2019, the players in the Windretter campaign handed over a list of signatures to Dr. Bernd Klaus Buchholz, Schleswig-Holstein's Minister of Economic Affairs (see H2-international issue July 2019). Combined with the demand for storage of green electricity as simply as possible in the form of hydrogen in the future, this list has since been handed over to the Federal Minister of Economics, Peter Altmaier. The head of the campaign, Sybille Riepe, therefore assumes that the joint commitment of the Windretter has made a not inconsiderable contribution to the initiation of the hydrogen strategy now announced by Altmaier.

- Maintaining and expanding technological leadership
- Moving from isolated individual projects to a systemic approach
- Implementing innovation projects on an industrial scale
- Enable viable business models for energy innovation and review the energy framework
- Realizing sustainable CO_2 savings

In the next issues of H2-international magazine, various real laboratories will be presented in detail one after the other.

START INTO THE HYDROGEN ECONOMY The real highlight on this day was the following statement of the Minister of Economic Affairs:

"We want to become number one in the world for hydrogen technologies."

The announcement that the German government intends to adopt a hydrogen strategy by the end of this year was only a marginal note in the press release. For the hydrogen and FC industry, however, it is precisely the hope that something will now be done conceptually and that political guard rails will finally emerge so that planning security could be guaranteed for the next few years.

The decisive factor, however, will be what the announced hydrogen strategy will look like in concrete terms. At the moment it sounds as if a process of rethinking might have taken place in politics, but as long as no corresponding steps have yet been taken, these remain just words for the time being.

Ingrid Nestle, spokeswoman for energy economics for the Green parliamentary group in the Bundestag, therefore warned in this context that "blue hydrogen" (hydrogen from natural gas), for example, could be too much of a transitional technology. She referred H2-international to the BMWi's opinion that "the import of 'blue hydrogen' is probably necessary", but that it also needs 'acceptance' (see BMWi quote).

BMU PRESENTS PTX ACTION PROGRAMME A good week before the Federal Minister of Economics, the Federal Minister of the Environment also went public with a new con-

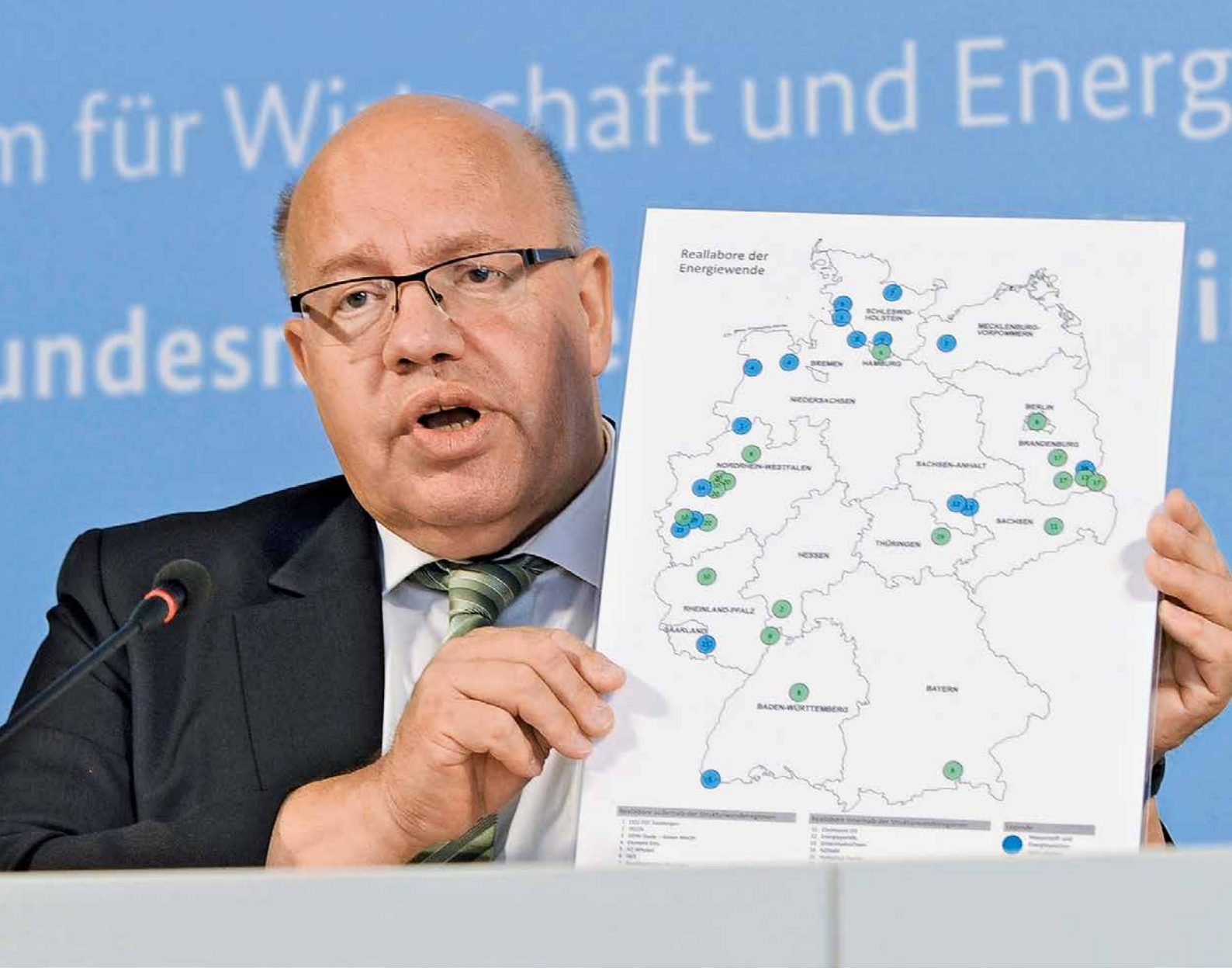

Fig. 1: Peter Altmaier presents the Reallabore [Source: BMWi / Susanne Eriksson]

cept. On 10 July 2019, Svenja Schulze presented an action programme aimed at promoting electricity-based fuels in the future in order to achieve CO_2 neutrality in Germany by 2050.

Key points of this programme are the establishment of a PtX competence centre in the Lausitz energy region and an internationally oriented PtX secretariat based in Berlin. In addition, Schulze is focusing on better networking (e.g. via a PtX symposium in Berlin in November 2019) and other model projects – also abroad. In contrast to the BMWi's real laboratories, the BMU would like to use this initiative to focus on the issue of sustainability and coordinate existing activities. ||

→ www.bmwi.de/handbuch-reallabore
→ www.reallabore-bmwi.de
→ www.energieforschung.de

"At least for a transitional period, it will not be possible to do without the import of 'blue' hydrogen alongside 'green' hydrogen. [...] The use of green hydrogen/gas is not economically viable at 3 to 6 times the price under current market conditions. Blue hydrogen can be a cheaper bridge technology until 2040/50. Political and social hurdles for the CCS technology required for this are seen as a challenge."

BMWi

"In the energy sector, there will be complete decarbonisation by 2050, which means that we will have to completely do without CO_2 emissions. [...] Power-to-X will make an important national and international contribution to climate protection in the future. For on the way to a climate-neutral world economy it will not be enough to switch only power generation to renewable energies. Green electricity will also play a central role in the transport sector and in industry. In some areas, green electricity can be used directly, for example in electric cars. In other areas this will remain difficult in the future, such as aircraft, freighters or – for process-related reasons – in the steel, cement or chemical industries. Here, electricity-based fuels will become an important substitute for fossil fuels. For the climate protection, it is imperative that these fuels are produced from renewable electricity. The Federal Ministry for the Environment will support the transfer of know-how in this important field and support companies in the development of the technology"

Svenja Schulze, BMU

Category: Policy | **Author:** Sven Geitmann

AUSTRIA AS HYDROGEN NATION NO. 1

Former Chancellor Kurz has big climate plans

On 2 July 2019, Sebastian Kurz, chairman of the new Austrian People's Party (ÖVP), and his party colleague Elisabeth Köstinger jointly presented their climate protection package. The goal formulated therein is to make the Alpine republic CO_2-neutral by 2045. According to Kurz, hydrogen should play a key role in this process: "This is not only a clean alternative hope for the future in the field of mobility, but also a great opportunity for Austria to become the world's number one hydrogen nation.

Part of this new H2-Ö-concept is the establishment of a hydrogen centre to attract the best minds and most innovative companies, especially from research and development, to Austria. In addition, the acquisition of hydrogen vehicles is to be promoted in particular and a nationwide hydrogen filling station network is to be established by 2025. 500 million is to be invested in this over the next ten years.

During his presentation, former Chancellor Kurz pointed out that Austria was one of the first countries to abandon coal-fired power and that more than 80 percent of its electricity is currently generated from renewable energies (especially hydropower). His next goal is therefore to achieve 100 percent clean electricity by 2030. On his website, Kurz also speaks out against tax burdens, since "a CO_2 tax would affect the socially weaker, commuters and people in rural areas".

HYDROGEN INITIATIVE In March 2019, the Austrian Federal Ministry for Sustainability and Tourism (BMNT), with the participation of the Federal Ministry of Transport, Infrastructure and Technology (BMVIT), had begun drafting a nationwide hydrogen strategy. The then Austrian Energy Minister Elisabeth Köstinger (see Fig. 1) had explained at the kick-off event: "In order to achieve our climate targets, we must make even more intensive use of all forward-looking technologies. In #mission2030 – the Austrian Climate and Energy Strategy – we outlined the way forward. With the hydrogen strategy, we are now implementing a lighthouse step by step. Only with companies and industry as partners can a successful energy turnaround be achieved. Renewable hydrogen will play an important role in this." The strategy is to be submitted to the European Commission by the end of the year.

"The environmentally friendly hydrogen technology will play an important role in the mobility and energy turnaround. The aim is to make the best possible use of the ecological and economic potential of this technology both as a forward-looking form of propulsion in transport and in the economy. The time is ripe [...] for Vorarlberg to lead the way with hydrogen."

Christof Bitschi, FPÖ Chairman of the Vorarlberg Regional Assembly

In 2018 Köstinger had already proclaimed the *Hydrogen Initiative* (see H2-international issue Jan. 2019) in Linz during the EU Council Presidency, which had been signed by 26 member states and the European Commission, among others.

SUPPORT FROM THE USA At Stanford University, Kurz met the Austrian physics professor Friedrich Prinz, an expert in energy storage. As www.derbrutkasten.com reported, Prince explained: "Nothing is as cheap as solar energy today. The Chinese have now reduced costs per kilowatt hour by 80 percent. In Europe, too, there is more than enough geographical potential. But you have to think of the energy solution as pan-European."

In addition to hydrogen, the Stanford expert also sees synthetic fuels as a good storage medium for green electricity: "This is an environmentally friendly alternative that is particularly exciting because electric cars and cars with fuel cells will be too expensive for the masses in markets like India and China, at least for the next fifteen years" In conclusion, he also made it clear "There will be no solution where one technology creates everything, but a broad diversification of technology is needed to achieve zero or even negative bottom-line CO_2 emissions." ||

Fig. 1: Elisabeth Köstinger [Source: BMNT]

"Hydrogen has the potential to revolutionize our energy system in the long term. It can help us as a long-term storage facility, for the integration of electricity and heat, in industry and in the transport sector. In this way he points out possibilities for a clean and sustainable energy future. In this way, even those sectors can be decarbonized that are difficult to reach by electrification alone."

Austrian Energy Minister Elisabeth Köstinger

Category: Policy | **Author:** Prof. Ernst Ulrich von Weizsäcker

CLIMATE CHANGE MEANS STRUCTURAL CHANGE

Comment by Prof. Ernst Ulrich von Weizsäcker

Climate change is very unpleasant. But it also becomes uncomfortable to do something about climate change. In Germany, the Coal Commission was formed with the task of conceiving and planning the phase-out of coal. It can last up to twenty years, it's been agreed. The affected regions painfully fast, and the climate protectors unbearably long. Germany's withdrawal from coal is not enough for global climate protection. Around 1,300 new coal-fired power plants are currently being built or planned worldwide. And 90 percent of all new coal-fired power plants are built in developing countries. Those who understand these figures will think that the game against climate change has long since been lost.

However, there is a solution. It is called the "Budget Approach" and was developed in Germany by the WBGU (German Advisory Council on Global Change). This approach aims to give countries of all kinds the same per capita budget for CO_2 emissions. However, the old industrial countries would have used up their budgets very soon and would then have to buy all their licences abroad. The exciting thing is this: For the first time in history, a developing country facing the decision to build a coal-fired power plant would not automatically start construction, but would first conduct a cost-benefit analysis for the two options: build or not build.

High prices for CO_2 licenses would make non-construction temptingly lucrative. And if renewable energies were promoted and energy efficiency greatly improved, the balance would very quickly move towards the non-construction option. And this for purely economic reasons.

Unfortunately, the USA, Russia, Saudi Arabia and a few others came to the Copenhagen climate summit with the clear intention of blocking the discussion on the budget approach. German industry was not enthusiastic either. However, I also consider it feasible and even economically attractive for countries such as Germany to run ahead.

It is certainly important to make sure that the price increase for CO_2 emissions progresses smoothly, so that almost nobody has to emigrate. You just have to make sure that nobody invests any more fresh money in the climate-damaging industry. And one must try to get as many countries of the "North" as possible to participate. The current speed of technological structural change should ensure that climate pioneers become the winners in international competition.

FRIDAYS-FOR-FUTURE A great effect of the student protests "Fridays-for-Future" is the fact that now finally a CO_2 tax is seriously spoken about. In several countries, e.g. Switzerland, Sweden and Canada, the tax is already a reality. And they have ensured that the poorer sections of the population do not suffer any damage. The political weakness is that a lot of mathematics is used to calculate the precise correct amount of the tax. This height is then either very painful or largely ineffective.

On the other hand, a strategy is recommended in which the tax starts small and then increases steadily, in line with the technical development of energy efficiency and renewable energies. Then the price burden for the families always remains fairly constant. For poorer families, a fixed amount can be agreed as a gift. Nevertheless, the climate impact remains very high because all investors immediately switch to climate friendliness in the knowledge of the increase and shape technical progress accordingly. State infrastructures are also being developed in this direction.

Hydrogen technology would benefit in particular from such a development. It is a much more elegant form of energy storage than classic batteries, with a much lower weight and very little metal waste. ||

Prof. Ernst Ulrich von Weizsäcker
since 1991 Member of the Club of Rome, Co-President (2012 to 2018)

Category: Policy | **Author:** Sven Geitmann

HEATED DEBATE CONCERNING THE CO_2 PRICE

Taxation or certificate trading

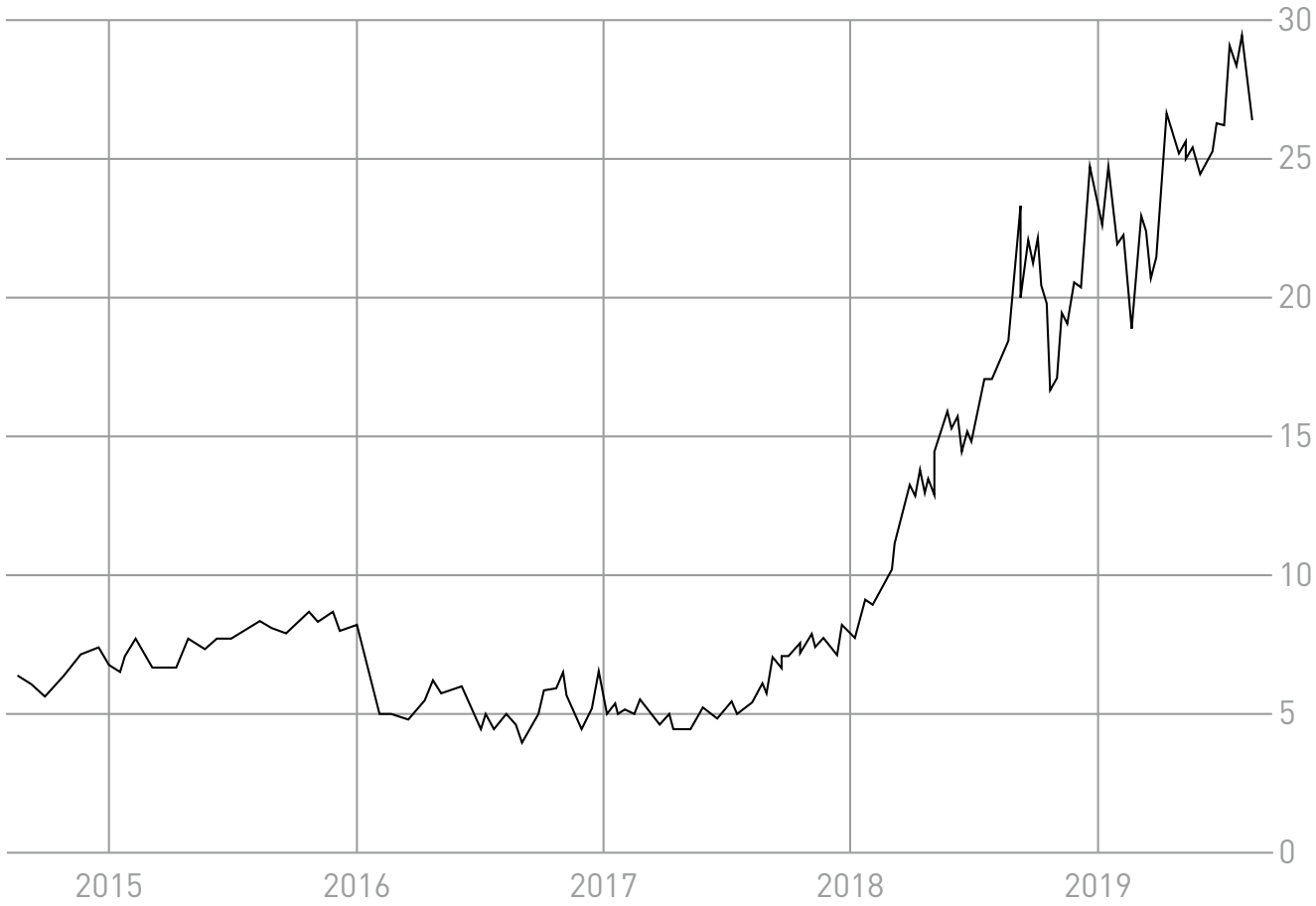

Fig. 1: Development of the CO_2 price since 2014 [Quelle: www.wallstreet-online.de]

Not so long ago, CO_2 certificates were still the epitome of a bureaucratic failure: Hardly anyone wanted them. They were introduced into the energy industry, but in a way that hardly allowed them to have any effect. The situation has changed fundamentally in recent months: Up and down the country, there are now lively discussions about pricing carbon dioxide emissions – in whatever way.

At first, the CDU was divided: While party leader Annegret Kramp-Karrenbauer clearly rejectedthe introduction of a CO_2 tax, her vice-president Armin Laschet, the minister president of North Rhine-Westphalia, initially appeared "just as open as other parties". Over the summer, however, he revised this stance and took a line with Chancellor Angela Merkel, who prefers a system that is controlled via certificate trading, because this could rather achieve a steering effect.

"I reject the CO_2 tax. The average Bavarian causes around three tons of CO_2 per year, which would be an additional cost of 150 euros, which would then be offset by a giant mechanism. That has zero steering effect, no incentive to save CO_2. People get paid, then everything is redistributed, nothing helps the climate."

Thomas Kreuzer, head of the CSU state parliamentary group, in Munich Merkur

"A CO_2 price is not a cure-all with which we can achieve all our climate goals. Together with other measures, however, it is an important building block for Germany to get away from burning coal, oil and gas. Particularly in the areas of transport and heating, there has so far been a lack of sufficient price incentives for switching to climate-friendly alternatives. In the future: Those who behave in a climate-friendly manner are rewarded.

Federal Environment Minister Svenja Schulze

SPD and Greens, on the other hand, spoke out clearly in favour of CO_2 pricing. Federal Environment Minister Svenja Schulze presented an expert opinion on the subject, which she had commissioned. The German Institute for Economic Research (DIW), the Institute for Macroeconomics and Economic Research of the Hans Böckler Foundation (IMK) and the Forum Ökologisch-Soziale Marktwirtschaft (FÖS) investigated possible CO_2 price developments for transport and heat. According to the authors, a climate premium is the best instrument for rewarding climate-friendly behaviour and at the same time reducing the burden on low and normal earners.

However, according to Schulze, the state should not "generate any additional revenue" through this, but the money should be used "to relieve the burden on citizens and com-

DRAMATIC CERTIFICATE SURPLUS

"In a recent study [2011] analysts at Deutsche Bank assume that by 2020 companies will have rights to 566 million tonnes of CO_2 left over. For comparison: Germany – the EU's industrial heavyweight – will receive rights for 452 million tonnes of CO_2 this year [2011]. According to Deutsche Bank calculations, this cushion of certificates means that their price will be consistently too low until at least 2020 to induce companies to invest in climate protection"

Message on Spiegel Online from 18/12/2011

panies". For it is "about a sensible climate protection instrument with a social and ecological steering effect". A climate premium, which would be paid out to thrifty citizens, would relieve the burden on low-income earners in particular.

LITTLE HELPFUL INTERVENTION WORK So far, industry and the energy industry have had to buy certificates when they emit carbon dioxide. Initially, they received a certain proportion of these CO_2 certificates free of charge, but had to buy some at auction. This procedure has been in practice in the EU for years, even though the price level has been so low that certificate trading has had little effect since too many certificates were launched on the market at the start of trading in 2010 (see box).

Dr. Hans-Jürgen Nantke, Head of the German Emissions Trading Authority at the Federal Environment Agency, had already commented on this in 2015: "Over the years, more and more emission allowances have accumulated, and the surplus in the EU now consists of well over 2 billion allowances. This is the reason for very low prices for emission allowances. There is little incentive for participating companies to invest in lower-emission technology." Although the system was reformed in 2018, resulting in moderate price increases, it has not yet had any steering effect.

Meanwhile, there are lively discussions about which is the better way to reduce CO_2 emissions: Taxation or certificate trading. Almost 70 percent of the members of the North German Renewable Energy Cluster Hamburg (EEHH) voted for a CO_2 tax in June 2019, while 27 percent voted for certificates.

Opinions on how high an appropriate CO_2 prices should be today or in the future (see Fig. 1), however, diverge widely. While some people say that the cost of CO_2 emissions in the transport sector must be at least 50 euros per tonne, others say that 20 euros is enough because the gasoline level remains within the range of normal fluctuations at the pump. Bundestag President Wolfgang Schäuble said: "Whether you make certificates more expensive or levy a tax: This goes in the same direction and should be examined by the responsible politicians. Only one thing must be guaranteed: Quick decisions have to be made. We can't afford ten years of further discussion."

Current speculations are going in the direction that a combined solution could end the disputes: For example, new CO_2 certificates could be introduced for various sectors, which would then have to be embedded in a European solution at a later date. In addition to these new certificates, a CO_2 tax could then close any gaps. A decision is expected in autumn. Chancellor Angela Merkel has announced a decision on the tax and social compensation for 20 September 2019. ||

"I am convinced that the CO_2 price is the 'Silver Bullet' after thinking about it for a long time. Intelligent pricing is the key to success."

Nikolas Iwan, H2 Mobility

"The idea is that CO_2 gets a price, so you tax greenhouse gases."

Federal Environment Minister Svenja Schulze

"A CO_2 price of 20 to 25 euros is no good at all."

Dr. Patrick Graichen, Agora Energy Turnaround

Category: Policy | **Authors:** Martin Kopp, Birgit Scheppat

POSITIVE INFLUENCE OF CO_2 PRICING

Market entry evaluation of Power-to-Gas plants

Synthetic gases will play an important role in the full supply of renewable energies for Germany's energy requirements. The meta-analysis of [1] shows that, according to several studies, an electrolysis capacity of more than 100 GW is required in the future energy system in Germany. If such an electrolysis capacity is to be installed in the course of the next few decades, it will be necessary to ramp up the market in good time so that market-driven, reliable and inexpensive plants can be made available. For this development, first scaling effects must be realized from a certain point in time. To this end, it is necessary to enable economically viable operation during the market run-up. This article will show the influence of CO_2 pricing on the economic efficiency of power-to-gas (PtG) plants.

First, the H_2 production costs are analysed as a function of the investment sum and the production quantity, whereby different variants of electricity procurement are considered. Subsequently, the influence of pricing CO_2 emissions is discussed.

The electricity procurement costs are minimised on the basis of a mathematical optimisation model, taking into account hydrogen sales, so that hydrogen production takes place predominantly in times with favourable electricity prices or at favourable control power prices [2].

SCALING EFFECTS REDUCE COSTS If the production quantity of a good increases, the manufacturing costs are reduced in accordance with the price experience curve. This effect has already been quantified in other technology areas. For example, the prices for PV plants were reduced by around 24 percent with a doubling of the installed capacity [3]. For wind turbines, an experience curve of 7 percent for offshore wind energy and 10 percent for onshore wind energy is cited [4].

Use to estimate future investment amounts for PtG plants [5] a factor of 13 percent for the reduction of the in-

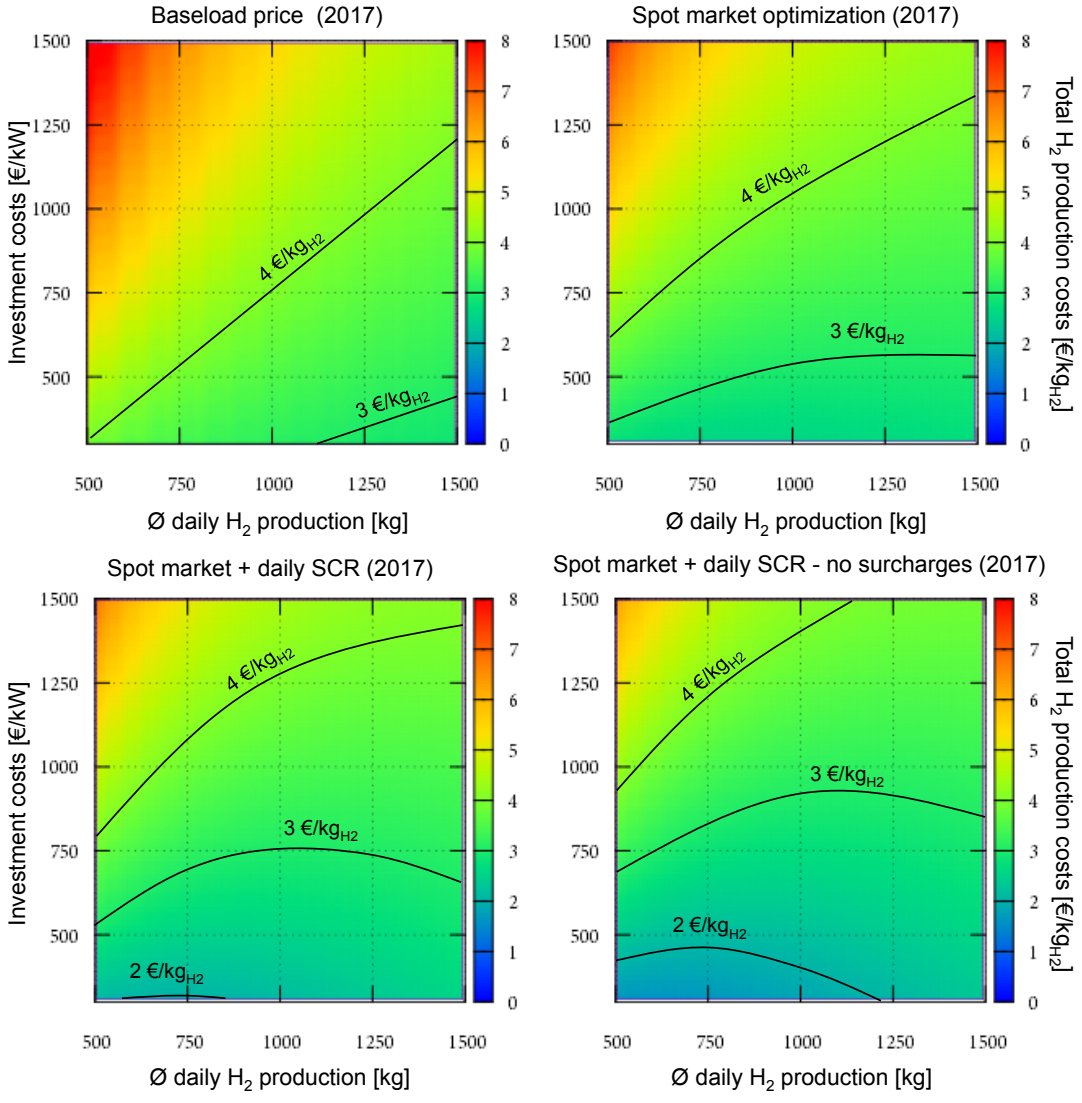

Fig. 1: H_2 production costs as a function of production quantity and investment total. The hydrogen production of the electrolysers becomes economically viable below the entered line of the respectively assumed price for hydrogen from the natural gas reformation.

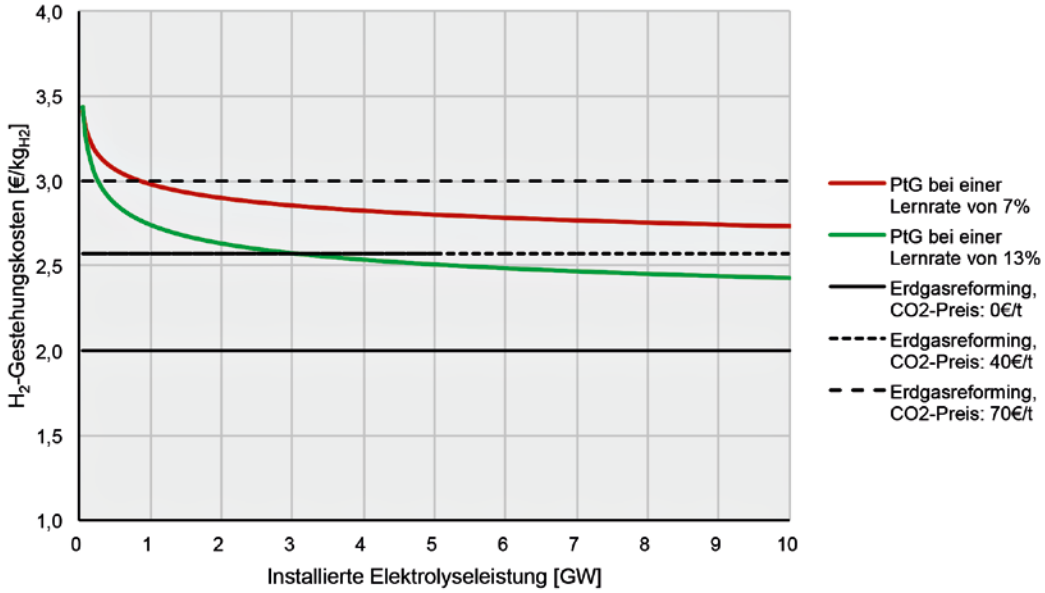

Fig. 2: Development of hydrogen production costs in the event of an expected market ramp-up of PtG plants [Source: University RheinMain]

vestment sum with a doubling of the installed capacity, a value that is estimated to be plausible for plants in chemical process engineering [5]. Based on this learning rate, the authors indicate a possible reduction of the investment amount for PtG plants to 500 €/kW with an installed capacity of more than 10 GW. The investment amount of 300 €/kW is valid after [6] as a possible cost reduction target. In order to achieve these cost targets, the authors state that larger production volumes, an improved supply industry and further technological improvements, such as in the field of membranes and catalysts, are necessary.

Based on the discussion of the price-experience curve approach, it becomes clear that a reduction of the investment sum for PtG plants depends significantly on the market development, which in turn is influenced by the possible production costs of hydrogen (see Fig. 1). The calculation of the production costs of PtG plants is based on the experience and the technical framework conditions of the 6 MW PEM electrolysis plant of the Energiepark Mainz project and is carried out on the basis of electricity prices, control power data and weather data for 2017. For the calculation of the production costs, a depreciation period of twenty years, a capital interest rate of 5 percent and annual operating costs amounting to 4 percent of the investment sum are assumed. For the levies and duties on electricity purchases, the assumption is made that the plant belongs to the manufacturing sector and receives a reduction on levies due to the energy intensity, whereby the full levies are payable for 1,000 MWh.

The potential of optimisation on the electricity market side becomes clear when comparing the various variants of electricity procurement. While the resulting H_2 production costs for electricity purchased at a constant price (baseload price 2017: € 34.19/MWh) with an average daily production of 1,000 kg_{H2} and an investment sum of € 1,000/kW amount to around € 4.48/kg_{H2}, these can be reduced to around € 3.83/kg_{H2} by optimising the electricity market on the spot markets. The saving of 0.65 €/kg_{H2} leads to a cost saving of approximately 237,000 € for the assumed daily production of 1,000 kg_{H2}, which corresponds to 15 percent of the total annual costs. This cost saving would only be achieved if electricity were purchased at a constant price when the investment sum fell to 700 €/kW. A further reduction in costs can be achieved through participation in the secondary regulatory power market (SRL) and the assumptions made for 2017 regarding the switch to a daily tender. In this case, the hydrogen production costs can be reduced from an average daily production of 1,000 kg_{H2} and an investment sum of 1,000 €/kW to approx. 3.46 €/kg hydrogen with the assumed daily production. This corresponds to a total saving of approx. 372,000 € or 23 percent of the total annual costs.

These calculations were based on the assumption that the PtG plant would benefit from reductions in ancillary electricity costs for energy-intensive companies. If the case were to arise that PtG plants would be completely exempted from levies and duties, this would lead to a further reduction of the production costs to approx. 3.16 €/kg_{H2} with the assumptions mentioned. If, on the other hand, the full levies and duties have to be paid, the hydrogen production costs increase by approx. 4.40 €/kg_{H2} compared to the figures mentioned. The competitiveness of PtG plants in comparison to hydrogen production by natural gas reforming is not achievable under these conditions.

In Fig. 1 it is further shown that with a decrease of the investment sum for PtG plants the hydrogen production costs can be reduced significantly. Should the investment sum for PtG plants be reduced to 300 €/kW, production costs between 2.20 €/kg_{H2} and 3.10 €/kg_{H2} are conceivable. In this case, the share of electricity costs in the total production costs would increase, so that optimisation on the electricity market side would gain in importance.

INFLUENCE OF CO_2 PRICING If, in addition, a financial burden is imposed for the emission of greenhouse gas emissions such as CO_2, alternative hydrogen production in natural gas reforming plants would become more expensive. The costs for this type of large scale H_2 production are calculated on the basis of [7] with 2.00 €/kg hydrogen accepted. [8] puts the share of natural gas costs in the total hydrogen production costs for large natural gas reforming plants at 50 to 68 percent.

Effective pricing of CO_2 emissions therefore has a direct influence on the production costs of conventional hydrogen production. Increasing the prices for CO_2 emission certificates could therefore directly increase the competitiveness of PtG plants.

After [9] CO_2 emissions of about 100 g CO_2/MJH_2 are caused during hydrogen production in central reforming plants. Based on the calorific value of hydrogen, CO_2 emissions of 14.3 kg result for the production of 1 kg of hydrogen. The hydrogen production costs of natural gas reforming plants thus rise proportionally to the price of CO_2 emission certificates. With with a CO_2 price of 10 €/t_{CO2} this results in additional costs of 0.14 €/kg_{H2}.

Currently, the traded CO_2 price is 26.72 €/t_{CO2} (as at: 01/07/2019). Assuming that the CO_2 price rises to 70 €/t_{CO2}, the additional costs for conventional hydrogen production would increase by 1 €/kg_{H2}. In this case, the total production costs, based on the assumed values according to[7]to 3.00 €/kg_{H2}. In this cost area, PtG technology could become competitive with the expected reduction in capital expenditure and optimisation on the electricity market side.

A prerequisite for this is that the electricity procurement costs for the PtG plant do not change as a result of CO_2 pricing. This is the case when conventional power plants only have a price-setting effect on the electricity exchange during a short period of the year, as is expected with an increased expansion of renewable energies. In addition, it should be noted that CO_2 pricing should be applied internationally so as to prevent energy-intensive companies from migrating to countries with lower CO_2 pricing.

POTENTIAL DEVELOPMENT OF H_2 PRODUCTION COSTS

In the course of a market ramp-up, learning rates of 7 and 13 percent respectively are assumed for the price experience curve. For the calculation of the investment sum, a currently installed electrolysis capacity of 60 MW and production costs of 1,000 €/kW are taken as a basis. According to the published information, PtG projects with a capacity of 26 MW are currently in operation in Germany.

The H_2 production costs were determined on the basis of the expected cost degression for the respective electrolysis capacities and the variant of optimised electricity procurement via the spot markets and a daily SRL participation (secondary control capacity). These calculations are based on the assumption that the production costs of natural gas reforming plants without CO_2 pricing amount to 2 €/kg_{H2}. It shows that with a learning rate of 13 percent (see Fig. 2), an installed electrolysis capacity of 0.3 GW is sufficient to enable H_2 production costs of 3 €/kg_{H2}. In this case, with an assumed CO_2 price of 70 €/t_{CO2}, the same production costs would be achieved as in natural gas reforming plants.

The calculated investment sum for PtG plants with an installed capacity of 0.3 GW is around € 725 per kW. Assuming a CO_2 price of 40 €/t CO_2, the cost equality between PtG plants and conventional H_2 production will be achieved with an installed capacity of about 3 GW. The calculated investment sum for this service is around 450 €/kW. In the case of a learning rate of 7 percent, an installed electrolysis capacity of 50 GW is required.

This analysis shows that the competitiveness of PtG plants can be achieved from an installed capacity in the low single-digit GW range if the CO_2 price is increased accordingly. In order to close the initial competitiveness gap and encourage a market ramp-up of PtG plants, an investment grant could be helpful.

The calculated development of the investment sum for PtG plants was carried out in this article on the basis of assumed learning rates. It remains to be seen to what extent these can be implemented in practice. In particular, pending electrolysis projects on a large scale of 10 to 100 MW could provide information on whether a cost degression can actually be achieved by increasing the installed electrolysis capacity. ||

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Category: Policy | **Interview Partner:** Franz Untersteller

"WE'RE STILL IN SHOCK."

Interview with Franz Untersteller, Environment Minister of Baden-Württemberg

Baden-Württemberg is home to a large part of the German automotive industry. However, the new headquarters of German battery research will be located in North Rhine-Westphalia, not in Ulm. Therefore, the HyFab project comes to Baden-Württemberg for this purpose. Franz Untersteller, Minister for the Environment, Climate and Energy Economy, calls in this context for greater investment in research and development in order to significantly reduce costs, for example for the electrolysers required.

H2-international: Minister Untersteller, are you satisfied with the current interim status of the energy turnaround?

Untersteller: We've achieved a lot. 44 percent of green electricity in the first half of 2019 throughout Germany is a success. And I hope that the much-discussed issue of climate protection will continue to boost renewables. I am also very pleased that we no longer have a discussion about costs due to the positive developments in renewables. Raising the expansion corridors in Germany would have hardly any effect

on the EEG levy. Other effects, such as the price difference between the low exchange electricity price and the EEG remuneration, increase the levy.

As of 2021, the first EEG plants will drop out of funding after they have received money for twenty years plus the year of installation. What does this mean?

This means that many plant owners will think hard about what to do with the free solar power from their own roof. Whether they want to market the solar power or perhaps purchase a battery storage tank. My own photovoltaic system will soon reach this age, by the way. But thoughts about the future of electricity are only one side of the energy turnaround. It's far more than just a electricity turnaround.

What has to happen?

The heat and transport sectors urgently need to be decarbonised. Heating and hot water generation account for almost a quarter of all greenhouse gas emissions in Baden-Württemberg. Almost 90 percent of this is accounted for by fossil energy sources. We therefore have a Renewable Heat Act (EWärmeG) in Baden-Württemberg. It is partly responsible for the fact that, at 16 percent, we are slightly above the national average of around 14 percent. In an evaluation report, we recently asked 1,000 people affected whether the law had added to their work. This was not confirmed by the respondents. However, the even thicker chunk of the energy turnaround lies clearly in the transport sector.

Baden-Württemberg is the location of several well-known car manufacturers who are facing a difficult transformation process. How can politics help?

Politics must accompany the transformation process from the old to the new world of mobility. It's about switching from the combustion engine to electric cars and cars with fuel cells. Autonomous driving and digitalisation are other trends that are driving car manufacturers. Three major manufacturers plus suppliers account for 440,000 jobs at our company. They are an essential reason for the prosperity of our federal state. The topic is very complex, especially in Baden-Württemberg. This is why minister president Winfried Kretschmann opened the so-called Strategy Dialogue Car Industry two years ago, which is to run for a total of seven years. Politics, industry and research are sitting at the same table. An intelligent charging infrastructure for electric and FC cars will also be considered.

A commission of experts commissioned by the federal government has selected Münster as the main location for battery cell production (see p. 40). How did you react?

Honestly, we're still in shock. From my point of view, there are many criteria that speak in favour of the Ulm location. Over Easter we had already promised state grant financing for the state of 180 million euros. The empty buildings are already ready and could be occupied tomorrow. In Münster, these would first have to be built on greenfield sites. One thing's for sure: Time is an essential topic in the development of cell production. I don't see how this is going to go any faster in Ibbenbüren.

Another prestigious project is the so-called HyFab-Baden-Württemberg (see p. 40). This project is supported by Audi, BMW and Daimler, among others. What's behind all this?

In the research factory for fuel cells and hydrogen, an automated production process with quality assurance procedures for so-called fuel cell stacks is to be developed and tested. In cooperation with the Fraunhofer ISE in Freiburg and other players from science and industry, the ZSW in Ulm will strengthen the supply industry and create an open, flexible platform. Hydrogen and fuel cell technology can play an important role in buses and trucks in particular. The state of Baden-Württemberg is providing up to 18.5 million euros in funding for the realisation of the research factory. In total, the HyFab project will cost a good 74 million euros over the next ten years.

Who should finance the necessary infrastructure? Do you see a duty on the state or on companies?

The state is not a fully comprehensive insurance that can be used for everything. It goes without saying that industry must participate in the construction of a charging infrastructure, as it does. We currently have thirteen hydrogen filling stations in Baden-Württemberg. Outside Baden-Württemberg it looks much thinner – by this I mean our neighbours in other European countries.

Is there no master plan for an H_2 economy like in Japan?

There is. In Northern Germany, the establishment of a hydrogen economy is currently being discussed very concretely. There is an agreement between the minister presidents of the northern states concerned. In addition, the electricity grid operator Tennet and the pipeline network operators Gasunie Deutschland and Thyssengas are planning to build a power-to-gas pilot plant with a capacity of 100 megawatts in Lower Saxony. However, there are still only a few hours in which hydrogen can be produced with excess production. But that will increase – from 2030 at the latest. It therefore makes sense to step up research and development in order to significantly reduce the costs of H_2 production and storage. We will also need our own electrolysis capacities in Baden-Württemberg by 2030 at the latest. ||

FRANZ UNTERSTELLER

He was born in April 1957 in Ensheim, Saarland. His studies of landscape planning at the then Nürtingen University of Applied Sciences brought him to Baden-Württemberg, where he successfully completed his studies in 1982 after a longer period of study in Colombia as a Diplom-Ingenieur (FH). He has been working at the Öko-Institut in Freiburg since 1981. He was a member of the Executive Board from 2002 to 2011. He earned his political spurs between 1983 and 2006 as an environmental and energy policy advisor to the Green parliamentary group in Baden-Württemberg's state parliament. He has been a member of the Baden-Württemberg state parliament since 2006. From 2006 to 2011 he was deputy leader of the Green parliamentary group in the state parliament. In May 2011, he was appointed Minister for the Environment, Climate and Energy of the State of Baden-Württemberg.

Category: Policy | **Author:** Angelika Heinzel

THERE WILL BE FC MOBILITY AND AN H_2 INDUSTRY

Comment by Prof. Angelika Heinzel

Fig. 1: Prof. Angelika Heinzel [Source: ZBT]

There is a lot going on in the energy sector at the moment. As a result of numerous activities and events – be it diesel scandals or CO_2 pricing, driving bans or Fridays-for-Future demonstrations, flight shame or real laboratories – more and more players are committing themselves to more sustainability as well as to hydrogen as an energy storage. But this time it doesn't seem to be just another FC and hydrogen hype. On the contrary, there is increasing evidence of the emergence of an actual energy turnaround. The H2-international editorial team therefore asked the long-standing hydrogen and FC expert Prof. Angelika Heinzel from the Zentrum für BrennstoffzellenTechnik Duisburg GmbH (ZBT) for answers to the following questions: What is different now from previous hypes? Where do you see any development potential? What are currently still obstacles? What must politics do?

Just two years ago the word electro-mobility was inseparably linked to the battery car, today it is different. Climate change requires comprehensive approaches; the storage of large quantities of electricity generated from renewable sources can only succeed with hydrogen technology. So there will be electrolysers and a hydrogen infrastructure. Since fuels are the most expensive energy sources that we burn (about 15 Ct/kWh for petrol compared to 7 Ct/kWh for natural gas) and battery cars have a limited range and require a longer charging process, the growing interest in fuel cell vehicles is logical. In addition, Japan, Korea and China rely on hydrogen and fuel cell vehicles, which our export-oriented industry cannot afford to ignore.

Conclusion: If we take climate protection seriously, there will be fuel cell mobility and a hydrogen industry will emerge. Achieving the 2030 CO_2 reduction targets is still possible, but not with a simple "keep it up".
Politicians must set a reliable framework and the right steering signals, and pursue the necessary change vigorously. Germany as a business location must not be neglected. The new products should and can be developed and manufactured in Germany in order to create new jobs. With the first hundred filling stations opened by the end of this year, it will be possible to drive a fuel cell vehicle in Germany. So it must now be our goal to bring enough vehicles onto the German market and to develop a business model from hydrogen technology.

The demand from fleet operators could ensure the acceptance of the first small-series vehicles, as Deutsche Post AG has done with the Streetscooter vehicles in the battery sector. After a start-up subsidy, the necessary cost reduction can be achieved through series production, also for fuel cell vehicles. However, filling stations for trucks are still largely lacking, and there is an urgent need for action here. The business model for hydrogen production is not yet sufficiently developed either. Electricity prices of 3 to a maximum of 6 Ct/kWh would be required in order to be able to offer the new energy source at the filling station at costs comparable to diesel and petrol. Direct coupling of electrolysers with renewable energy plants is seen as the key to success here. The import of hydrogen, for example from the sunny countries of North Africa, is also a future option.

What would be the effect of all these measures? Is it worth the effort to develop a double infrastructure (charging infrastructure for battery vehicles and hydrogen filling stations) and two different drive concepts? The answer is definitely yes.

1. Hydrogen filling stations can replace the charging infrastructure where charging of many vehicles at fast intervals is necessary, as the amount of energy transferred during gas filling can be about 2 to 3 MW compared to 50 to 100 kW at an electricity charging station. A hydrogen filling station therefore replaces 20 to 60 charging stations. If necessary, expensive local amplification of the electrical distribution grid can be avoided.
2. Since fuel cell vehicles enable long ranges and good payloads and will therefore rather replace today's diesel vehicles, the CO_2 savings are high. A lot can be achieved with

just a few vehicles. The transition from the industrial hydrogen used today to "green" hydrogen is rapidly possible. Several large companies have already developed electrolysers of the MW class and are waiting for the right political framework conditions. This conversion could even be faster than making the electricity available in the grid free of CO_2.

3. Fuel cell vehicles benefit from developments in the battery sector: The electric drive train is similar. For fuel cells as power generators, however, other raw materials are needed than for the Li-ion battery: Instead of lithium, cobalt, nickel and manganese, it's platinum, steel and carbon. A broad material base reduces the risk of scarcity and price increases.
4. While catching up in the production of high-energy batteries is a challenge, fuel cell production currently still offers opportunities. The production of fuel cells requires high material and component qualities, low rejection rates and established recycling processes, especially because of the precious metals used – qualities that can be found in German production technology. A first industrial consortium has just announced the start of series production.

These should be enough arguments to inspire politicians and industry with the technology. Toyota and Hyundai are showing us what to do. The two companies have announced that they will produce 30,000 and 40,000 vehicles per year respectively over the next few years. In any case, the demand for the vehicles far exceeds the supply. ||

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H_2 TEST FIELD AT THE ZBT

A hydrogen test field with laboratories and H_2 filling station is currently being built at the Centre for Fuel Cell Technology (ZBT) on the campus of the University of Duisburg-Essen (see H2-international issue July 2017). On 26 June 2019, the project, financed with public funds from the state, the federal government and the EU, was presented in the presence of NRW Prime Minister Armin Laschet. The current occasion was the "Hydrogen Week in NRW", during which a new H_2 filling station in Duisburg was inaugurated at the same time.

The area comprises various electrolysers (Carbon2Chem, see H2-international issue Oct. 2018), a test platform for H_2 filling stations (H2TestOpt), a mobile filling unit (MobFuelH_2, see H2-international issue Apr. 2018) and a quality laboratory (Hy-Lab).

Dr. Christian Spitta of the ZBT explained: "The mapping of the entire chain of the H_2 infrastructure for mobility, from generation to delivery to vehicles, as well as the connected quality laboratory are unique in their form. Together with industry, we want to investigate and test the economic efficiency, safety, quality, cost-effectiveness, availability and regulatory framework conditions of a suitable H_2 infrastructure in the real world" minister president Laschet said: "Hydrogen has special potential, it is a versatile energy source, hydrogen can be used in power generation and as a fuel for fuel cell vehicles and can replace CO_2-rich fuels." (sg)

Thema: Politik | **Autor:** Christian Küchen

GREEN HYDROGEN FOR LOW-EMISSION REFINERIES

Guest article by Prof. Christian Küchen from the Mineralölwirtschaftsverband (Petroleum Industry Association)

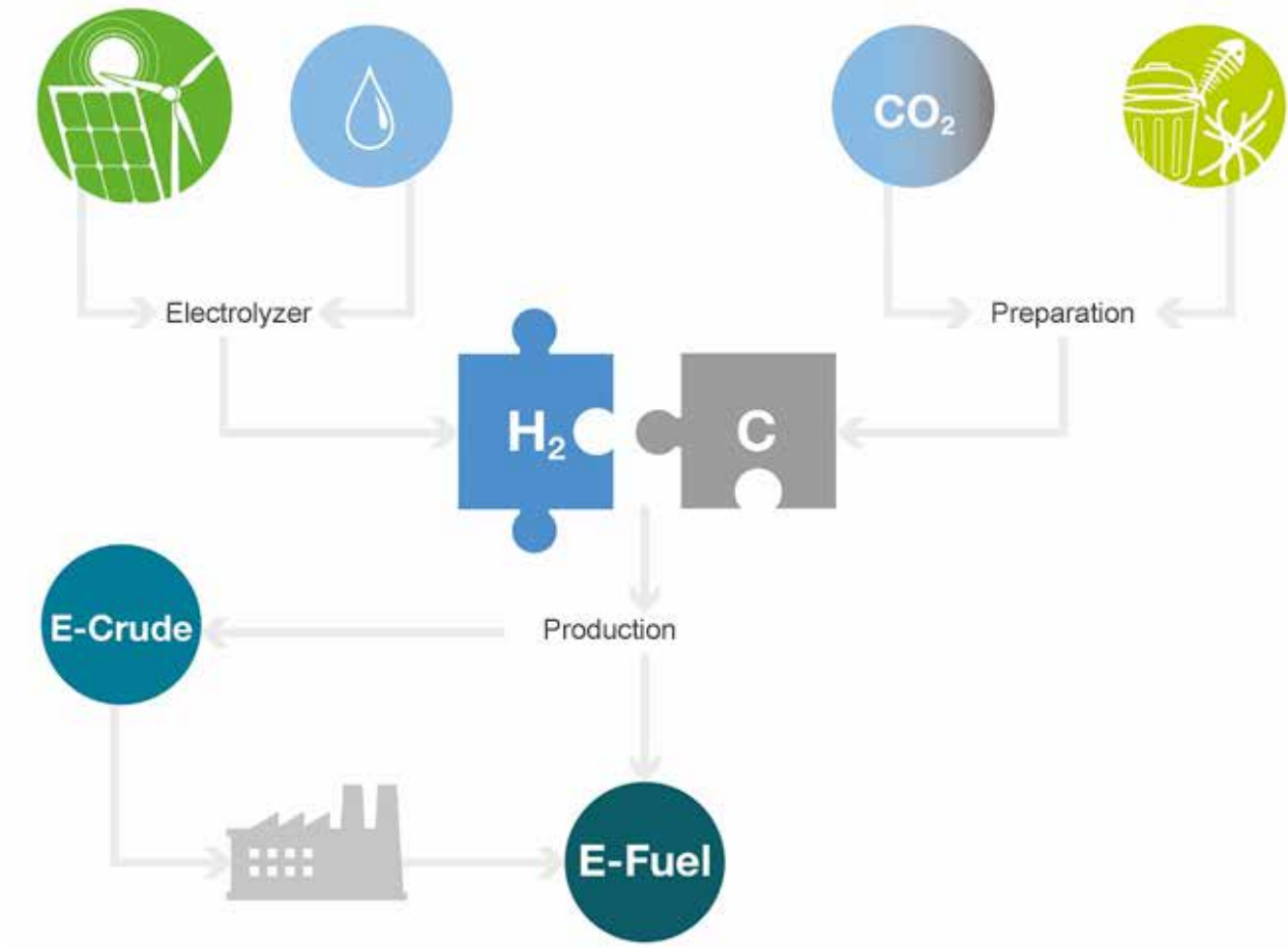

Fig. 1: Technical Options for Fossil Energy Replacement [Source: MWV, iwo]

The member companies of the German Petroleum Industry Association (MWV) welcome the Paris Climate Protection Agreement and the associated targets to reduce greenhouse gas emissions in all sectors. The petroleum industry can make a significant contribution to achieving the targets with renewable fuels.

At the European level, European refining companies published their concept for achieving climate targets last spring: In April 2018 the European petroleum association FuelsEurope presented its VISION 2050 [1] to the Council of EU Economic and Energy Ministers. The core is the transition to the production of low-greenhouse gas or greenhouse gas-neutral liquid energy sources and a continuous reduction in emissions from refineries. Hydrogen plays an important role here.

Numerous studies and analyses confirm that liquid energy sources and raw materials are also needed in substantial quantities in the long term. The transport sector plays a major role in this. Today – including the railways – 98 percent of the final energy demand in transport is covered by liquid energy sources. This figure alone makes it clear that with an electrification strategy alone neither the ambitious sector target of 40 percent greenhouse gas reduction in the transport sector by 2030 nor the climate targets for 2050 as a whole can be achieved.

INCREASING EFFICIENCY AND ELECTRIFICATION ARE NOT ENOUGH The analyses carried out within the framework of the National Platform on the Future of Mobility have also shown that it is not enough to rely solely on increasing efficiency, electrifying and expanding public transport, especially rail transport. Even if it is possible to bring around ten million electrically powered passenger cars and a significant number of electrically powered commercial vehicles onto the roads by 2030 and to cope with considerable growth in freight and passenger transport by rail, a share of around 20 percent renewable fuels will be needed in 2030 to achieve the 40 percent target.

The development and market ramp-up of renewable fuels is therefore a necessary measure to achieve the climate targets. Various climate-friendly technologies are available for this purpose:

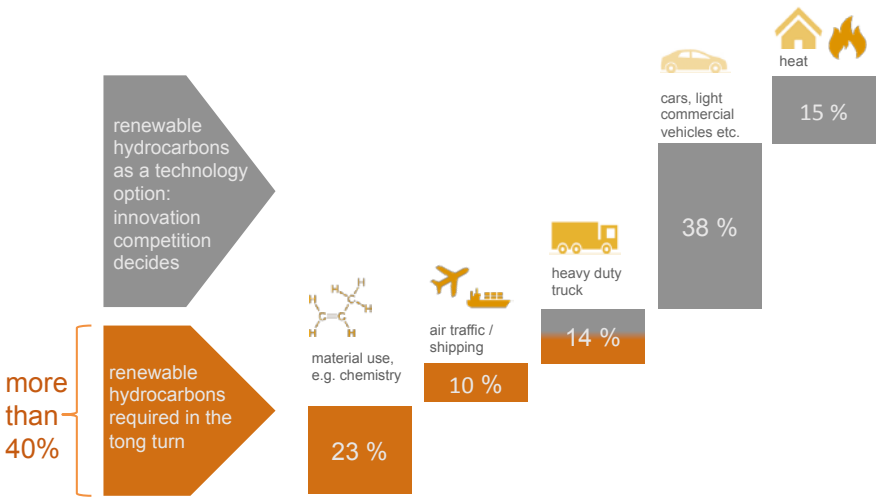

Fig. 2: Use of hydrocarbons in Germany 2018 [Source: Prognos]

- The use of greenhouse gas neutral hydrogen in fuel production in refineries
- Co-processing, e.g. of biogenic residues and waste materials – hydrogen is also required for this purpose
- New advanced biofuels based on residual and waste materials
- Electricity-based fuels (E-Fuels)

Mineral oil refineries use large quantities of conventional hydrogen to refine mineral oil components and achieve the required product properties. Many of the technologies mentioned for the production of greenhouse gas-reduced or even greenhouse gas-neutral hydrocarbons will further increase the hydrogen demand of refineries in the future.

The hydrogen required is largely produced as a by-product in other refining processes. However, these quantities are not sufficient to meet demand. This is why additional hydrogen is already being produced today, above all by steam reforming of natural gas. This results in CO2 emissions.

More than 90 percent of greenhouse gases can be avoided if "green" hydrogen is produced and used from green electricity. Since hydrogen is also found in the material of the products, this automatically increases the renewable portion in fuels and combustibles.

THE FIRST STEPS HAVE BEEN TAKEN H&R Ölwerke Schindler has been operating an electrolysis hydrogen plant in Hamburg since November 2017. The refinery uses surplus wind power for this purpose. The high-energy gas is used in production processes for the manufacture of special mineral oil products such as paraffins, white or process oils.

Construction of the Refhyne hydrogen electrolysis plant has begun at the Shell-Rheinland refinery (see H2-international issue Apr. 2018). From 2020, the plant is expected to produce 1,300 tons of hydrogen per year, which can be fully integrated into the refining process. Although this corresponds to only one percent of the hydrogen quantity required in production, it shows that refineries have great potential to advance the path to large-scale plants and thus reduce the costs of electrolysis.

REFINERIES CAN HELP SHAPE THE ENERGY TURNAROUND One of the pioneers in the use of green hydrogen is the BP refinery in Lingen, Emsland. In 2018, it used climate-neutral hydrogen to produce fuels for the first time worldwide. A total of about 130,000 cubic meters of electrolytically produced hydrogen were obtained from a power-to-gas plant for the production of green autogas. This pilot project has shown that oil refineries can play an active role in shaping the energy turnaround in the transport sector.

The Heide refinery in Schleswig-Holstein has two projects in preparation that involve the production of green hydrogen through the use of surplus wind power: The West Coast 100 real laboratory and KEROSyN 100. The hydrogen produced in this way is to be used as 100% climate-neutral kerosene for the production of climate-friendly fuels for aircraft (see H2-international issue Jan. 2019 and Oct. 2017).

But not only hydrogen is in the focus of the climate neutrality of refineries. As part of the strategy dialogue for the automotive industry, the MiRO refinery in Karlsruhe is involved in the Refuels project. For the first time, the potential of greenhouse gas-reduced synthetic fuels will be investigated from their production using renewable energies to their use in vehicles.

The OMV refinery Wien-Schwechat is testing the conversion of old plastics into synthetic crude oil using the ReOil process. Additional methanol production capacities are being built at the Total refinery in Central Germany. In the case of purely material use for the chemical industry, CO_2 emissions are avoided by possible combustion.

STABLE FRAMEWORK CONDITIONS REQUIRED The mentioned examples are only the beginning. Larger production facilities for greenhouse gas-neutral hydrogen and products made from it are essential if the climate targets for 2030 are to be achieved. This requires stable framework conditions for investments. For first plants, the petroleum industry, together with other associations, is demanding a market launch programme for Power-to-X technologies [2] as part of the recently founded PtX alliance.

A further important prerequisite is that the possibilities for offsetting green hydrogen against the fuel suppliers' obligations to reduce greenhouse gas emissions from fuels as laid down in the EU's Renewable Energies Directive (RED II) are quickly transposed into German law. Greenhouse gas abatement costs are particularly high in the transport sector. If the greenhouse gas reduction obligations of fuel suppliers in Germany are not met, payments of 470 euros per tonne of CO_2 become due.

The refinery sector thus offers great potential, particularly in fuel production, for supporting the market ramp-up of climate-friendly electrolysis hydrogen technology. ||

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POTENTIALS OF A FUTURE ENERGY SYSTEM

Findings from the hydrogen study in North Rhine-Westphalia

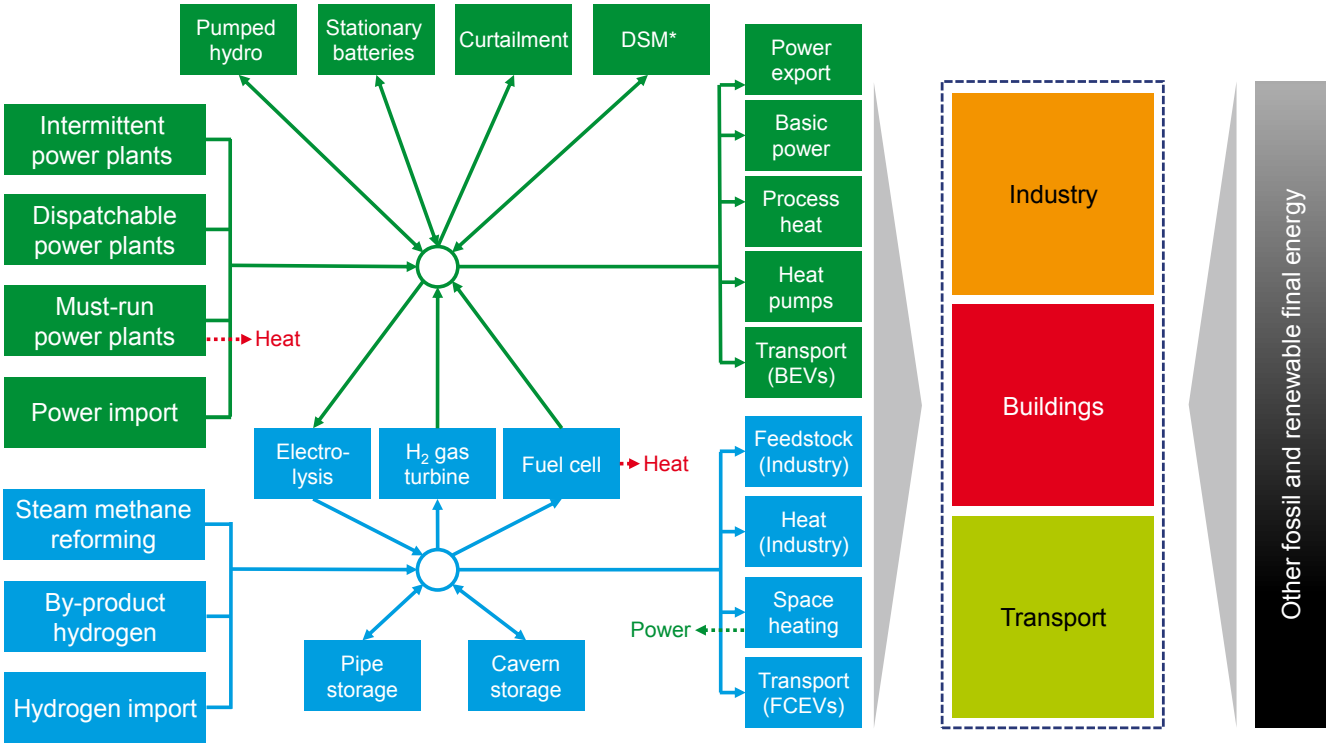

Fig. 1: Limits of the energy system in modelling

The energy system of the future faces numerous challenges with its increasing decarbonisation, the further expansion of renewable energies and the coupling of the electricity, heat, transport and industrial sectors. At the same time, however, the advancing energy turnaround also offers economic opportunities through additional added value, new jobs and a reduction in dependence on imports of fossil energy sources. In this context, hydrogen produced from renewable energies can be seen as an important pillar in achieving the energy policy triangle of climate protection, safety of supply and economic efficiency.

The Hydrogen Study NRW, which was commissioned by the state of North Rhine-Westphalia and carried out by Ludwig-Bölkow-Systemtechnik (LBST), focuses on the economic and climate-relevant potential of hydrogen in a future energy system in Germany and NRW. On the basis of a differentiated evaluation of hydrogen, the study provides well-founded insights into the value of hydrogen as an energy source in a future energy system. The cost-optimized design and operation of the future energy system were modelled. On the other hand, on the basis of these results, further economic effects of hydrogen in terms of value creation potential were examined in more detail.

INTEGRATED MODELLING OF THE ENERGY SYSTEM The evaluation of the potentials of hydrogen is basically based on a comparison of two applications with low or high H_2 demand. On the one hand, the focus on electrification is predominantly on direct electrical end applications, with electricity being the main energy source, so that the power grid has to be expanded accordingly. The lower demand for hydrogen, for example for material use in industry, is served locally by electrolysis. On the other hand, the focus on hydrogen on a larger scale uses hydrogen-based end applications supplied by a dedicated H_2 pipeline network.

The study considers a total of six scenarios that differ for the three GHG reduction targets (GHG = greenhouse gas) across all sectors from 55 percent in 2030 and 80 percent and 95 percent in 2050, respectively, on the basis of the two application cases. The GHG target of 95 percent means a complete decarbonization of the remaining energy system due to unavoidable residual emissions, for example from agriculture or cement production.

In a first step, the energy supply for the sectors electricity, buildings, transport and industry was simulated temporally and spatially for all scenarios as part of an integrated modelling in order to determine the cost-optimal expansion for hourly operation of the individual components for the generation, conversion, storage and transport of electricity and hydrogen from a system perspective (see Fig. 1). The state of North Rhine-Westphalia was considered in greater spatial detail than the rest of Germany.

On the basis of the results from the comprehensive system analysis, the domestic value added, job effects and a reduced energy import dependency were then analysed in a second step in a cost-based approach and on the basis of the literature values on value added shares and employment intensities. The study was rounded off with recommendations for action for politics, industry and research.

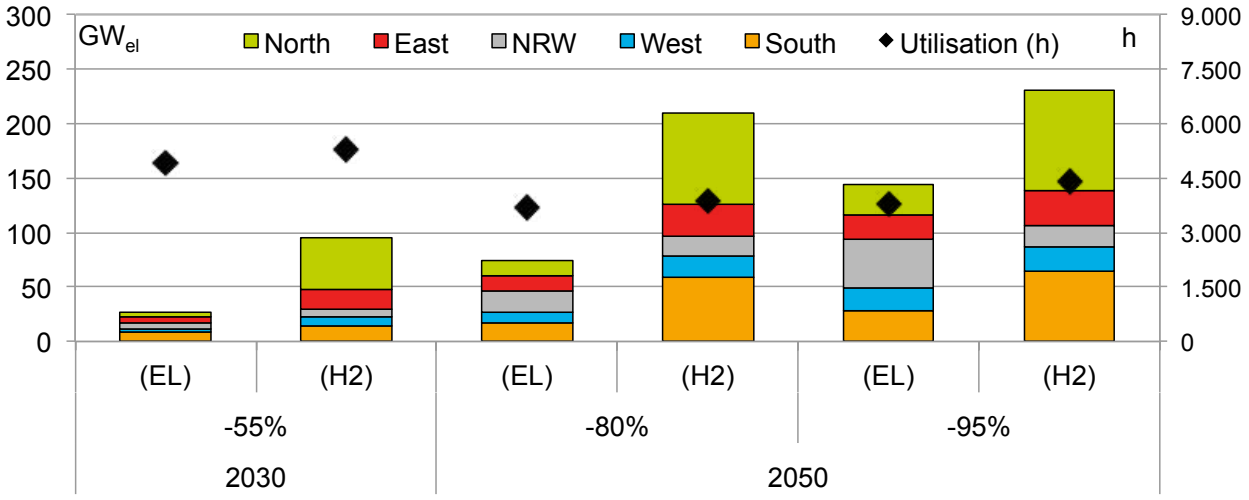

Fig. 2: Installed capacity and utilization of the electrolysis plant in individual regions. EL = focus on electrification; H2 = focus on hydrogen

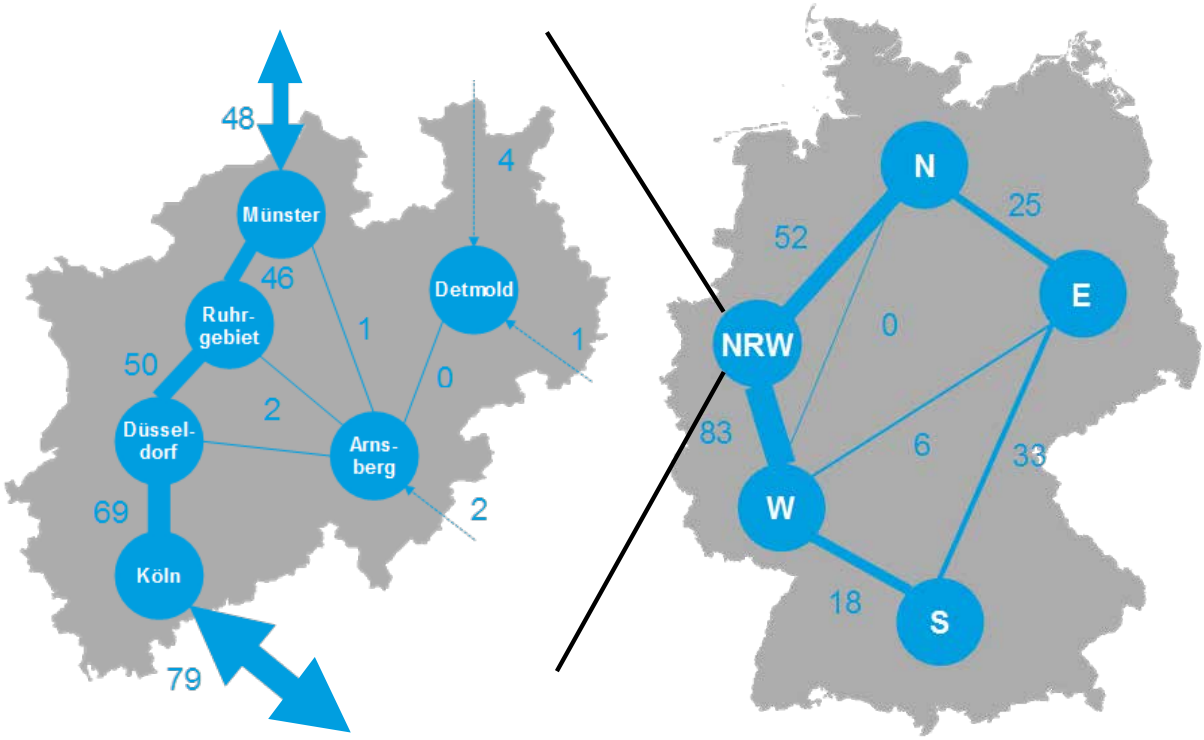

Fig. 3: Demand for hydrogen pipelines in GW in Germany and NRW with a GHG reduction target of 95 % in 2050

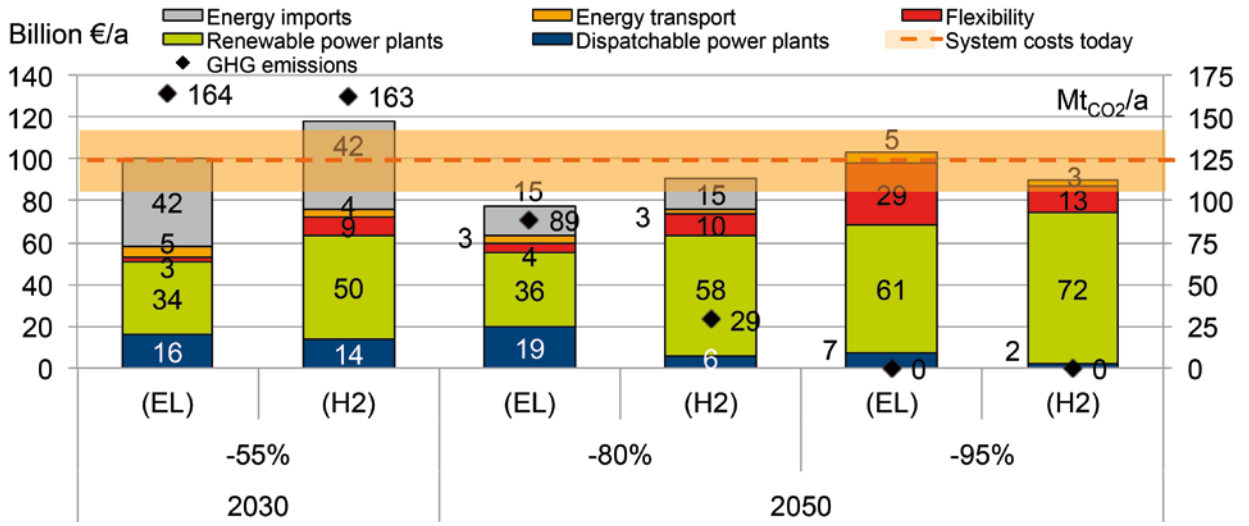

Fig. 4: Annual total costs of the German energy system and GHG emissions [Sources: LBST]

HYDROGEN AS AN IMPORTANT SUPPORT Under the assumptions of the study, a wide range of hydrogen demand is assumed, depending on the scenario. By 2030, Germany-wide hydrogen demand in all sectors will amount to 100 to 300 TWh per year and, depending on the GHG reduction target and scenario focus, will rise to 200 to 650 TWh per year by 2050. Within North Rhine-Westphalia, the long-term demand for hydrogen can be disproportionately high compared to other federal states, at up to 160 TWh per year. This is due not only to the high population density and the corresponding demand in the building and transport sector, but also to the demand from industry, whereby the steel industry is likely to play a special role by converting production processes to hydrogen direct reduction and thus has the potential to become a game changer in NRW.

For the corresponding hydrogen supply, the required electrical electrolysis capacity throughout Germany is 25 to 100 GW in 2030 and 75 to 250 GW by 2050 (see Fig. 2). In all scenarios with 4,000 to 5,000 full-load hours, electrolysis achieves a comparatively good utilisation rate in the cost optimum and in compliance with the climate protection targets, but this also leads to the fact that hydrogen is not always produced in a completely renewable way with less ambitious GHG reduction targets. Nevertheless, electrolysis as a flexible load makes an important contribution to the integration of renewable energies into the energy system in all scenarios.

In the long term until 2050, the peak load will be secured with a GHG reduction target of 80 percent, predominantly with natural gas power plants, and with the ambitious 95 percent target with H_2-operated power plants and stationary fuel cells. At the same time, the ambitious climate protection target creates a large long-term demand for seasonal energy storage of 40 to 60 TWh, which can be covered cost-effectively by H_2 storage (especially salt caverns). In addition, H_2 transport in dedicated pipelines in the scenarios focusing on hydrogen significantly reduces the necessary expansion of the electricity grid (see Fig. 3). Hydrogen can thus become an important support in the production, conversion and transport of large quantities of energy in a cost-optimal system with a high proportion of renewable energy.

POSITIVE ECONOMIC EFFECTS An initial analysis of the overall economic costs of the German energy system shows that the strengths of hydrogen cannot yet be exploited to the full with GHG reduction targets of 55 and 80 percent and that the system costs are lower in the scenarios with a focus on electrification (see Fig. 4). Nevertheless, with high hydrogen demand, the system costs in the 80% scenario are below the costs of today's energy system due to low-cost renewable energy generation, reduction of fossil energy imports and increasing sector coupling. In addition, in this scenario the GHG reduction target is exceeded in the optimum and renewable energies are more strongly integrated into the system.

With the ambitious GHG reduction target of 95 percent, the advantages of flexibilisation through the use of hydrogen outweigh the disadvantages of reduced system efficiency, so that the system costs are lower if the focus is on hydrogen. At the same time the average electricity costs can be reduced to below 60 Euro/MWh and the H_2 production costs to below 4 Euro/kg_{H2}.

Depending on the scenario, the additional value added attributable to the production of hydrogen amounts to 10 to 50 billion euros per year, whereby 1 to 10 billion euros per year can be allocated to North Rhine-Westphalia. In all scenarios, the largest share is accounted for by the indirect added value generated by the additional generation of renewable energy for the production of hydrogen. The effects on jobs generally follow the creation of value. The use of hydrogen can create between 200,000 and one million new jobs in the energy supply sector in Germany and between 20,000 and 130,000 in NRW. However, this figure does not include potential jobs from production and operation of end-uses (e.g. FC vehicles), so that the actual number of jobs caused by hydrogen use may be even higher.

HYDROGEN AND ELECTRICITY IDEAL PARTNERS The analyses make it clear that cost-optimal design and operation of the future energy system Germany and NRW will require a compromise between system efficiency and flexibility. In this context, hydrogen as a universal energy source offers numerous benefits for intelligent sector coupling. Electrolysis as a flexible load and the cost-effective storage of large amounts of energy in the form of hydrogen not only support the integration of renewable energies, but can also have a positive effect on system costs as well as domestic value added and jobs under appropriate framework conditions. The use of hydrogen in the various sectors will thus strengthen Germany and NRW as business locations.

In addition, the continued use of the existing natural gas infrastructure and the resulting reduction in the expansion of the electricity grid can, under certain circumstances, increase acceptance of the energy turnaround among the population. It will be particularly important for North Rhine-Westphalia to prepare and establish the corresponding infrastructures to meet the disproportionately high demand for hydrogen, whether produced locally or imported.

In addition, the study shows that the result depends strongly on the climate protection targets and that the characteristics of a cost-optimal energy system can differ significantly between the GHG reduction targets of 80 and 95 percent. For this reason, binding energy policy targets can reduce the risk of undesirable bad investments and unnecessary lock-in effects, for example through the use of hydrogen, since cross-sectoral approaches and infrastructures already need to be developed and tested today if the energy turnaround is to succeed. Overall, the two energy sources, electricity and hydrogen, can complement each other in this respect and, by exploiting synergy effects, contribute as ideal partners to the success of the energy turnaround. ||

The study, financed by the Ministry of Economics, Innovation, Digitisation and Energy of the State of North Rhine-Westphalia, was published in May 2019 and presented at the specialist event "Hydrogen – Solutions for the Industry of the Future" of the new state initiative IN-4climate.NRW.

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LIGNITE VERSUS HYDROGEN POWER PLANT

Could coal-fired power plants already be shut down today?

Source: Stefan Oest

A stable energy supply in the future can only be ensured with the storage of energy on a large scale. On the basis of the liquid organic hydrogen carrier system (LOHC) and with the aid of PEM electrolysis and solid oxide fuel cells, the dimensions and above all the capacity of a storage power plant to replace a conventional power plant will be determined using the example of a lignite-fired power plant. If this is applied to all lignite-fired power plants in Germany, the potential of using surplus electricity from hydrogen becomes apparent.

In order to enable the energy turnaround to progress, energy produced by wind and sun must be able to be stored over longer periods of time in the terawatt hour range. By 2022, when the nuclear phase-out will also take place, 30 percent of the coal capacity is to be shut down. Electricity is already being produced in excess of demand and is currently largely regulated, i.e. not used. The large-scale storage of energy in the form of hydrogen is of great importance for the temporal compensation of fluctuations in electricity production and for meeting the electricity demand during a dark lull.

How could electricity supply be guaranteed when coal-fired power is phased out, so that the energy turnaround can be implemented? How, for example, could hydrogen be used to replace a lignite-fired power plant? What storage capacities are required?

SURPLUS ELECTRICITY FOR H_2 GENERATION With the help of the literature, it can be determined that large-scale storage system such as pumped storage power plants and compressed air storage power plants have little expansion potential, so that energy can only be stored on a large scale with hydrogen. Above all, surplus electricity should be stored using this. In the currently used electricity system, which is not very flexible, surplus electricity is generated not only by weather-dependent renewable energies, but also by must-run power plants, most of which are operated conventionally. If too much electricity is generated, solar and wind power plants are switched off, power plants are shut down or ramped up, or electricity is exported. Much energy is lost from year to year in increasing measure unused, although this energy could be used for hydrogen, which is produced by electrolysis.

PEM electrolysis with high efficiencies of up to 74 % is best suited for the conversion of fluctuating power generation [1]. Fuel cells can then, if required, re-introduce the energy stored in chemical form. The solid oxide fuel cell appears to be the most suitable for continuous power delivery in terms of current efficiency at 50 to 65 % and the possibility of using the waste heat. In turn, the PEM fuel cell would be preferred for the provision of control power due to its flexibility in load changes and short start-up times.

So far, only hydrogen pressure storage in salt caverns has been taken into account on an industrial scale. Correspondingly suitable geological conditions are given by salt deposits, especially in Northern Germany, which is rich in excess electricity. The technical potential for hydrogen storage in salt caverns by 2050 is estimated at 126 TWh. However, the time span from preparation to commissioning is about ten years. However, the USA and Great Britain have decades of practical experience with such hydrogen storage.

LOHC FOR ENERGY STORAGE In recent years, however, another possibility has emerged for the storage of hydrogen in

large quantities: In liquid organic hydrogen carrier system (LOHC; see H2-international issue July 2018), hydrogen can be stored and transported at high energy density under ambient pressure for as long as required. From a technical point of view, dibenzyltoluene is the most promising LOHC system, as it has fewer problems in terms of toxicology, availability and physical properties than other systems [2].

Technically, hydrogenation and dehydrogenation have long been known methods in industry. The potential for the construction of storage tanks is high as sites are not geologically bound and can therefore be chosen more flexibly than other storage technologies. The production of the energy carrier dibenzyltoluene is also already taking place on a large scale due to its use as a heat transfer fluid (e.g. under the brand name Marlotherm SH).

Hydrogenation and dehydrogenation units can be spatially separated from each other. The transport and storage of loaded and unloaded dibenzyltoluene can be implemented in the existing liquid fuel infrastructure [3]. Making this technology available can be done more quickly than cavern storage. In a direct comparison of the two H_2 storage options (see Table 1), LOHC storage systems outperform caverns both in terms of efficiency and energy density and in terms of exploiting their expansion potential.

The efficiency for the dehydrogenation of the LOHC depends on the supply of the dehydrogenation heat. An efficiency of 71% is achieved when hydrogen is burned and heat is removed there. 100 % can be achieved by extracting heat from a heat accumulator heated by solar energy, for example, or by using a solid oxide fuel cell (energy loss definitely occurs whether the energy is recovered from solar cells or the waste heat from a SOFC is used). The system efficiency is thus between 39 and 73 %, and 36 to 47 % for the storage cycle with solid oxide fuel cells. The cycle efficiency of the cavern storage correspondingly with fuel cell is 26 to 42 %.

COMPARISON: LIGNITE – HYDROGEN In a hypothetical framework, the dimensions required to replace a lignite-fired power plant with a hydrogen storage power plant consisting of PEM electrolysis, LOHC storage technology and solid oxide fuel cell can now be determined. Modern lignite-fired power plant units such as Boxberg or Lippendorf and parts of Neurath or Niederaussem have net nominal outputs of between 944 MW and 2,120 MW.

Our calculation assumes a power plant with 1,750 MW and an annual electricity production of 12 TWh, which is to be fed into the grid as normal after the H_2 has been converted back into electricity. With the current best possible cycle efficiencies of 47% for LOHC technology, the initial energy requirement for the H_2 storage power plant is 25.5 TWh. For this, almost 570,000 t of hydrogen must be produced from almost 5.7 million m^3 of water.

How large must the capacity of the storage system be? For simplicity's sake, it is estimated that the lignite-fired power plant's electricity production is constant and that the daily feed-in quantity is thus 32.9 GWh. In extreme cases, a dark lull of 14 days should be expected [4]. In order to guarantee a minimum filling level of the storage system at the beginning of the dark lull, it must contain sufficient hydrogen for a total of 28 days. With an FC efficiency of 65 %, this would correspond to 1,416 GWh or a dibenzyltoluene volume of 745,500 m3. This LOHC quantity can be stored in 15 tank silos with a capacity of 50,000 m^3.

Since the lignite-fired power plants in operation generate a total of 137.79 TWh net electricity and this corresponds to about 11.5 times the production of the lignite-fired power plant, a storage capacity of 16.3 TWh results from the shutdown of all lignite-fired power plants in Germany to ensure grid security. With an electrolysis efficiency of 74 %, this results in a requirement of 22 TWh, which is stored in about 660,000 t of hydrogen (= 11.6 million m3 dibenzyltoluene). This LOHC quantity fits into 232 tank silos of 50,000 m^3 each.

The storage capacity determined according to public estimates for securing the electricity supply in the context of the energy turnaround is in the double-digit TWh range [2]. Although the two-digit TWh range has a large spread, the calculated 16.3 TWh, which only apply to the compensation of the switched-off lignite-fired power plants, fall within this range and thus support the fact that this result is within a suitable frame.

By way of comparison, the 15.7 TWh surplus electricity from 2017 [5], which resulted from feed-in and grid bottleneck management throughout Germany, can be cited as a comparison. If all lignite-fired power plants had been shut down, a complete replacement would not have been possible at that time (difference: 0.6 TWh, excluding electricity exports). However, this would be feasible if renewable energies were to be expanded further.

CONCLUSIONS However, there are regional differences in surplus electricity production in Germany, so that corresponding over-capacities cannot currently be absorbed at a central location. Therefore, a study of the exact surpluses of all kinds in terms of quantity, duration and region would first have to be carried out. The electrolysis capacity also depends strongly on the actual surplus electricity hours. Since the provision of water can also become sufficiently problematic, a solution must also be found for this.

Researchers are already working on seawater electrolysis. Decentralised hydrogen storage system on a smaller scale at several locations with a distinct energy surplus would be preferable. Since it is possible to transport hydrogen in stored form, it would also be conceivable to convert it back into electricity at another, perhaps central, location. The transport would, however, result in further energy loss-

Tab. 1: Efficiencies of the process steps for the injection and withdrawal of H_2 into dibenzyltoluene (changed according to [1], [5])

PROCESS STEP	LOHC EFFICIENCY	CAVERN STORAGE EFFICIENCY
PEM electrolysis	56 to 74 %	56 to 74 %
Hydrogenation / Storage injection	98 %	90 to 95 %
Dehydrogenation / Storage	71 to 100 %	97 %
System	39 to 73 %	51 to 64 %
Volumetric energy density	2,143 kWh / m^3 at 1 bar	468 to 600 kWh / m^3 at 200 bar

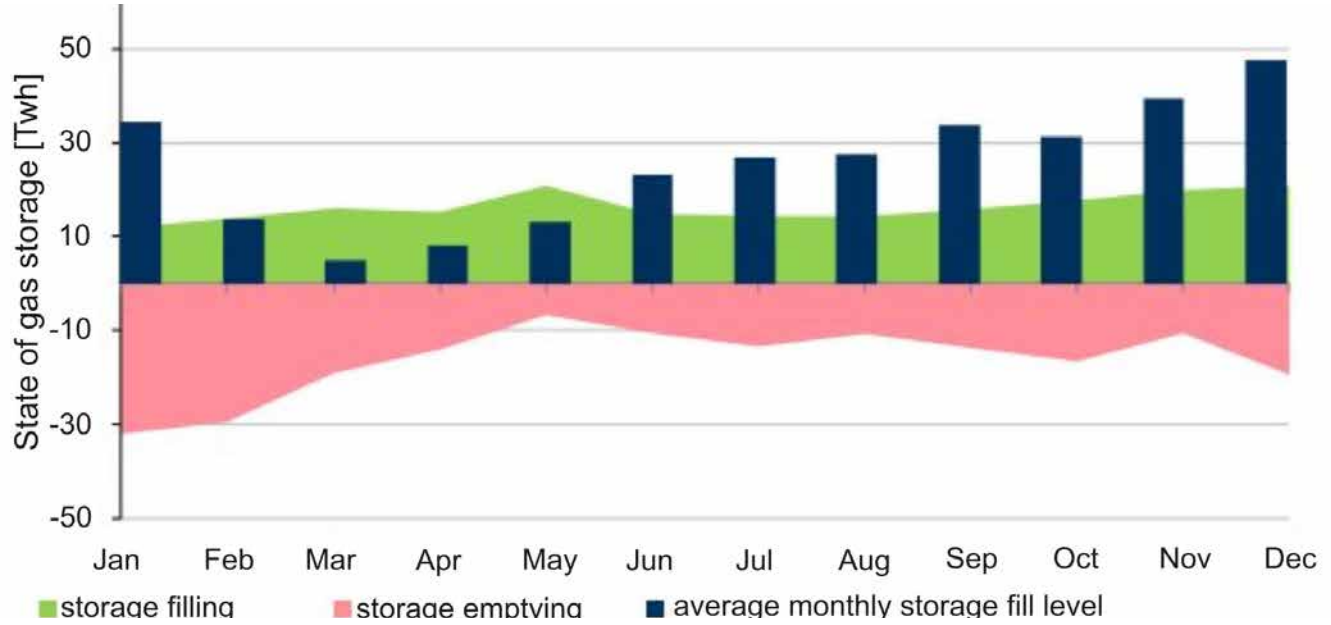

Fig. 2: Storage level on a monthly basis [Source: [4]]

es that have not yet been taken into account. The possibility of using the existing infrastructure of liquid fuels without restriction makes the LOHC storage medium very attractive in any case. The associated relief for the transmission grids is, however, only interesting as long as the grid expansion continues to be delayed.

Despite existing large-scale production processes, the production of dibenzyltoluene would have to be clarified. The questionability of this material should not go unnoticed, as can be read in the safety data sheet of Marlotherm SH, for example. In addition, fossil raw materials are currently used for production. As the oil can only be used for a few hundred storage cycles, it is still necessary to clarify how disposal, in this case as hazardous waste, should take place or whether recycling is possible. From this point of view, it is worth considering LOHC storage technology only as an interim solution for hydrogen storage system, as the path should clearly lead away from fossil resources.

In any case, it remains undisputed that in the near future the seasonal storage of electrolysis hydrogen will be necessary for electricity supply, even if hydrogen is not a cure-all and other storage technologies must be included in parallel. In addition, grid expansion, load management, energy efficiency and smart grids are also pillars for successful energy turnaround. The storage of energy in hydrogen and the conversion back into electricity entails losses, but the surplus energy generated would otherwise be lost unused. Higher efficiencies are therefore desirable in order to be able to use the largest possible amount of energy, but not a prerequisite.

The surplus energy produced, which will rise steadily as renewable energies continue to expand, can ensure grid stability. Making this amount of energy usable is now the most urgent task of the energy industry. It is important that action is started now. Hydrogen makes a significant contribution to the full use of renewable energies. ||

This article is the result of a bachelor thesis, which the author has written in distance learning at the Wilhelm-Büchner-Hochschule in the course of studies energy process engineering.

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Category: Energy storage | **Author:** Sven Geitmann

HYFAB – FC RESEARCH FACTORY IN ULM

Research production of battery cell in Münster

Fig. 1: Daimler CEO Ola Källenius with minister president Winfried Kretschmann (right)

The scientists on Ulm's Eselsberg might have experienced a real roller coaster ride of emotions at the beginning of July 2019. First came the no to the battery location, but then the yes to the fuel cell location.

The commitment to the HyFab came personally from the minister president of Baden-Württemberg, Winfried Kretschmann, within the framework of the Strategy Dialogue Automotive Industry BW. This was much more than just a small consolation for Ulm after the announcement that the planned "battery factory" would be located in North Rhine-Westphalia. After all, within the framework of the HyFab project , a research factory for fuel cells and hydrogen is to be built by 2024 which will emphasize the importance of this location in the south of Germany for the H_2 and FC industry beyond the national borders. Although this does not involve hundreds of millions of research funds, it does involve a total of 74 million euros distributed over ten years, of which 18.5 million are available provided by the state.

In February 2019, Baden-Württemberg's Environment Minister Franz Untersteller (see interview on p. 16) and Economics Minister Dr. Nicole Hoffmeister-Kraut had made a commitment to the German government to financially support HyFab. She wrote: "Industrial fuel cell production has enormous potential for climate protection and for Germany as an industrial location HyFab, which is led by the Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW) and the Fraunhofer Institute for Solar Energy Systems, aims to create an open, flexible platform, strengthen the supply industry and develop and test fast, automated production processes for fuel cell stacks.

"In addition, we are working in the Strategy Dialogue Automotive Industry BW on developing a concept and infrastructure for emission-free local public transport based on hydrogen and fuel cell technology."

Minister president of Baden-Württemberg Winfried Kretschmann

NEW BATTERY SITE IN NRW At the same time, the Tübingen university city also applied for the location of the planned research factory for battery cells, which is scheduled to go into operation in 2022. However, the contract was awarded – surprisingly for some players – to Münster, so that the associated financial injection of more than 500 million euros from the Federal Ministry of Education and Research also goes to Northern Germany.

One of the decisive factors for the award to the team from Münster Electrochemical Energy Technology (MEET) was the professional reputation of Professors Achim Kampker and Günther Schuh from RWTH Aachen University, who had entered the race as a team of three with Forschungszentrum Jülich. In addition, the fact that the federal state of North Rhine-Westphalia announced a participation of more than 200 million euros at the end of May 2019 may have helped. This money is to be used, for example, to finance land and buildings and to make a permanent contribution to the basic financing, of which 12 million euros alone are to be used for the promotion of young researchers. An additional 7.5 million euros are to come from the municipalities. The Fraunhofer-Gesellschaft is to be responsible for setting up and operating the site. The Federal Minister of Education and Research, Anja Karliczek, stated that "the other locations will nevertheless be considered". ||

"It is an existential question for Germany that we want and have to be successful with battery research and production and also with further development towards green batteries. [...] We have some catching up to do in global competition."

Federal Research Minister Anja Karliczek

Category: Policy | **Author:** Volker Quaschning

HYDROGEN VERSUS BATTERY

Comment by Prof. Volker Quaschning

Prof. Volker Quaschning has been drawing attention to the climate problem for months with many public contributions and actively supports the Fridays-for-Future-Kids by, for example, setting up the Scientists-for-Future group and thus providing scientific support for the youth movement. In mid-August, he published a fact check on the question: Which car has the best climate balance? In this context, he also pursued the thesis that it would be better to rely on the fuel cell car rather than the battery car for climate protection. He writes about it:

In order to operate a fuel cell car, hydrogen must first be produced and brought to high pressure. In the car itself, this must then be converted back into electricity with the help of a fuel cell. Both cause high losses, so that a fuel cell car needs almost three times as much electricity to produce the necessary hydrogen as a battery car needs to charge the batteries. So if you want to compare both vehicle variants, you also have to consider the production costs for the hydrogen for the fuel cell car. This eliminates the high manufacturing energy required for the battery. At the end of the day, the carbon footprint of both vehicle variants hardly differs [Ste19].

Prof. Volker Quaschning

Currently, a large part of the hydrogen in Germany is produced from natural gas. This does not generate any benefits for climate protection. If we wanted to replace all cars with fuel cell cars and produce hydrogen through renewable energies in Germany, we would have to install almost three times as many wind power and solar plants. However, at least for the installation of the necessary wind power plants the necessary locations are missing in Germany [Qua16]. With the hydrogen solution we would therefore be dependent on the import of regenerative hydrogen. It is likely to be difficult to achieve this within the time windows required for climate protection. In addition, the hydrogen solution will also be more expensive than the battery version due to the high losses in the end.

It is therefore very likely that the hydrogen solution will be used primarily in vehicles with high daily mileages such as trucks, buses or cars for extreme frequent drivers. The normal car for average applications will very probably be a battery car in the future. There are no environmental disadvantages as a result. ||

→ www.volker-quaschning.de/artikel/Fakten-Auto/

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Category: Electro-mobility | **Authors:** Jan Michalski, Jan Zerhusen, Ulrich Bünger, Werner Zittel, Steffen Nicolai, Samir Kharboutli, Cristian Monsalve, Stephan Ruhe

FC CARS PAY OFF IN THE LONG TERM

Infrastructure Study of the Ludwig-Bölkow-Foundation

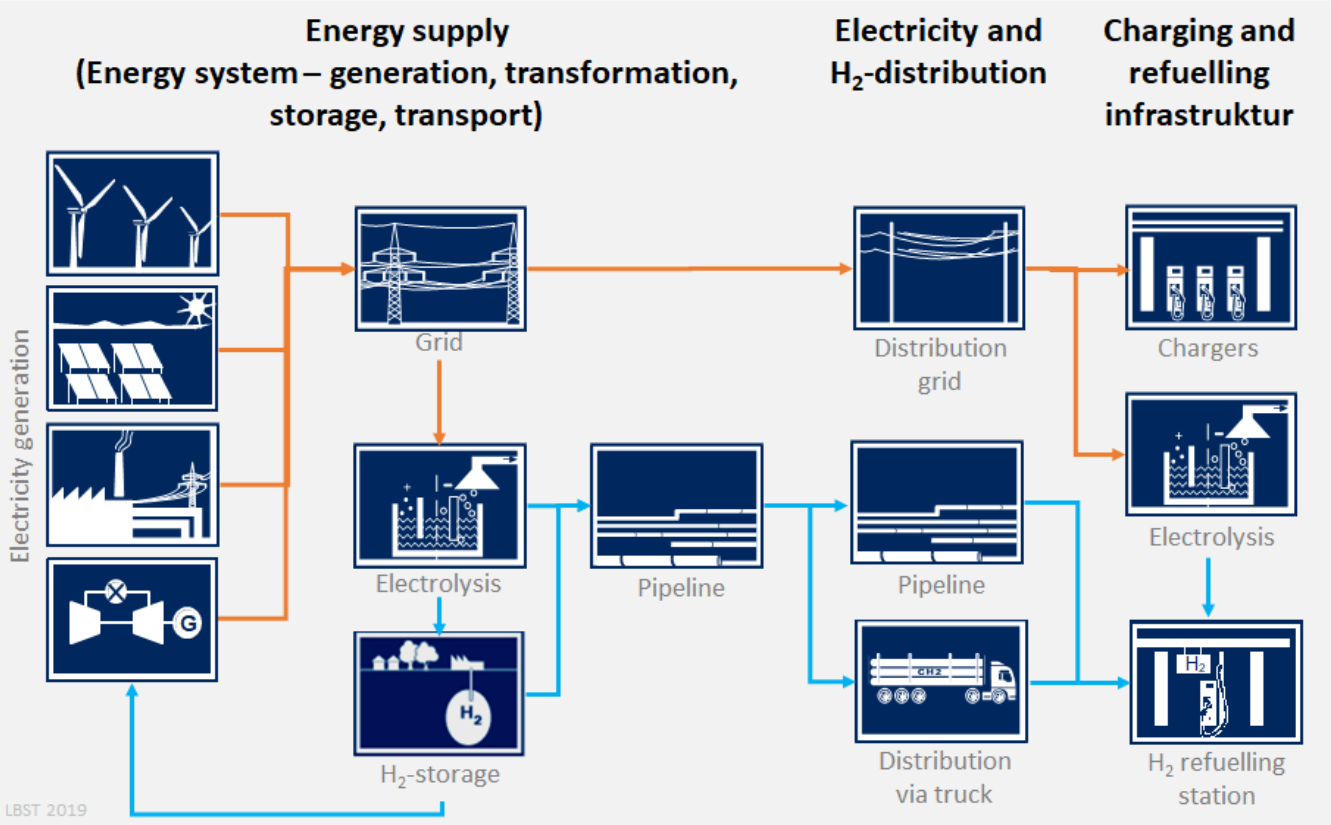

Fig. 1: Simplified representation of the power supply system for zero-emission passenger cars

When it comes to the subject of "infrastructure of electric vehicles", there are many different opinions regarding costs, the possibility of integrating the infrastructure into the power grids and the efficiency of energy supply. Depending on one's point of view, the infrastructure for battery cars is sometimes better than that for fuel cell cars. In order to advance the discussion with tangible facts, the Ludwig-Bölkow-Stiftung, supported by Ludwig-Bölkow-Systemtechnik GmbH and Fraunhofer IOSB AST, has published the study "Infrastrukturbedarf E-Mobilität – Analyse eines koordinierten Infrastrukturaufbau zur Versorgung von Batterie- und Brennstoffzellen-Pkw in Deutschland" (Infrastructure Requirement E-Mobility – Analysis of a Coordinated Infrastructure Structure for the Supply of Battery and Fuel Cell Cars in Germany), sponsored by the ADAC Foundation. A broad-based project advisory board accompanied the preparation of the study, which was published in Berlin on 27 June 2019 after about two years of work. Key assumptions and selected results of the study are explained in the following article.

The study considers the infrastructure needed to supply 40 million zero-emission passenger cars in Germany by 2050. Zero-emission passenger cars here are vehicles with battery or fuel cell technology. In addition to the necessary charging and refuelling infrastructure, its integration into the German energy system was also considered. This includes energy distribution (electricity distribution grids and hydrogen supply), energy transport (electricity and hydrogen transport), energy storage (stationary battery and hydrogen storage) and electricity and hydrogen production (see Fig. 1). One focus of the study was a detailed analysis of exemplary electricity distribution grids.

A total of three scenarios were considered, each with a different proportion of battery and fuel cell vehicles. In the "Focus BEV" scenario, 80 percent of the zero-emission fleet has a battery electric drive available, the remaining 20 percent uses fuel cell technology. In the "Focus FCEV" scenario, the proportion of vehicles with fuel cells is 80 percent, while the proportion of battery vehicles is now 20 percent. In the "mix" scenario, both drive technologies account for 50 percent each. In addition to the 2050 target year, the 2030 and 2040 support years were also considered. However, the following remarks are limited to the target year 2050.

CHARGING POINTS AND HYDROGEN FILLING STATIONS

The need for charging points to supply battery cars was determined on the basis of figures from the former National Platform for Electric Mobility (NPE). Depending on the scenario, between 9.6 (focus FCEV) and 38.4 million (focus BEV) charging points are required for 2050. The associated annual costs for maintenance, servicing and investment depreciation are between EUR 2 billion in the focus FCEV scenario and just under EUR 9 billion in the focus BEV scenario. The private charging points, which were assumed to cost an

average of 1,650 euros each (hardware including planning, grid connection and installation), have a significant influence on the costs.

The number of hydrogen filling stations is around 2,000 (focus BEV) and 6,000 (focus FCEV) with average filling capacities of 1,400 and 2,000 kg_{H2} per day respectively. The H_2 filling stations have significantly higher capacities available in comparison to the H_2 plants installed today (approx. 200 kg/day) in order to exploit economies of scale and to enable economical operation. A comprehensive hydrogen supply is thus guaranteed for all three scenarios.

In the medium term, hydrogen will be supplied to filling stations primarily by trucks delivering pressurised hydrogen (500 bar) with a rising proportion of liquid hydrogen supplied over the long term, by pipelines (partly converted natural gas pipelines) and by on-site production using electrolysis. The annual costs for the hydrogen refuelling infrastructure, including the delivery of the hydrogen but excluding hydrogen production, will amount to between 1 billion (focus BEV) and 3.7 billion euros (focus FCEV) in 2050.

LOW- AND MEDIUM-VOLTAGE POWER GRID The effects of the charging and refuelling processes of the zero-emission passenger cars on the electricity distribution grid and the resulting need for upgrading were determined on the basis of detailed calculations of exemplary grids. Low and medium voltage grids from rural areas, small towns and suburbs as well as from a large city were used for this purpose. Each example grid was assigned a certain number of battery and fuel cell passenger cars on the basis of current car registration figures, the year under consideration and the scenario definition. Taking into account relevant parameters such as simultaneity factors, conventional electricity demand, electricity generation from renewable energy plants, charging capacities and connection points of the charging points, the grid loads in the example grids were determined. The reactions were investigated with regard to the thermal load of transformers and cables, the voltage quality, a possible phase skew (phase asymmetry) and, in the medium voltage range, a violation of the N-1 criterion (failure probability).

For each exemplary low-voltage grid, up to 5,000 variants for different load situations were considered in order to obtain a representative statistical evaluation of the relevant parameters. For this purpose, the probability of injury of the various parameters was determined. On the other hand, standardized profiles were used in the medium voltage to determine the hourly values of the parameters.

The analysis of the example grids shows that the charging and refuelling infrastructure required to supply zero-emission passenger cars can in principle be integrated into the electricity distribution grid. This, however, requires some upgrading measures in the grids. The type and scope of the measures required depends on the respective grid structure, the grid level, the local framework conditions (e.g. conventional electricity consumption, building structure, proportion of newly installed heat pumps), the year under consideration and the scenario selected. In general, it can be said that the need for upgrading in low-voltage grids is higher than in medium-voltage grids, which have a higher reliability (N-1 criterion).

The number of battery vehicles, i.e. the scenario and year under consideration, have a decisive influence on the extent of the measures required (see Fig. 2). This situation can be improved by considering charging management systems that can reduce the maximum charging performance of battery vehicles. The integration of hydrogen filling stations and rapid charging infrastructure into the medium-voltage grids is comparatively easy or requires little expansion.

ENERGY SYSTEM ANALYSIS AND TOTAL COST COMPARISON The timely and local provision of electricity and hydrogen must be guaranteed by the German energy system. Energy must be provided not only for passenger cars, but also for the industrial and GHD sector (trade, commerce, services) for heat generation in private households and for other mobility sectors. With the exception of the mobility sector, energy consumption and assumptions in the sectors are identical for all three scenarios.

The energy system analysis is carried out in a model developed for this purpose, which determines the cost-optimal plant park (e.g. power plants, storage facilities, electrolysis) with regard to investment and operating costs on the basis of given framework conditions (e.g. greenhouse gas budget, existing power plants, energy costs etc.). The framework conditions for the analysis were chosen so as to be compatible with the Paris climate protection targets.

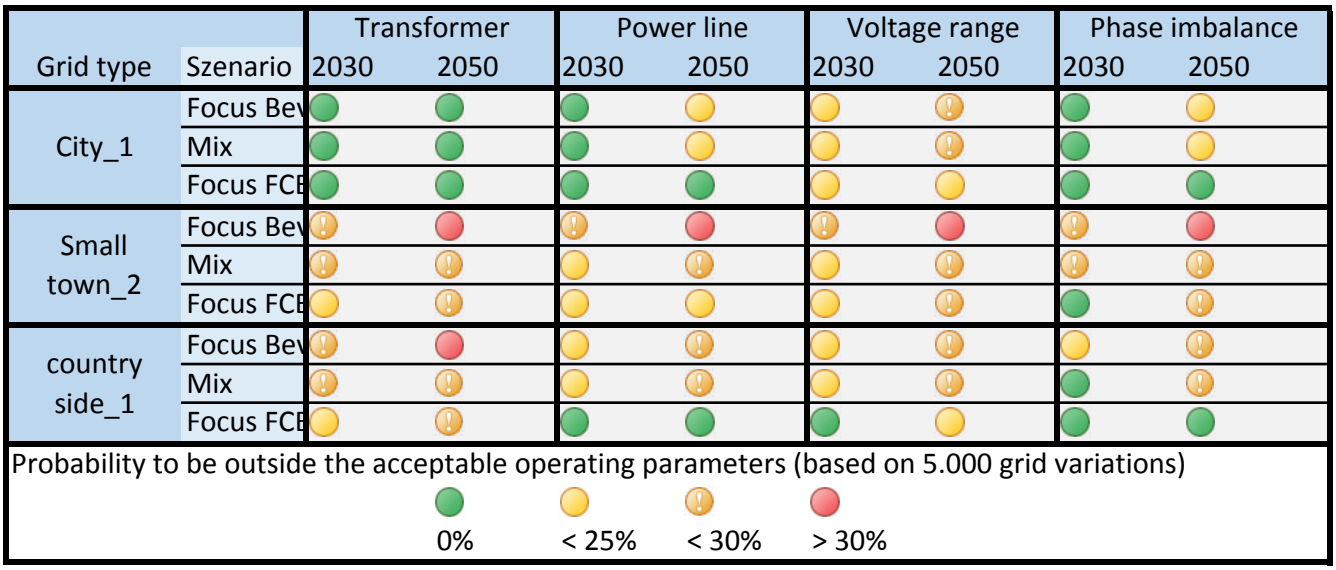

Fig. 2: Injury probabilities for selected example grids in the low-voltage level per scenario for 2030 and 2050

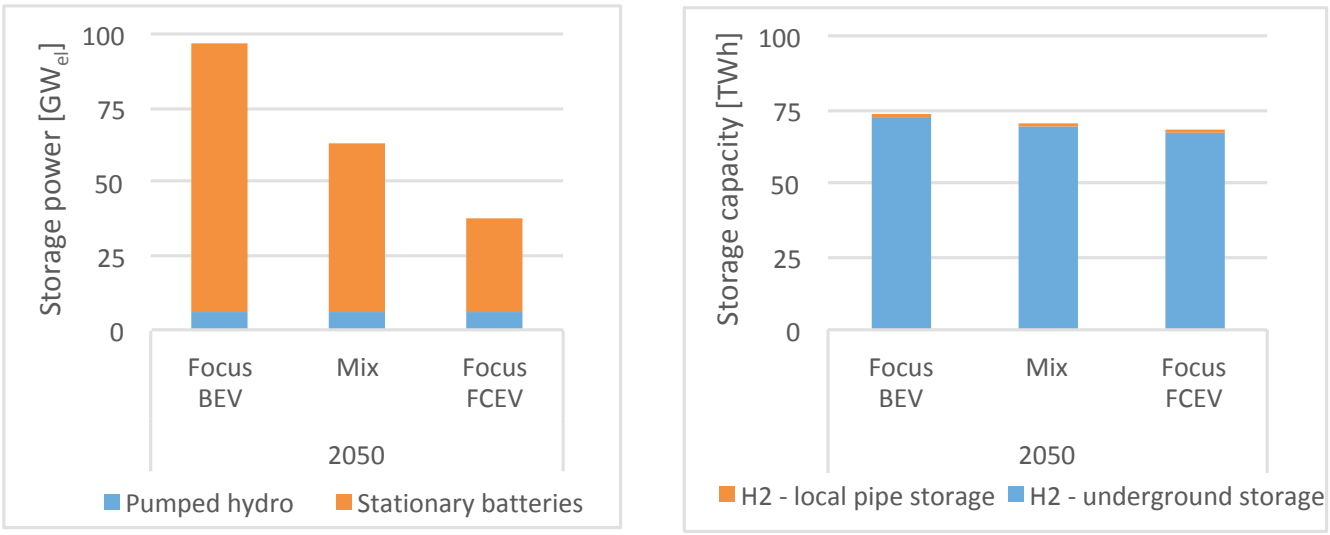

Fig. 3: Power and energy storage requirements 2050, depending on mobility scenario [Sources: LBST]

Fig. 3 shows a clear correlation between the proportion of battery vehicles and the amount of power storage required. However, the demand for energy storage capacity is largely independent of the technology mix of the vehicle fleet. The model for 2040 shows a significantly lower demand for power and energy storage devices. This is because GHG emissions in the electricity and energy sectors are still permitted in 2040 and conventional power plants with energy sources (e.g. natural gas) can therefore be used to provide secure output. In 2050, however, stationary batteries and GHG-neutral (chemical) energy sources, such as hydrogen, will have to be used as power and energy storage devices in order to be able to provide electricity as required, e.g. for charging battery vehicles, even in times of low electricity generation from wind and photovoltaics.

Part of the electricity for battery vehicles is therefore provided by a stationary hydrogen storage system with a re-conversion unit (see Fig. 1). In a GHG-neutral energy system with a high proportion of fluctuating power generation, the efficiency of the energy supply for battery and fuel cell vehicles is therefore approaching. This is also reflected in the costs determined within the framework of the energy system analysis. For 2050, there are no longer any relevant cost differences in the three scenarios.

The situation is somewhat different when considering the total costs (i.e. costs within the framework of the energy system analysis plus costs for dedicated charging and refuelling infrastructure and energy distribution). Although the total costs will also be at almost the same level in the medium term, cost advantages for scenarios with a high proportion of fuel cell vehicles have been identified in the long term. These result mainly from different costs for charging points compared to hydrogen filling stations. Above all, the high number of private loading points and the associated costs contribute significantly to cost increases.

CONCLUSION In summary, the study shows that the electricity distribution grids have to be upgraded on a case-by-case basis to accommodate a large number of battery-powered passenger cars, and tend to be in rural areas. The hydrogen refuelling infrastructure, on the other hand, can be integrated comparatively easily into the electricity grids. With an increasing share of fluctuating renewable power generation, the good storage capacity of hydrogen will gain relevance for the entire German energy system in the medium and long term. Guaranteed performance, also for charging battery cars, will then be ensured in the long term in part by stationary hydrogen storage systems with re-conversion units. The efficiency chains of energy supply for both passenger car technologies are thus approaching each other in the long term. ||

→ www.stiftung.adac.de/infrastrukturbedarf-e-mobilitaet

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WHERE DOES ELECTRO-MOBILITY STAND?

Recommendations of VDE and VDI

Electric mobility represents an important contribution to climate protection and the use of renewable energies in the transport sector. VDE/ETG, VDI-FVT and VDI-GEU have therefore attempted to present the current state of development of fuel cell passenger cars (FCEV) and battery electric passenger cars (BEV) within the framework of an interdisciplinary working group made up of universities, research institutes and industry.

Electro-mobility offers versatile potential for improving mobility. Nevertheless, the discussion is currently concentrating primarily on battery-powered drive systems. This contradicts the objectives of the Federal Government, which provide for a technology-open further development of the National Innovation Programme and the Mobility Fuel Strategy (MKS). According to FMD, the most efficient drives are to be selected, whereby alternative energy sources (fuels) are also to be included in the assessment. The necessary infrastructures must also be taken into account.

This means that synthetic energy sources are also taken into account in the evaluation in addition to systems supplied with electricity. Under certain application criteria, they can also fulfil an important function in the transport sector.

With regard to electro-mobility, the fuel cell should be included in the assessment on an equal footing with battery technology. Discussions with potential users such as operators of fleets, commercial vehicles etc. show that from their point of view hydrogen-supplied vehicles offer various advantages that speak against a one-sided predetermination on battery vehicles.

REDUCTION OF ECONOMIC COSTS Electric mobility offers potential for further strengthening the leading position of German companies. This presupposes, however, that the economic costs, insofar as they burden the companies, are reduced. At the same time, political support must be given to the establishment of the company's own production facilities and the prerequisites must be created to make low-cost hydrogen available for fuel cell vehicles.

Economic costs in relation to the transport sector result from the consumption of resources and environmental pollution. The consumption of resources concerns the use of energy sources and the materials used to manufacture the vehicles. The reduction of resource consumption requires an improvement in efficiency.

With the introduction of electro-mobility, efficiency can be expected to increase by a factor of 2 compared to conventional vehicles, especially with BEV. A simple estimate confirms this: compared to a vehicle with a fuel consumption of 6 l per 100 km (60 kWh), a BEV can be expected to consume 30 kWh of electricity (with conventional electricity generation at 40 % efficiency).

However, the efficiency improvement will only be sustainable if the electricity used to supply electric vehicles comes from renewable energies. This goes hand in hand with a reduction in exhaust and noise emissions, which is reflected in a reduction in environmental pollution.

EFFICIENT MATERIALS MANAGEMENT Conservation of resources also affects the materials required to manufacture the vehicles. In order to avoid an increased demand for raw materials and thus additional economic costs, the recycling of valuable raw materials is absolutely necessary. The extent to which efforts to save raw materials have already progressed in the field of electro-mobility is illustrated by the need for platinum in fuel cell vehicles:

VDE/ETG:
Energy Technology Society in the Association of Electrical Engineering Electronics Information Technology e.V.

VDI-FVT:
Society for Vehicle and Traffic Engineering of the Association of German Engineers e.V.

VDI-GEU:
Society for Energy and Environment of the Association of German Engineers e.V.

While the platinum requirement in the first years of development was more than 1 mg per cm^2 of reacting fuel cell area (stack area), today it is only 0.4 mg/cm^2. For a vehicle like the Toyota Mirai, this means that about 30 g platinum is required per kW (0.26 g per kW). By 2020, the demand per kW is to be reduced to 0.125 g for an 80 kW unit, so that a FC drive system requires less platinum than the exhaust system of modern diesel vehicles.

PRODUCTION OF BATTERIES AND FUEL CELLS The production of batteries and fuel cells is considered demanding. According to the VDMA, Germany nevertheless has the potential for its own production capacities and thus for the generation of jobs. A roadmap drawn up in cooperation between RWTH Aachen, Fraunhofer Institute for Systems and Innovation Research ISI and VDMA and published in 2014 has examined this more closely. Accordingly, the greatest challenges for the manufacture of high-performance energy storage devices lie in the areas of process stability with simultaneous increase in production throughput, scalability to volume production, sustainability and, above all, quality improvement with simultaneous cost reduction. However, technological breakthroughs are still needed in fifteen core areas. In particular, this concerns pilot lines, access to major international projects and the ability to offer complete lines.

With regard to fuel cells, there are already many activities in Germany. They offer the potential to increase local value creation by manufacturing fuel cells, including associated components. According to the Fuel Cell Industry Guide Germany 2018 of the Fuel Cell Working Group of the VDMA, 57 companies and institutions are already active in the field of fuel cells. Sales in 2017 amounted to 190 million euros. A number of companies in Germany and Europe are also active in the field of material and component suppliers. The list of the Fuel Cell and Hydrogen Joint Undertaking (FCH JU) for Europe shows that at least fifty companies are active in the field of FC vehicles – except FC buses – of which about fifteen are vehicle integrators.

EMISSION-FREE HYDROGEN PRODUCTION Seen globally, hydrogen is freely available and is considered an international commodity. Supply would thus be possible in the medium term via corresponding supply contracts. However, the broad market launch of fuel cell vehicles requires the procurement of green and low-cost hydrogen.

In the long term, a H_2 production from renewable energies is to be aimed at. In contrast, hydrogen is currently produced from natural gas by means of reforming processes. The production is inexpensive with about 2 € per kg_{H2}, but is associated with high CO_2 emissions (approx. 360 g_{CO2}/kWh).

In terms of sustainability, it is therefore important that H_2 based on renewable energies is provided in an environmentally friendly and cost-effective way by electrolysis. The prerequisites for this are favourable power purchase agreements and high utilization rates of the electrolysers. The aim should be that the production costs of emission-free hydrogen should be in the order of the production costs of reformers.

PROMOTION OF SECTOR TYING The aim of sector coupling is to link the electricity, heating and cooling, transport and industrial sectors. Optimization potentials are to be tapped in a joint approach. For electro-mobility, this means that the purchase of electrical energy must be based on the general demand for electricity. Demand-dependent charging processes with corresponding tariff structures will gain in importance accordingly. This trend will become even stronger with the accelerated use of renewable energies. The coverage of the electricity demand of electric vehicles must take into account the fluctuating electricity volume from wind and sun, which requires close networking with the electricity sector in order to avoid undesirable developments.

The use of hydrogen is conceivable in almost all areas. This energy source thus offers the opportunity to intensify sector coupling. The use of gas is possible in electricity and heat supply as well as in traffic and industry. A high degree of networking of the different sectors is thus possible. This also applies to the heat generated during hydrogen production. It can be used for heat supply by means of heat distribution systems.

Great advantages also result from the storage capacity of H_2. By means of caverns or other natural cavities, it is possible to store the gas over longer periods of time, so that a seasonal energy balance can be achieved. This makes it possible to decouple supply and demand, especially in connection with the use of electricity from renewable energies.

Finally, both charging devices and H_2 generation plants offer potential for supporting electricity supply. By operating the charging and generation processes according to demand, they can be used to smooth peak loads and optimize load flow in the sense of grid service operation. A redispatch by electrolysers to eliminate grid bottlenecks is also conceivable.

POLITICAL SUPPORT The aim of politics is a rapid market penetration of electromotive drive systems. Politicians are therefore promoting the purchase of electric vehicles with purchase premiums. Additional supporting measures are recommended:

- Push ahead with market development: This can be driven forward by integrating key customers. These are usually fleet operators, in both the public and private sectors. Their presence and visibility alone contribute to a rapid increase in the acceptance of new technologies. In addition, the buyer power creates the basis for the early reduction of production costs through larger production volumes.

- Expansion of the hydrogen infrastructure: The plans for the next few years are based on 400 filling stations, but initially only 100 will be built. The production of the rest is planned depending on the demand. This reluctance, however, has a negative impact on the market development of FC vehicles. A hen-and-egg problem is provoked: Without sufficient demand there is no sufficient infrastructure and without infrastructure there are no vehicles. The planned 400 filling stations were therefore to be built without cutbacks.

- Review of the regulations for hydrogen filling stations: Currently, many federal states and municipalities have their own regulations for the construction of hydrogen stations. This makes implementation more difficult. It would be advisable to have uniform regulations nationwide in order to set up hydrogen filling stations according to a uniform standard.

- Hydrogen for a secure energy supply: Hydrogen offers versatile applications in all economic sectors and enables the decoupling of supply and demand. It is therefore important to consider this energy source as an option for long-term security of energy supply.

- Framework conditions for production facilities: German companies have available the necessary expertise to manufacture batteries and fuel cell systems. However, setting up production facilities is cost-intensive. Without support measures, only limited economic success can be expected in terms of competitiveness.

- Accompanying research: Experience shows that with regard to the ancillary systems of electric vehicles and the service life and degradation behaviour of batteries and fuel cell systems, there is not yet sufficient knowledge of real operation. It is therefore advisable to accompany market development with research programmes. ||

The VDI/VDE study "Fuel Cell and Battery Vehicles" was published in May 2019 with the aim of being able to offer as objective a comparison as possible of the advantages and disadvantages of both drive types and to give representatives from politics, the media and the public the opportunity to obtain balanced information.

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Category: Electro-mobility | **Author:** Sven Geitmann

NEW CALL FOR FC FORKLIFTS

Logistics relies on emission-free drives

Fig. 1: BZ forklift fleet from Still near Carrefour in Vendin-Le-Vieil, France [Source: Carrefou]

For years there has been a discrepancy in the hydrogen sector between North America and Europe: Over on the other side of the Atlantic, fuel cell-powered industrial trucks are enjoying great popularity, while their number in Germany is more in keeping with homoeopathic doses. The reasons for this have already been reported many times (see H2-international issues Jan. 2018, Jan. 2016, Jul. 2013). However, there are still promising approaches and also positive empirical values which indicate that in future more and more diesel forklifts will be replaced in Europe by electric forklifts – increasingly by fuel-cell powered ones.

At the end of 2018, around 21,000 H_2-powered industrial trucks were in operation worldwide – 300 of them in Europe. 70 of these drove in the BMW plant in Leipzig alone. The indoor tow tractors there, are used in the production of the i3 models to supply the assembly lines and are part of the total fleet of 400 vehicles. It was commissioned as part of the follow-up project to H2IntraDrive, which initially involved eleven forklifts and tractors in December 2013 (see H2-international issues Jan. 2014 and Jan. 2016).

In addition to BMW, Linde Material Handling, Günsel Fördertechnik and the Technical University of Munich are participating as research partners in the current FFZ70 project, which runs until 2021. Their motivation is to check the operating conditions for an economical operation. During the first trial period it had become apparent that the economic efficiency had not been guaranteed until then, also because too few vehicles had been used. However, with a larger number of units, both the investment costs and the maintenance, operating and approval costs should be reduced, so the expectation.

> "Industrial trucks with fuel cell technology in logistics can reduce CO_2 emissions by at least 25 percent while increasing productivity and reducing storage space and loading time."
>
> *Wolfgang Axthammer, NOW*

Important elements of this second phase are the standardisation as well as the establishment of plug & play solutions for fleet conversion and the validation of service life, but also the elaboration of a training concept for the operation of H_2 equipment, reported Wolfgang Axthammer, Managing Director of the National Organization for Hydrogen and Fuel Cell Technology. NOW's aim is also to establish an industry standard (H2Ready) "which will open up the possibility for other manufacturers on a broad basis to use the innovative technology in new or retrofitted vehicles in their own production".

PLUG SHOWS NEW GENDRIVE GENERATION The growing interest in hydrogen industrial trucks is now also evident at trade fairs and congresses. Linde Material Handling, for example, was at LogiMAT, the intralogistics trade fair for fuel cells, at the beginning of 2019. The Hamburg-based logistics company presented its new H_2 electric forklift trucks Linde E20 to E35 to the media centrally at its exhibition stand and praised them as "new FC roadsters". As they do not require an A-pillar, their larger field of vision makes them particularly suitable for indoor areas with heavy passenger traffic, according to the manufacturer.

The fuel cell systems used come from the US manufacturer Plug Power. The company, based in Latham, New York, was also present at LogiMAT in Stuttgart, where it presented the latest generation of its fuel cell units. The Class 1 GenDrive systems, which are specially designed for industrial pallet trucks, offer higher efficiency and reliability as well as a ten percent longer service life than their predecessors thanks to larger fuel tanks, according to the manufacturer. These were not only used by BMW, but also by the competitors Mercedes and Toyota.

However, it can be problematic for potential customers that Plug Power, as a FC manufacturer, does not cover all performance classes. Although some interested parties would like to switch to fuel cell technology, they would then like to convert all industrial trucks to hydrogen, which is currently not yet possible.

Still also relies on the GenDrive units from Plug Power. Since 2013, a total of 137 fuel cell vehicles from the Hamburg logistics company have been in operation in the new logistics base of the French trading company Carrefour in northern France: 36 FM-X reach trucks, 78 CX-S horizontal order pickers, 6 EXD-S double-deck high-platform trucks and 17 EXU-S low pallet trucks. The first 57 units were delivered in September 2017. A further 80 vehicles followed in January 2018 as part of the EU-funded HyLIFT-EUROPE project, which was completed at the end of last year. They are refuelled with a dispenser from Air Liquide.

Carrefour site manager Alain Audegond was delighted: "By using the hydrogen-powered vehicle fleet, we were not only able to reduce our CO_2 footprint, but also make handling easier and more ergonomic for our employees by eliminating the need to replace batteries. In addition, the filling station does not require a locked room, but could be installed directly next to the ramps. And finally, we need fewer vehicles overall and for the fuel cell vehicles no exchange batteries and other infrastructure for a battery change." During the final completion of the project, Björn Grünke of Still: "We are proud to have successfully installed Europe's largest fleet of hydrogen-powered industrial trucks to date."

Prelocentre has been testing FC industrial trucks from another logistics company, Jungheinrich, for more than three years, which are also equipped with plug power stacks. By the end of 2018 there were 75 of them available, and more are to come, so that the entire fleet could soon have fuel cells at its disposal. In a test period of two years, more than 40,000 refuellings were carried out, with the average operating time of the fuel cells lying between 97 and 99 percent. The conclusion therefore: "We see fuel cell technology in material handling not as an R&D approach, but as a mature and proven solution for medium to large fleets in two and three-shift operations.

"The customer is satisfied, the drivers are happy."
Björn Grünke, Still

Toyota also uses plug power stacks and uses ten models – a BT RRE 140, a BT RRE 160 CC and eight BT OSE 250 P – at Asko in Norway. In contrast, Daimler now relies on Infintium Inc, a subsidiary of the Dare Group, a Chinese technology group active in the automotive and aerospace industries as well as in new energy technologies and space travel. Since the end of 2018, Infintium has been supplying Mercedes Benz with Hydrogen Power Cell systems in which FCgen-1020ACS and FCvelocity-9SSL stacks from Ballard Power Systems are installed in order to equip industrial trucks at Daimler's production site in Vance, Alabama.

CONNECTION TO HYLIFT-EUROPE On the part of the FCH JU was determined after termination of HyLIFT-EUROPE: "These projects have shown that, in addition to the cost issue, there are also obstacles on the end-user side, for example in approving the installation of hydrogen refuelling infrastructure in buildings and in the training of staff" In order to be able to connect seamlessly here, a call from FCH 2 JU is currently underway as part of the work plan for 2019, under which over 250 industrial trucks at one or two locations are to be funded with 10 million euros.

CIN SYMPOSIUM
The next Clean Intralogistics Net meeting – a best practice workshop – will take place on 12 November 2019 at the BMW Group plant in Leipzig – with a tour of the FFZ70 project.

BMVI LAUNCHES CALL FOR FUNDING Wolfgang Axthammer, NOW managing director and head of the Clean Intralogistics Net (CIN) industry network, explained: "Our common goal is to further establish fuel cell technology in Germany and Europe. In North America, warehouses and production facilities are already operated with fuel cell powered industrial trucks." It had already sounded similar when the CIN was founded in 2016, but since then there has been no significant boost in the logistics sector either in Germany or in the EU.

In April 2019, the Federal Ministry of Transport and Digital Infrastructure (BMVI) launched a call for funding for fuel cell-powered industrial trucks in fleet applications (at least 10 units) in order to accelerate development and standardise (see above). By the end of July, applications could be submitted for vehicles as well as for the necessary refuelling infrastructure and the installation of electrolysers for the on-site production of hydrogen, for which a total of EUR 4.2 million was made available.

FUEL CELL IN THE HEAVY-DUTY SECTOR Meanwhile, we are hearing from North America that Hyster wants to make true what was announced in 2017: It is planned to offer an H2 heavy-duty forklift truck with a load capacity of 48 tonnes (see H2-international issue Jan. 2018). In the spring of 2019, the US company substantiated its plans and reported that an emission-free electric reach stacker was currently being developed. Specifically, it is a container stacker which is expected to enter service in 2021 in the MSC terminal of the port of Valencia and also in the port of Los Angeles.

Hyster has been active in both battery electric industrial trucks and fuel cell models since the parent company Nacco Materials Handling Group acquired Italian FC manufacturer Nuvera in 2014. Jan Willem van den Brand, Director of Big Trucks at Hyster Europe, said: "We expect the new reach-stacker to run uninterrupted and emission-free throughout the entire shift and to achieve a performance comparable to that of a conventional internal combustion engine."

The development of this truck is supported both in Europe and in the USA: The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) from Brussels is supporting the project as part of the H2Ports project, and money from the California Air Resources Board (CARB) from the California State Emissions Trading Scheme (CCI) is flowing into the development. ||

BALLARD COOPERATION WITH HYSTER
In April 2018, Ballard Power Systems and the Hyster-Yale Group signed a framework agreement to supply a minimum quantity of air-cooled FCgen® 1020 stacks for use in class 3 pallet trucks. This agreement, which runs until 2022, is aimed in particular at low-power applications and will complement Nuvera's existing fuel cell solutions.

Category: Electro-mobility | **Author:** Uta Mummert

ELECTRO-MOBILITY IS MORE THAN JUST BATTERY ELECTRIC

Much French hydrogen on the EVS32

In 1969, exactly 50 years ago, some young visionaries enthusiastic about technology organised the first Electric Vehicle Symposium. Accordingly, the EVS32 was dignifiedly celebrated from 9 to 12 May 2019 in Lyon in the presence of the now elderly but still dynamic founding members.

Today, the Electric Vehicle Symposium is one of the world's largest events in the field of electro-mobility and is held every 12 to 18 months on a different continent. After Stuttgart (2017) and Tokyo (2018), over 7,000 visitors from 65 countries came to France this year. In addition, there were several hundred exhibitors from 30 countries. More than 40 two- and four-wheeled electric vehicles (incl. fuel cell vehicles) were tested on the Ride-&-Drive site, and well over 300 scientific presentations were presented at the conference.

The EVS has become more than "just" a scientific conference, because the market is calling. The variety of topics at the conference ranged from the latest battery technology and mobility as a service and autonomous driving to charging infrastructures, electrification of the drive train on rail and road, component and electronics development, urban mobility and hydrogen. Still: In all subject areas, the Electric Vehicle Symposium remained clearly battery electric.

With regard to the programme, one could almost think that hydrogen has just been assigned a place within the framework of "political correctness" or in the course of the integration of minorities. However, the hydrogen has spread well in this place, as is its physical nature. It remains to be seen whether this can be attributed to the current "hydrogen hype" (which is not only noticeable in France).

ESTABLISHMENT OF H_2 ISLANDS At the opening ceremony, almost every prominent speaker mentioned the word "hydrogen" at least once – be it Elisabeth Borne, French Minister for the Energy Turnaround and Solidarity, Gilles Normand von Renault, Philippe Monloubou von Enedis, Prince Albert II of Monaco, Espen Hauge as President of Avere or Laurent Wauquiez, President of the Auvergne Rhône-Alpes Regional Council. In addition, several hydrogen islands were to be found at the EVS accompanying trade fair.

The largest was undoubtedly the "Hydrogen Zone" in front of the entrance to the Paul-Bocuse-Plenarsaal, albeit a very francophone zone. Battery and fuel cell technology were equally represented in the "EDF Cluster Zone" and above all at the German joint stand, for example by NOW GmbH, e-mobil BW GmbH and Mann+Hummel. Especially Baden-Württemberg used the EVS32 as a framework for international networking and to inform about the manifold competences of the federal state in the field of electro-mobility. Accordingly, Baden-Württemberg's Minister of Transport Winfried Hermann emphasised that in the context of effective climate protection it was important to "use all climate-friendly technologies, be they battery electric drives or fuel cell technology".

Outside these islands, however, hydrogen and fuel cell technology had to be sought with much goodwill. Evil tongues even spoke of an "infrastructure fair", and indeed there was a swarm of countless charging stations (with strikingly good design) at every corner and end. The Siemens booth was also purely battery electric. No reference to the Group's electrolysers expertise.

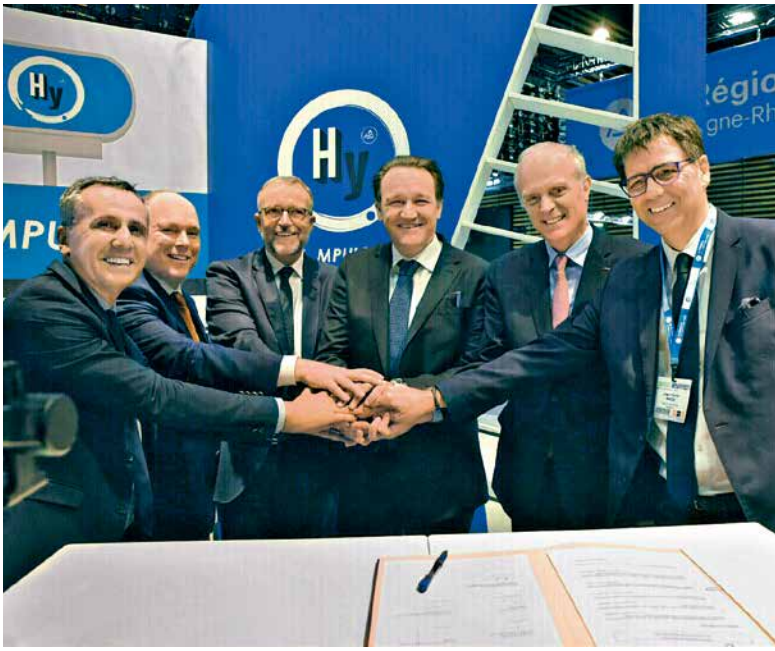

Fig. 1: Happy togetherness in the hydrogen zone [Source: Nicolas Rodet]

At the stand of FEV, the Aachen-based development service provider, there was a flyer on the subject of fuel cells, albeit hidden. AVL France SAS (AVL List GmbH) or Stäubli only mentioned their expertise in fuel cell or hydrogen technology in the exhibitor catalogue. Faurecia and Nel, on the other hand, had two tracks: So there was a Norwegian joint stand. In addition, the Norwegian electrolyzer manufacturer also exhibited on the blue carpet of the "Hydrogen Zone" together with its French sales partner. The Netherlands is now fully committed to hydrogen – which has been talked about at all corners of the "Hydrogen Zone" – but nothing was to be seen at the actual Holland stand.

On the other hand, the Auvergne Rhone Alpes region's zero-emission valley project was advertised in an unmistakably large way. Michelin clearly and clearly committed himself to the hydrogen technology. A large number of the important French players were also present (Ad-Venta, AFHYPAC, Atawey, CEA, Engie, McPhy, Michelin, Symbio, etc.), but also Hydrogen Europe, the FCH-JU, John Cockerill (formerly CMI Group) and Toyota exhibited here. In addition, the "European Hydrogen Valleys Partnership", an alliance of four European hydrogen regions (Auvergne-Rhone-Alpes, Normandy, Aragon and North-Holland), was publicly presented for the first time in the Hydrogen Zone.

Here on the blue carpet there were daily presentations in the EVS Agora and you met (almost) everyone who has a name in the hydrogen world – the Japanese Prius father

and Mr. Fuel Cell Katsuhiko Hirose, Bart Biebuyck together with colleagues from FCH JU, the French "Miss Hydrogen" Valérie Bouillon-Delporte as well as representatives of Toyota, Honda, Nikola and many more.

What remains regrettable is that the conference was too separated from the trade fair area and that many stands did not attract the expected number of visitors. Only half of the poster walls were covered with posters, and even there hydrogen and fuel cell topics had to be looked for almost like a needle in a haystack.

Still, you can hold on: Hydrogen and fuel cell technology has outgrown its infancy. Adieu laboratories, experiments and prototypes. Hydrogen and FC technology is filling its place in electric-mobility with increasingly market-, environment- and economically realistic projects and products.

Let us observe the further development from 14 to 17 June 2020 at the EVS33 in Portland, USA. ||

H2ME – EUROPE TAKES STOCK OF PROGRESS

H2ME is considered to be the largest hydrogen project in Europe: Since 2015, around 170 million euros have been invested in over 1,400 hydrogen vehicles and almost 50 filling stations throughout Europe – 67 million euros of which in the form of subsidies. More than 40 institutions are working together under the Hydrogen Mobility Europe programme to build a transnational grid. The aim is to establish a minimum number of hydrogen filling stations and to put a sufficient number of zero-emission vehicles on the road in Europe. On 25 October 2019 the conference "Hydrogen for clean Transport" will take place in Hamburg to document the mid-term results.

Hydrogen Mobility Europe is divided into two project phases: H2ME1 started in June 2015 and will run until mid 2020. Based on the resulting experience, H2ME2 was launched in May 2016 to significantly expand the vehicle fleet and improve its technical maturity. In addition, this six-year second programme will identify barriers to commercialisation and make a clear commitment to this technology. The funding for this comes from the Fuel Cells and Hydrogen Joint Undertaking (FCH JU).

H2ME 1
· 29 locations
· 300 vehicles
· 70 million € Capital expenditure
· 32 Mio. € funding

H2ME 2
· 20 locations
· 1,100 vehicles
· 100 million Đ Capital expenditure
· 35 Mio. Đ funding

Among the first one hundred H_2 vehicles put on the roads in early 2017 were 60 Renault Kangoo ZE-H2 in France and Great Britain and 40 Mercedes B-Class F-Cell in Germany. By autumn 2018, 110 Kangoo ZE-H2, 80 Toyota Mirai, 10 Honda Clarity and 60 other hydrogen vehicles had been added. In Germany alone, 20 filling stations are supported by H2ME.

H2ME is comparable to Hydrogen Mobility, which is working within Germany to have 100 hydrogen filling stations in operation by the end of 2019. It is similar with Mobilité Hydrogène in France, Scandinavian Hydrogen Highway Partnership in Scandinavia and UK H2 Mobility in the UK. These four initiatives pursue slightly different strategies adapted to their respective home countries, but their results are all summarised in H2ME. ||

THE GROVE CAR'S COMING


Quelle: Grove

Similar to Tesla years ago, completely new players are now entering the market in the fuel cell sector, with the potential to mess up the previous business of vehicle manufacturers. In May 2019, the Chinese start-up Grove Hydrogen Automotive Co., Ltd. presented itself to the public for the first time after three years of preparation. The Wuhan-based company's repertoire includes two fuel cell studies that were shown at the Shanghai Motor Show in April: the Limousine Granite and the SUV Obsidian. The Granite, with its range of about 1,000 km, could go into series production in 2021. CEO Prof. Yiguo Hao is already preparing cooperations with various cities and car rental companies in order to be able to bring the vehicles onto the market.

The company was founded in 2017 by the Chinese Institute of Geosciences and Environment (IGE), which also wants to set up an H_2 infrastructure. Grove has so far had development partnerships with Pininfarina, Hofer Powertrain and the FEV Group, and is drawing on the expertise of Christopher Reitz, who has already worked for Fiat, Nissan and Volkswagen, as Chief Design Officer. There is also a design and development centre in Barcelona. ||

RECTIFICATION

In the article "Quiet aviation" of the July 2019 issue of H2-international (Issue 3) it was written on page 37 that the Boomerang drones came from Horizon. I apologize for this misrepresentation. The drones were of course from Bluebird Aerospace. Horizon's "HES Energy Systems" division supplied a fuel cell system, which was exchanged for the existing battery system in the prototype for a presentation.

In addition, it was said that Horizon had spun-off its "armaments division". This was wrong and misleading because Horizon never had an armaments division. Horizon spun-off its HES Energy Systems division which was acquired by H3 Dynamics in 2015. ||

Category: Development | **Authors:** Sebastian Porstmann, Martin Biák

FIT-4-AMANDA – STACK ROBOT DELIVERED

Automatic production line for PEM stacks

Fig. 1: Economical production puts fuel cell technology on the road

Fuel cell technology offers an immense opportunity for future emission-free mobility. One of the biggest challenges for their breakthrough, however, is the currently still high costs compared to the gasoline or diesel drives established on the market. This is mainly due to the use of non-standardized components and the still insufficiently automated production of polymer electrolyte membrane fuel cell (PEMFC) stacks, which makes them comparatively expensive. The EU-funded development project Fit-4-AMandA (Fit for Automatic Manufacturing and Assembly) will therefore focus on the automated series production of PEM stacks and their components. The knowledge gained could then contribute to the economical production of fuel cell systems in larger quantities.

A significant milestone in this project, which has been running since 2017, was the delivery of a new stack robot to Proton Motor Fuel Cell GmbH at the end of May 2019. With the help of this automated PEM stack assembly line (see Fig. 2), production in Puchheim is to be increased to up to 5,000 fuel cells per year. The international project team, consisting of six institutions, jointly developed this robot and participated in a rigorous testing program to perfect its performance and capacity so that, with a slightly modified machine layout, up to 30,000 stacks could be produced per year.

First of all, it had to be clarified how high the desired degree of automation and the required plant throughput should be, how fragile and flexible components should be handled and how quality assurance should be carried out. In comparison to manual production, the need for optimisation essentially arose from the significantly faster feeding as well as the separation and manipulation of the components during automated assembly. In addition, the redesign of several stack components was necessary in order to significantly reduce manufacturing costs.

In this project, IRD Fuel Cells A/S will assume the position of supplier of the new stack components to be developed. This includes the redesign of the process and tool technology for the production of the bipolar plates from composite material. The second key component to be newly developed is the membrane electrode assembly (MEA). Requirement

Fig. 2: Plant for automatic BZ stack assembly

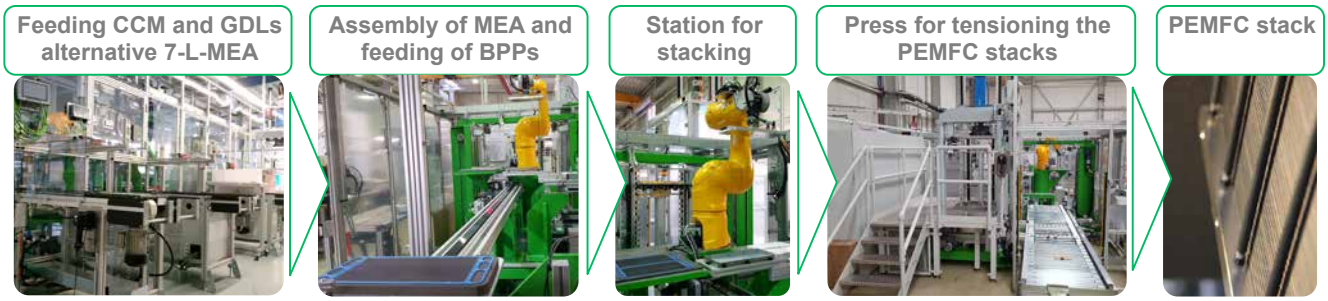

Fig. 3: Functional units of the fuel cell stack assembly [Sources: Fit-4-AMandA]

criteria are the achievable performance, compliance with dimensional tolerances and process optimisation, with the aim of direct integration into the automated assembly line.

Aumann Limbach-Oberfrohna GmbH is responsible for the development and design of the automated production plant for PEM stacks. On the basis of the experience gained in recent years in the field of stack assembly, a scalable plant for processing metallic and graphitic bipolar plates with integrated MEA assembly and finished multi-layer MEAs for different stack dimensions and heights has already been developed, covering all process steps from automated feeding of the components to MEA assembly, stacking of the components and clamping and fixing of the stack by tie rods.

Furthermore, the project is supportedby the Fraunhofer Institute for Machine Tools and Forming Technology IWU and the Chemnitz University of Technology (Chair of Alternative Vehicle Drives – ALF). Project management is the responsibility of Uniresearch B.V.

The Fraunhofer IWU is responsible for the theoretical analysis and improvement of the current stack components and the evaluation of manufacturing processes, especially for metallic bipolar plates, and the derivation of current case studies taking into account the benefits resulting from the series production of PEM stacks. The Chemnitz University of Technology is responsible for the analysis, evaluation and selection of test and diagnostic methods for quality assurance in the automated production of components and stack assembly. This involves the identification and elimination of bottlenecks in the manufacturing process with regard to the selected test methods. In addition, the implementation of the developed in-line inspection into the production plant and subsequent verification by the TU will be realized, whereby a significant reduction of the faulty PEM stacks can be guaranteed.

As an application example, it is planned to install a Proton engine system with a PEM stack produced in this way in a UPS delivery vehicle. UPS Europe SA's approach is to equip discarded but still operational diesel vehicles with an electric drive. In addition to ensuring that the vehicle (body, interior and chassis) is recycled in a way that conserves resources, the motivation is to be able to operate it locally emission-free in the future.

The PEM stack enables a significant increase in range flexibility, a reduction in battery size and the scarce resources required for this, as well as short refuelling times. In the future, these factors may lead to a flexible handling of spontaneous tour changes that require a higher range. For this purpose UPS prepared a feasibility study for the integration of the fuel cell system and other components into their vehicles. In addition, UPS implemented the PEM stack and developed and implemented the subsystems (BoP). Furthermore, it was necessary to develop a corresponding understanding of the transport OEMs for maintenance in the form of maintenance of the fuel cell unit and acceptance by future users.

SIGNIFICANT COST SAVINGS Within the Puchheim assembly line, which is currently in test operation, FC stacks of metallic and graphitic bipolar plates can be produced in various stack dimensions and heights. The alternating stacking of bipolar plates and MEAs by a robot takes place on a flexible workpiece carrier, which then transports the position-secured stack into the pressing station. There the stack is compacted accordingly and fixed by tie rods.

With the automated stack assembly, Proton's project partner can benefit from advantages such as

- Increase of the annual production capacity to 5,000 to 10,000 PEM stacks (depending on stack size),
- Reduction of stack assembly time by approx. 95 %,
- Cost reduction for the assembly process of approx. 90 %.

The targeted cost reduction of a PEM stack of at least 50 percent is not achieved by the automated production line alone. Rather, the measures required as a result of automation with regard to component optimisation play an important role here. Furthermore, the larger quantities purchased from suppliers have a cost-reducing effect.

The results of the development project will be used by Proton Motor for the production of fuel cell systems, IRD for the series production of fuel cell components and Aumann for the sale of automated fuel cell stack assembly systems. ||

The project is funded under the EU FCH JU Grant Agreement No. 735606.

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Category: Development | **Authors:** Aldo Gago, Svenja Stiber, Pia Aßmann, Andreas Friedrich

COST-EFFECTIVE AND FLEXIBLE

Modular stack design for high-pressure PEM electrolysis

Green hydrogen, preferably produced by electrolysis, links the energy, industry and mobility sectors and is an important tool to enable the integration of renewable energies. Proton exchange membrane electrolysis (PEMEL) is considered the most promising technology due to its power density and dynamics. However, large plants cannot yet meet the Fuel Cells & Hydrogen Joint Undertaking (FCH-JU) performance indicators in terms of cost, efficiency, lifetime and functionality. Consequently, the state of the art must be further advanced. The EU has therefore launched a call for tenders for a ground-breaking project to improve this technology, which will run until the end of 2020.

Fig. 1: Schematic of the 100-bar PEMEL system as a container solution from the project partner iGas Energy [1]

The consortium of the EU project PRETZEL intends to implement a 25 kW PEMEL system based on an innovative patented cell concept with which a potential differential pressure of 100 bar can be achieved. The electrolyzer operates dynamically between 4 and 6 A/cm2 at 90 °C and can nevertheless achieve a revolutionary high efficiency of 70 percent (calorific value). This performance will be demonstrated for more than 2,000 operating hours in the project, but will be further tested beyond the duration of the project. In addition, the investment costs for the stack components are significantly reduced by using non-precious metal coatings and advanced ceramic aerogel catalyst carriers. The plant periphery is also optimized with regard to cost reduction and reliability.
The high-pressure electrolysis system will become part of the product portfolio of a German manufacturer. This company will use the contacts from the EU project PRETZEL to further develop the R&D cooperation with partners from France, Spain, Greece and Romania and to strengthen their business relations in these countries. The hydrogen produced by the demonstrated PEM electrolyzer will be used to supply the fuel cell test stands in one of the partner laboratories.

The partners in the EU project PRETZEL *(Novel modular stack design for high pressure PEM water electrolyzer technology with wide operation range and reduced cost)* have set themselves the goal of developing an innovative proton exchange membrane electrolyzer (PEMEL) with significantly improved efficiency and functionality in order to meet the requirements of the energy turnaround. Such electrolysers, for example, are urgently needed for grid balancing.

In order to ensure their maturity for market launch, PRETZEL strives to achieve the following goals:

1. Development and manufacture of a high-pressure PEMEL for operation at elevated temperatures
2. Stack development and production based on the novel principle of hydraulic compression
3. Establish and implement common procedures for evaluating the development process
4. Integration of the stack into a test facility and validation of general performance and operational criteria
5. Preparation for market launch

Since the beginning of 2018, the project partners have been working on ground-breaking improvements to the PEMEL, which are intended to reduce overall system costs in order to replace alkaline electrolysis. Key optimisation aspects relate to increasing efficiency and achieving high-pressure operation at PEMEL. To achieve these goals, the PEMEL stack must be redesigned to achieve high current densities at an appropriate cell voltage (efficiency) and high output pressure. This also reduces the use of expensive raw materials and critical materials (e.g. precious metals, proton-conducting polymers and titanium) and simplifies the system configuration (one of the compression stages is omitted; see Tab. 1).

This results in further technical objectives for the project, such as the development of an innovative PEMEL system with an electrical power consumption of max. 25 kW, which generates 4.5 m^3_{H2}/h at nominal power, an output pressure of 100 bar and a feed water temperature of max. 90 °C.

At the system level, the specific energy demand will be below 56 kWh/kg hydrogen and 70 percent at a nominal production rate. In addition, this system can operate in overload mode at a production rate of up to 6.8 m^3_{H2}/h (1.5 times

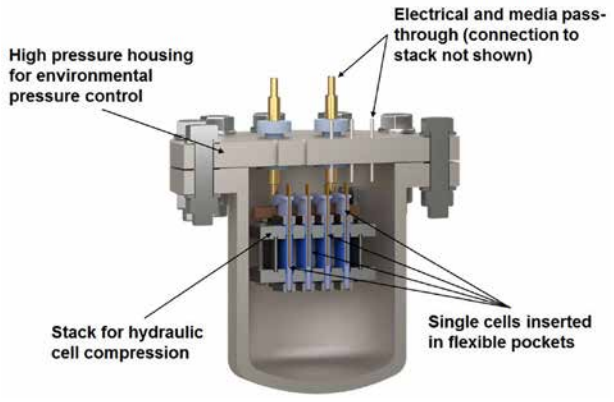

Fig. 2: Schematic of the 100-bar PEMEL stack in a high-pressure housing [2]

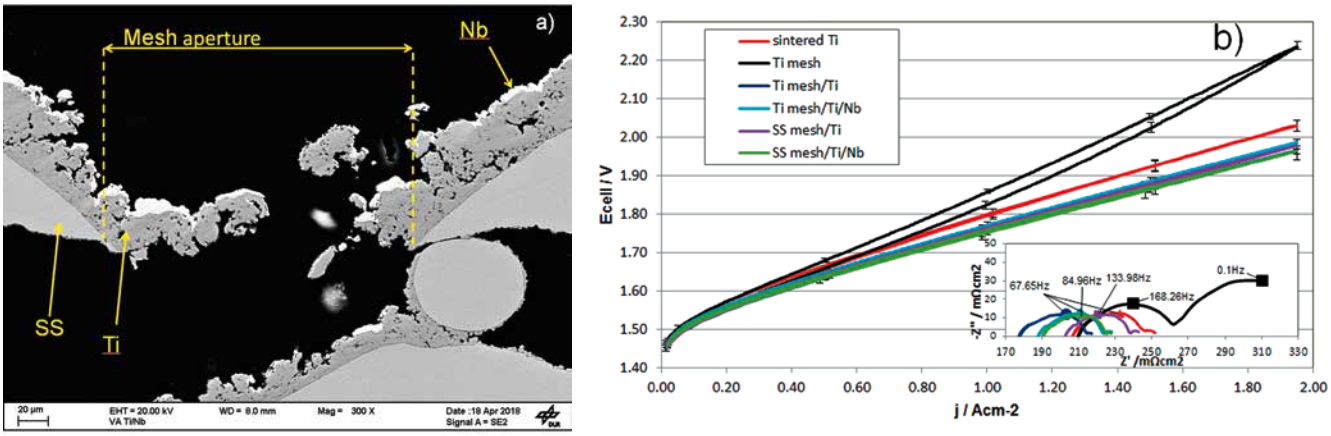

Fig. 3. a) SEM images of the cross-section of the thermally sprayed Nb/Ti-MPL on steel lattice as PTL, b) polarization curves of PEMEL cells with an active area of 4 cm^2 and macroporous layer (MPL), which were applied to porous transport layers (PTL) of Ti and steel lattice by plasma spray technique. The corresponding Nyquist diagrams (at 1 A cm^{-2},, from 50 kHz to 100 mHz) are shown in the lower right corner of the screen.

overload). Other operational objectives include rapid system responsiveness with one second for warm start and ten seconds for cold start.

At the stack level, the project will implement a patented design approach based on the compression of hydraulic cells. This design (see Fig. 2) enables the use of large planar cell components required for future mass production, as well as effective cooling at very high production rates and temperature levels. With a view to sufficient stack conditioning, a cooling system is being developed for voltages of maximum 2.0 V per cell at rated power and 2.3 V per cell in overload mode. In addition, the development of a high-pressure PEMEL stack – with specific stack costs of less than 500 Euro/kW in the future – is an important goal. Since a compressor is not required for production at 100 bar, specific system costs in the range of 750 Euro/kW are possible for the targeted system.

More than one and a half years have passed since the start of the project, and there have already been important innovations in terms of materials and components for PEMEL. Within the project, anode catalysts were developed that contain 70 percent less precious metal than commercial products. These catalysts are more active and more stable than the current benchmark. The integration of these materials into a functional electrode is currently being carried out. With regard to the bipolar plates, the partners have already developed dense coatings of titanium (Ti) using plasma spraying, which completely protect the base material copper from corrosion. The substitution of Ti by niobium (Nb) slightly increases costs, but allows a significant reduction in contact resistance. Furthermore, the partners have developed the next generation of porous transport layers (PTL) with graded pore structure for efficient water and gas management.

One of the most innovative developments at PRETZEL is the macroporous layer (MPL) at the interface between the oxygen electrode and the PTL. Based on earlier developments [3, 4], the partners have applied this MPL of Ti and Nb by thermal spraying to low-cost expanded metal grids of stainless steel as PTL (see Fig. 3a). In comparison to the uncoated steel nets, those with Nb/Ti coating (see Fig. 3b) show a reduction of the overvoltage of more than 300 mV at 2 A/cm^2 in the polarization curves (E_{cell}-j curve). This result means an efficiency improvement of about ten percent, which can hardly be achieved with more active anode catalysts and thinner membranes. The electrochemical impedance shows a reduction in ohmic resistance for all cells with plasma spray coated network structures. Furthermore, the coating virtually eliminates mass transport limitations at high current densities. The Nb/Ti coatings thus lead to considerable improvements in cell performance at high current densities. By increasing efficiency, these coated PTLs can potentially reduce the investment costs of PEM water electrolyzers (PEMWE).

PRETZEL will achieve its goals and make available a new PEMEL technology with ground-breaking innovations through material and component innovations and the improvement of the stack based on hydraulic compression technology as well as the simplification of the system. This enables the production of green hydrogen at 100 bar at reduced costs. ||

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Category: Market | **Auhtor:** Sven Jösting

BZ COMPANIES POSITION THEMSELVES

Stock analysis by Sven Jösting

The reports are coming thick and fast: Chinese companies and some provinces are planning to initially invest 17 billion US-$ in hydrogen technology. A master plan already provides for 1 million FC vehicles on the country's roads in 2030. Dr. Wan Gang, Chairman of China's Technology Council (higher ranking than a minister), now clearly prioritises the fuel cell over the battery for future mobility and complementary clean green energy issues. It was he himself who originally gave the battery the necessary support that made China a global pioneer and led to the dramatic rethinking of the global automotive industry. And also in Germany there is finally movement in this topic, although still many politicians and business representatives (example VW) connect electro-mobility one-sidedly with the battery and expect only in five to fifteen years the break-through of the fuel cell, which seems to be a gross misjudgement.

The topic of hydrogen and fuel cells is also becoming increasingly hotly debated on the stock exchange. The takeover of Hydrogenics, the Canadian frontrunner in fuel cell systems for trucks and rail vehicles as well as for electrolysers, by the US company Cummins Engine, should make people sit up and even trigger a wave of further takeovers or participations of listed companies in the industry. Leading previously unlisted companies such as ProtonOnsite (USA) had already found a buyer – in this case the Norwegian Nel Asa – and thus also received the indirect IPO. At Ballard Power – the global market leader – strategic Chinese investors are already major shareholders. Guess why!

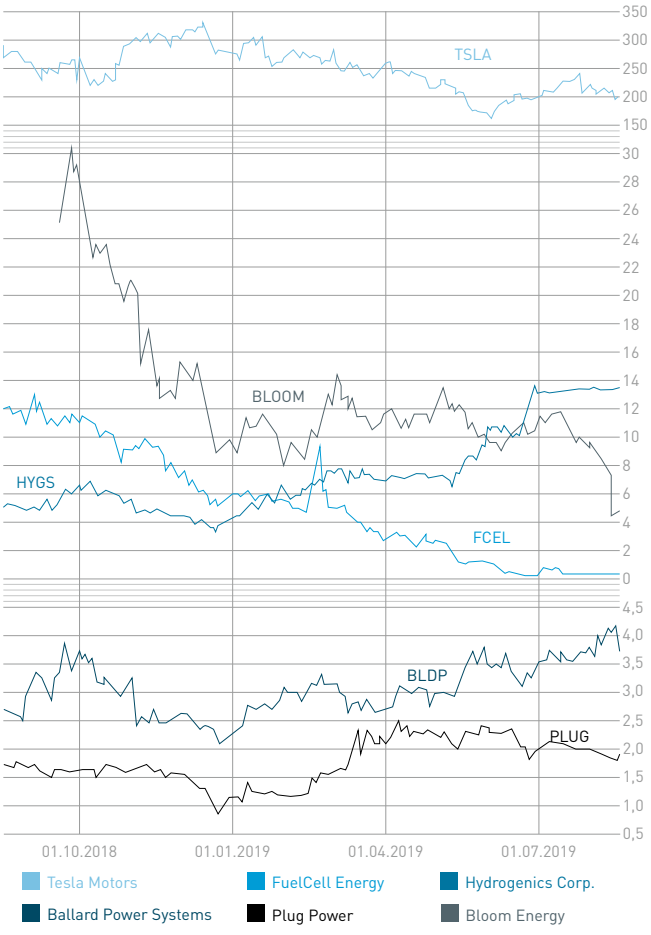

Fig. 1: Share price development of the six discussed companies [Source: www.wallstreet-online.de] Prices from 16 August 2019

BALLARD POWER – TAKEOVER UNLIKELY

The surprising takeover of the Canadian competitor Hydrogenics will also have a positive impact on Ballard Power's stock market valuation: Both companies have been frontrunners in FC development for many years. Their activities overlap in rail vehicles and trucks. They are both absolutely tops: Hydrogenics with Alstom and Ballard with CRRC and Siemens. Ballard also has many other activities in the major markets of the future, such as the use of fuel cells in drones.

Depending on the order intake in the various areas and the standing of the customers, the stock exchange will increasingly increase the potential of the share and anticipate 2020/21, as in these years the clear transition from research and project work (prototypes) to operative markets is likely to take place. For strategic reasons, companies such as Bosch or Siemens should invest in Ballard. Bosch already cooperates with PowerCell and Nikola Motors, as well as with Weichai, which in turn is the largest single shareholder of Ballard and also of Kion/Still (material handling – forklift trucks etc.; 45 % share).

These overlaps also make capital links and cooperation in different markets, where synergies arise, useful. So far, Chinese companies (Weichai, Broad Ocean) hold about 30 percent of Ballard. Another major shareholder from Europe would be perfect not to leave the field unilaterally to the Chinese. Ballard has already positioned itself very well in China together with Weichai via its own stack production (LCS) and serves the world market (stacks for buses, trucks, forklifts, etc.) from there, while Weichai concentrates on China – a perfect geographical division of labour. However, I rule out a full takeover by the Chinese. That is where the Canadian state would put the stop sign.

CURRENT DEVELOPMENTS – 92 FC BUSES ORDERED Solaris recently announced to Ballard an order for twelve fuel cell buses to be used in Italy. Wrightbus from Ireland has received another order for fifteen FC buses from Aberdeen, Scotland, for which the Canadians are also supplying the stacks. In total there are now 92 vehicles in Ballard's order book – a nice start, but an order of magnitude that is only the beginning of major orders. You can be curious.

The European H2Bus consortium is already talking about 1,000 FC buses, all of which will probably receive the FC stacks from Ballard. The price development is interesting: Whereas five years ago a hydrogen-powered bus cost more than 1 million Euro and three years ago about 650,000 Euro, today (according to Ballard) the price is 375,000 Euro and the hydrogen price is expected to be between 5 and 7 US $/

kg. A few years ago, a bus needed more than 20 kg for 100 km, today it is less than 7 kg/100 km. And in the long run, "green" hydrogen will cost no more than $2 to $3 per kg in production. The scaling effects have an effect.

SECOND QUARTER IN LINE WITH EXPECTATIONS Sales were expected to decrease slightly to $23.7 million and a non-GAAP loss of $0.03 per share was expected. The backlog of orders, however, grew to over US-$ 211.6 million. And the cash balance did not fall as I expected due to the investments in China but remains very high at $163.7 million at the end of the second quarter. According to Ballard CEO Randy MacEwen, the right growth of the company will come in 2020 – we can be curious.

Conclusion: Ballard is and remains the key investment if you want to invest in the fuel cell on the stock exchange.

> "We see a significant pipeline of projects that will feed into the 2019 backlog."
>
> *Randy MacEwen, Ballard*

HYDROGENICS – CUMMINS ENGINE ACQUIRES THE COMPANY

Source: Cummins

Cummins Engine, the US engine manufacturer (trucks, ships, rail vehicles), offers $15 per Hydrogenics share. If you paid 4 US-$ at the turn of the year, this is a nice increase (I pointed here several times to the perspectives). Unfortunately, the stock market story is now over. Clear recommendation: Invest the equivalent in Ballard Power or Bloom Energy and a highly speculative small part in FuelCell Energy.

Cummins as well as the management of Hydrogenics and major shareholder Air Liquide have agreed on the takeover, so that 15 US-$ per share is the last price and one should sell there – holding does not make sense. The story is hereby positively concluded. However, this shows that large companies are increasingly looking to acquire their own lack of know-how through takeovers in the industry. However, there are not that many listed FC companies.

BLOOM ENERGY – PRICE TURBULENCE DUE TO OUTLOOK 2020

The situation was turbulent on 13 August, after the figures for the second quarter of 2019 were published and fully in line with expectations: 234 million US-$ turnover (previous year: 168 million) and a loss per share of $0.13 (previous year: loss of $0.27). The statement of the CEO that growth in 2020 may not be in line with current forecasts, as important markets in California and New York are unfortunately expected to rethink the use of regenerative energies, made us sit up and take notice. As a result, the share price fell by 45 percent to approximately 4.50 US-$ in just one meeting. Just think: the company has a good

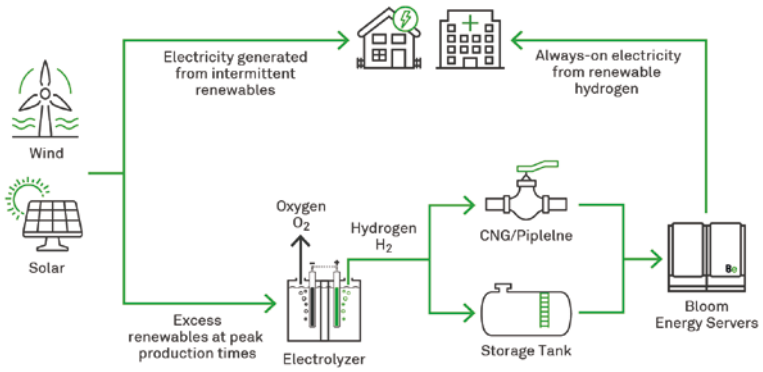

Fig. 3: Permanent energy supply with green electricity using Bloom-Boxes [Source: Bloom]

310 million US-$ in the bank, which is more than 50 percent of the stock market valuation. And the sale of FC power plants will bring another $200 million. A typical Wall Street exaggeration.

Duke Power acquires some of Bloom's own fuel cell power plants from Bloom. Bloom thereby obtains new, additional capital, which also generates income from the sale of electricity (PPAs) and heat, among other things. Bloom will know why you need the capital generated from the sale. The purchase price is estimated at over 200 million US-$. The already high liquidity of more than 300 million US-$ will thus probably be expanded not insignificantly. Conclusion: The outlook has not changed. The massive decline in the share price makes it advisable to buy additional shares or to reduce the price of existing positions.

PLUG POWER NOW ALSO ACTIVE FOR DRONES

Plug Power has now acquired the Canadian company EnergyOr, which claims to have a leading technology in hydrogen powered drones and robotic systems. Since Plug is already working closely with Amazon (conversion of forklift trucks with FC stacks for hydrogen operation) this can be an interesting new complementary market for Plug, as Amazon is currently working on delivering goods via drones (Note: Ballard Power is already very well positioned here via Protonex, today: Ballard Unmanned Services). In any case, a huge market of the future, which clearly gives hydrogen and fuel cell technology priority over battery technology (weight, service life).

In just a few years, worldwide sales of drone systems are expected to reach 52 billion US-$. This raises the question of whether and, if so, when Amazon will also become a Plug shareholder, since Plug has given up an option right to buy its shares.

Plug is meanwhile on a right track: Sales increased to 58.6 million US-$ (previous year: 58.6 million US-$): 39.2 US-$). A loss of 0.08 US-$ per share was reported. The billings are expected to amount to 235 to 245 million US-$ this year. Plug has now delivered a total of 28,000 systems and can call itself the largest buyer of liquid hydrogen. An impressive 200 million hours were driven by forklifts with fuel cells. The first of four major announcements are that DHL's Plug StreetScooter will be equipped with fuel cells, increasing the radius of its vehicles to 500 km. 200 specimens are considered to be the basis for 2020. Another three important positive announcements are to be made in the further course of the year. It is also said that the company is well on the way to breaking even. So you can be curious.

FUELCELL ENERGY – ROLLER COASTER RIDE ON THE STOCK EXCHANGE

If you hold this H2-international issue in your hands, we will know how FuelCell Energy will continue – whether it will continue: Chapter 11 (US insolvency) or reorganisation. What has happened? Enormous amounts of shares were traded daily by FuelCell Energy – on some days up to 150 million (computer arbitrage programs?). These were felt more than there actually are (reason: Conversion of preference shares). The interim price gain resembled an explosion, as there were even short-term prices of 1.00 US-$, while the price days before was still 0.13 US-$ (all, of course, under the aspect of the 12:1 reverse split). Was there a plan behind this? Had they tried to destroy the company or take it over at a favourable price via bankruptcy?

In the meantime, however, there are developments that give rise to hopes that the company will be able to leave "the valley of tears": Huron Consulting Services, a successful business consultancy according to Forbes, took over the helm in June 2019 and is to restructure the company. The Huron employee Laura Marcero (44) became Chief Restructuring Officer. The company pays very well for your services: Your hourly rates are over $750. Success bonuses also beckon.

As one of the first measures, the company "amicably" parted company with CEO Arthur A. "Chip" Bottone, who, in my opinion, was able to pay himself a sumptuous salary, but in his eight years as CEO and President, he was not able to give the company convincingly positive impulses. One must regulate now first of all the bank debts (Hercules bank) again and/or repay these, since probably credit conditions could not be kept. I just wonder why this bank isn't accommodating. Huron is working on finding a solution step by step. An ATM program (at the market) is to be implemented, according to which new shares will be placed on the stock exchange at a value of 42 million US-$ (technical term: subject to market). The proceeds can then be used to settle the debt. Meanwhile, the prices must also be right. On the other hand, this step shows that the company wants to maintain its stock exchange listing, which should also be in the interest of the business consultancy Huron. After all, the company itself could participate with a success fee, which would give the normal remuneration a not inconsiderable windfall when FuelCell is repositioned. We will see.

EXXON PAYS LICENSE FEE A good omen, however, is that Exxon finally gave a signal by acquiring "non-exclusive" rights of use for its proprietary carbon capture technology for 10 million US-$. Here I had rather expected large orders for the conversion of chemical plants than a license deal, but that may still come. Meanwhile, the UK commissioned a feasibility study for a carbon capture project with the aim of reducing CO_2 emissions by 80 tonnes per day. Drax, Selby (Yorkshire), where there used to be a nuclear power plant, is now one of the largest renewable energy regions in the UK. An order from this project should only be a matter of time. In Europe, the company is also active in various FC projects and sees a great need for smaller, very efficient FC power plants with carbon capture potential, according to a press release.

POSITIVE NEWS FROM SOUTH KOREA After one year of production, the company announces that a 20 MW FC power plant in South Korea from Korea Southern Power is performing better than expected. O-Ton: "Highly efficient and affordable electrical output and heat production." In view of the price turbulence on the stock exchange, such a report provides important and necessary confidence, as it confirms the professionalism of FuelCell Energy and, above all, its technology.

The long-standing legal dispute with the Korean licensee Posco was resolved amicably by arbitration (settlement) at the beginning of July. Unfortunately, there are no figures on this, but a solution seems to have finally been found. Posco itself wants to say goodbye to the fuel cell sector or has already done so, while competitors are heading in exactly this direction. This is like in the German automotive industry, where some (VW) focus primarily on the battery, while others are focusing more and more on the fuel cell and hybrid versions. It's corporate policy. The future will show who is right and which path will ultimately prevail.

BUSINESS AS USUAL But all this shows that you do "business as usual". What matters now is how a complete recapitalisation can be implemented, as the company has various

SAMPLE DEPOT AT WIKIFOLIO: BZVISION

It should be mentioned here that I also take a very close look at many other listed FC companies. I compare the key data of the companies such as turnover, orders on hand, growth, but also the stock market valuation and the respective business model and take a look at the technological standing. However, companies such as the Swedish company PowerCell, the Norwegian Nel Asa and the English ITM Power (see H2-international issue Apr. 2018, with a good profit) are much too highly valued compared to companies such as Bloom Energy, Ballard and others, or the latter are too low, even though companies such as Nel Asa are strongly recommended by German stock market media, with more than 1.2 billion shares. It is also clear, however, that with the accelerating speed of the FC train on the stock exchange, all listed companies in the industry will profit from this in terms of share price – only those I prefer, feel, more / stronger.

For one year, since July 2018, I have been maintaining a sample/game depot at Wikifolio (www.wikifolio.com – BZVision) with a gaming capital of 100,000 Euro. This currently includes Ballard Power and FuelCell Energy. Hydrogenics was closed after the Cummins takeover bid and sold at a high profit, as well as the position in Plug Power was realized after the strong increase. The profit offset the loss in FuelCell Energy (after 12:1 reverse split). At the same time, I had increased Ballard Power from 20,000 by 2,000 units to 22,000 as well as FuelCell Energy in stock by 15,000 units to 18,500. After the price slump at Bloom Energy, I sold the purchased 2,000 Ballard shares with a good profit and reinvested them in 2,000 Bloom Energy.

I am confident that Ballard Power will develop disproportionately well (over the next one to three years) and that FuelCell Energy will achieve a turnaround. If this is not the case with the latter, I expect much more than just loss compensation through the price development of Ballard Power. Looking at it the other way: Should FuelCell (highly speculative) achieve the turnaround, i.e. the recapitalisation, this will of course have a positive effect on the share price and the overall portfolio. After realization I would then – in case – further expand the position in Bloom Energy (2200), but only to achieve a better risk diversification. This game depot is purely theoretical in nature. No commitment!

Fig. 4: Giant stack from FuelCell Energy [Source: FuelCell Energy]

projects, proven technology and full order books, including service and maintenance contracts for existing plants (1.4 billion are shown). Bankruptcy or delisting makes no sense. Rather the opposite is the case, as new financial resources can be better collected via the stock exchange.

Generate Capital has granted FuelCell credit lines for projects up to 300 million US-$. Why shouldn't this investment company be prepared to give the company a new credit line or to become a major shareholder by taking over shares? The result would be a massive increase and revaluation of the company. It could also restore confidence.

Since I cannot judge the short sellers (investors of preference shares?), I see the perspective of the share price in two extremes: Either the (less probable) delisting via Chapter 11 or the successful restructuring with the potential of a multiple share price. I do not expect a further reversal split (capital consolidation), even though the number of shares is again in excess of 100 million and continues to increase as a result of the ATM program. I'm looking at Nel Asa, who will soon have issued 1.3 billion shares. But you have to work hard to bring the stock exchange price above 1 US $, because then the change of the stock exchange segment is prevented. According to the latest news, there is a good 180 days left here.

A conclusive assessment is unfortunately not possible for the time being, since one can only guess at the interests of the parties involved but does not know them conclusively. There is still the greatest possible risk, but also the total rebirth as Phoenix from the ashes. I'm betting on the latter.

Bloom Energy should take over FuelCell Energy via an exchange of shares, because in my opinion their carbon capture technology would be the perfect technological complement.

TESLA – STRONG PRICE REACTION AFTER SHARP SLUMP

Fig. 5: Model Y [Source: Tesla]

170 US dollars, a good 30 US dollars lower than I had expected (200 US dollars), marked the lowest price of Tesla's share in the recent past, before the strong rebound to over 260 US dollars – until the disappointing figures for the second quarter of 2019 started the reverse. The basis for this interim rally is the rising sales figures and especially the increased deliveries of Model 3 in the second quarter of approximately 95,000 units (sales declines for Model S and X, based on an increasing number of competitor models). In addition, reports are circulating that suppliers have received larger orders indicating higher production of Model 3.

The general scepticism expressed in analyses by well-known investment banks, however, overshadows the share price development, because a strong increase in growth is not discernible, even though the second quarter was very good in this respect and Tesla reported sales in excess of 6 billion US-$ in the quarter – but again with a loss of 408 million US-$, which would have been even higher had Tesla not massively scaled back its investments (CAPEX). Is all this really sustainable?

The further development of the share price will now again be driven by the company figures: In addition to the loss of $408 million, or more than $2 per share under GAAP – significantly more than expected – the cash position was maintained at a healthy $5 billion after the capital increase of $2.7 billion gross. Recent reports have been circulating that Tesla plans to increase production capacity, as demand for Model 3 has grown well and the focus is on the new Model Y (2020), derived from Model 3. The decline in the high-margin Models S and X contradicts this. So is this another marketing trick? In parallel, Tesla introduced various discounts in the last quarter, which would not have had to be granted if sales were going so well, right? However, advance payments have declined sharply. In addition, the tax incentives in the USA (but also in China and other countries) are increasingly disappearing, so that the discounts and reductions in conditions granted for leased vehicles can probably be seen as compensation. The fact that now owners of Model S and X can refuel free of charge again, may be an incentive to buy, but Tesla of course also has higher costs here.

CHINA STRATEGY WITH CONDITIONS Meanwhile, the construction of the new Gigafactory, which is scheduled to start production of Model 3 as early as 2019, is progressing rapidly. However, China and Shanghai have linked the construction of Tesla's new Gigafactory there to various conditions. Tesla will have to invest 2 billion US-$ in the new factory over the next five years and pay a minimum annual tax of 323 million US-$ from 2023. With non-compliance, the property (and the Gigafactory?) will revert to the city of Shanghai. In addition, no production approval for the e-cars is yet to be obtained, which is the condition for the start of production.

TOP MANAGERS ON THE RUN Tesla also has to struggle with the permanent departure of top managers, such as a former Audi manager and even the co-founder of Tesla and CTO JB Straubel. He ended his position and became a consultant. These key people know more. Rumour has it that even a team of experts consisting of eleven programmers has left the business because the pressure to succeed caused by Elon Musk was too high for them. The Tesla story is not only about the smart electric cars, but also about the complexity of battery production, the development of the subsidiary SolarCity and the general indebtedness and its impact on the cash balance (repayments and interest) and its development (cash burn). According to Elon Musk himself, the 2.7 billion US-$ from the last capital increase should already be "premature" in ten months. And the China strategy may come rather late (too late?), since the People's Republic clearly prefers the potentials of the fuel cell to those of the battery. The subsidies for the battery will be discontinued and introduced for the fuel cell.

FULL-BODIED FORECASTS Despite all this, 15,000 vehicles per week are Elon Musk's new declared goal. China is supposed to fix this. In addition, there are loud thoughts about setting up a third Gigafactory in Europe. Musk, however, is relying too much on quantities as on their profitability.

A rethink would be good, but Elon Musk only sees the battery. And it already exists, the Tesla as a hybrid with a fuel cell. Tesla should achieve this after the Dutch team of the company Holthausen, which converted a Tesla on its own initiative to a Hesla (H stands for hydrogen), in order to create the combination of battery and fuel cell via hybrid. This could mean a real revaluation, but Elon Musk unfortunately does not see these potentials of the "Foolcell" (O-Ton) at all.

It's not too late yet. I would give up my sceptical attitude towards Tesla if the fuel cell was given more consideration. My next course target: 150 US-$. ||

Category: International | **Author:** Cory Shumaker

LIFE AS A HYDRONAUT IN CALIFORNIA

Field Report of an Hydrogen Fuel Cell Car Driver

Fig. 1: A hydronaut in the midst of many gasoline vehicles [Source: CHBC]

I'm a hydronaut. No, that's not a term for an underwater astronaut, but a term Honda uses to describe me, as one of their Clarity Fuel Cell electric vehicle (FCEV) drivers on California's road today. Between three automakers (Honda, Toyota, Hyundai) there are now over 7,000 (Aug 1, 2019) FCEV's on the road. Living life as a hydronaut is a unique experience, filled with the jubilation of driving a zero emission car with 300+ mile range AND fast (3 ~ 5 minute) refueling! However, introducing a new transportation fuel also includes an occasional frustration as hydrogen stations are still facing growing pains. Luckily, California is well on its way to the first 100 hydrogen refueling stations, and those 13 in Los Angeles County create even more jubilation. The number of hydronauts is growing every month.

Some folks may have been converted to FCEV's due to the high penetration marketing campaigns developed by the automakers. Driving down the 405 freeway, which runs north to south in the Los Angeles area, you can see the only place in the world where there is a FCEV billboard competition. On one side of the freeway as it nears Carson, there's a billboard advertising the Toyota Mirai, displaying a picture of the car sitting on water with the phrase under it: The only emission is water. This definitely does a good job of depicting the car as a clean, green choice for the environment and consumers. Less than a mile away, a Honda billboard boasts "3-5 minute refueling; The All-New Clarity Fuel Cell." These are the big car company's attempts to recruit more hydronauts and it seems to be working. While the increase of battery electric car vehicle (BEV) drivers is a bit steeper, each month more drivers in California are saying "yes" to FCEVs.

Marketing strategies, like billboards and radio ads, are one way to get more people to drive FCEVs, but another consideration are financial incentives. "Cash is King", as they say, and nothing gets a potential FCEVs driver's attention like the State of CA offering a $5,000 rebate to purchase a zero-emission car (for low income applicants, this rebate increases to $7,000). Thanks to California's Clean Vehicle Rebate Project (CVRP), which is funded by the State's Cap & Trade Program through the California Air Resources Board, FCEV drivers are eligible for the rebate when buying or leasing a clean, zero emission hydrogen FCEV. The Honda Clarity FCEV is being offered as a lease in California for $379 a month + tax and includes FUEL. That's right, hydrogen fuel is provided in the lease, for up to $15,000 over three years! In a city where

the price of gasoline per gallon is more than a Starbucks latte, it was smart to reduce the fuel cost burden so including fuel should not be dismissed when car shopping. It was a genius move by all of the OEMs offering FCVs in California today. By taking away the price of fuel, it brings the total cost of leasing a FCEV below many of its fossil fuel competitors BEFORE getting the CVRP rebate. This is a great step forward to a future where the price of hydrogen will no longer need to be subsidized, as the increase in volume and infrastructure economies of scale lowers the fuel cost of hydrogen to parity with gasoline.

The average driver in Los Angeles spends between $150-200 a month on gasoline. In my calculations, I applied that savings to my leasing cost for my Honda Clarity FCEV, which brought it down to a (net) monthly $169 plus tax. A very affordable price to pay for state-of-the-art technology in a luxury package. The down payment of $2,878 is more than paid for by the $5,000 cash rebate, and if you amortize the remaining $2,122 over 36 months of payments, the cost of leasing that beautiful new water emitting FCEV drops to $110 per month plus tax. This is just talking pure economics that convinced me to take the fearless leap of becoming a savvy, money saving hydronaut. On top of that, Honda provides a 21-day car rental voucher with local rental car agency Avis. This allows FCEV drivers to rent a normal gasoline car when an FCEV is not feasible, such as for drives outside the station coverage area, or when a larger vehicle is needed for those trips to the ski slopes of Mammoth Mountain. The other FCEV OEMs, Toyota and Hyundai, have similar packages for fuel and car rental vouchers.

Every day I smile as I pass the gasoline station watching the gas prices go higher and higher, even exceeding $5 per gallon, while I zoom along quietly in my water emitting, air cleaner (yes, the air coming out of my Honda Clarity FCEV is actually cleaner than the Los Angeles air going into it). I'm on cloud nine pulling up to the hydrogen pump behind the dinosaur oil spigots, pulling out my shiny Honda fuel card that pays for my hydrogen, and stepping over to the pretty blue (in some locations) hydrogen dispenser. No more than 5 minutes later I'm back in my car and on my way with a big smile on my face. Fast fueling is a great feature of FCEV zero emissions driving that comes in handy when making those long trips from Los Angeles to San Francisco. Another envy of BEV driver.

So…what about that "frustration" comment earlier? It's clear that the infrastructure has improved over the years since the early days of hydrogen refueling. Today the new H70 filling nozzles make it easy to connect and disconnect, so no more getting stuck with a frozen connection. While some stations have shown slight weakness for reliability and are improving over time, other stations have become "old faithfuls" with outstanding resilience such as the station located at Harris Ranch between Northern California and Southern California. It's known as a "connector station", literally describing how it connects So Cal to Northern California. I'm thankful to be located in Venice Beach where there are four hydrogen stations within a 7-mile radius. That's the benefit of living in a large metropolitan city. Other remote parts of California may be difficult to fuel in today, but with a network of 40 (and counting) hydrogen stations spread out through most of populated California, and a goal for 100 in a few years, there's great potential for even better road trips to world renowned tourist sites up and down the Golden State that make California a hot spot vacation site for the world to visit.

This summer in California, southerners have had it much better than northerners when it comes to hydrogen availability. In the first week of June, the hydrogen supply became impacted via a supply depot incident, and although repairs are well underway it caused challenges for those drivers in the Bay area. So yes, there are still some frustrations due to growing pains! Future stations will be far more robust with redundancy built in and with far higher capacity to buffer the day to day supply challenges. The car OEMs did what they could to help the situation; Honda, Toyota and Hyundai all provided free car rental vouchers that didn't count towards their 21 day allocation from their lease, to give otherwise stranded drivers transportation for their daily driving needs.

During this period, I made the brave decision to venture out of Southern California, where hydrogen was plentiful, and go right into the "hydrogen desert" of the San Francisco Bay and Sacramento area. Both trips that I took up the State in July were uneventful, as the hydrogen station on the way into the San Francisco Bay Area was online and the Sacramento station had resumed normal operation a week before my trip north.

Traveling up and down California in an FCEV is easy thanks to the ever reliable Harris Ranch True Zero hydrogen station strategically placed about 190 miles from Los Angeles, 190 miles from Sacramento and 190 miles from San Francisco. It's quite a fun experience to roll into the Harris Ranch Express BBQ and Service station past the lineup of Tesla fast chargers. In less than the amount of time it takes to use the bathroom and buy a water, my hydrogen tank is full again for up to 350 miles of zero emission driving. Meanwhile, the owners of pricey battery EVs are standing by their cars for a minimum of 45 minutes before they can resume the open road. It's that specific moment that makes dealing with the variability of hydrogen stations well worth it. The feeling of moving around the Golden State emitting nothing but water vapor in a sleek, peppy, comfortable FCEV makes me want to take long road trips up the gorgeous California Coast multiple times a month.

Cory Shumaker is a Development Specialist for California Hydrogen Business Council. The article does not necessarily represent the views of the CHBC or its members.

California still has a long way to go in terms of providing enough hydrogen infrastructure. However, it should be noted the length of time it took gasoline infrastructure to become as resilient as it is today. It happened over the course of 100 years, with huge, cross-sectional demand, and multiple business models serving the supply chain. What the hydrogen infrastructure market has achieved in the last 20 year is remarkable, considering it started with 0 public stations at the turn of the millennium. While California is third, behind Japan and Germany, in terms of hydrogen stations, we have by far the most cars. It's amazing the ratio of cars to stations compared to the rest of the world. The California Fuel Cell Partnership has published a "2030 Vision" called the Hydrogen Revolution that outlines the pathway from the 1st 100 stations to 1,000, which will support up to one-million FCEVs! See: www.cafcp.org to download and read the document. Over 7,000 people have said yes to hydrogen in California so far, still considered early adopters but it's becoming more and more normal for the everyday driver. On several occasions I, along with other hydronauts, have been inquired upon by gasoline guzzlers while at the pump. They ask, "Does your car burn hydrogen?", "What are you putting in that?", "How does it work?" and my favorite "That's the future isn't it?" It's always my pleasure to bring them up to speed on the awesomeness that is zero emission hydrogen fuel cell electric vehicles. There's still a lot of work to be done by organizations such as the California Hydrogen Business Council on regulations and legislation, and the California Fuel Cell Partnership in terms of outreach and education. The average Californian does not know about hydrogen, yet, but what began with a small number of early adopters over a decade ago is growing into a movement towards zero emissions with zero compromise. Former Governor Brown agreed, and put forward a goal of increasing the number of 100 stations planned for 2024 to 200 stations by 2025. Dr. Shane Stephens, Founder and Chief Development Officer of True Zero (operator of 19 HRS) stated, "Hydrogen stations are starting to scale in both volume and number; hydrogen station developers see a pathway to profitable and competitively-priced hydrogen with gasoline." There will come a time very soon in California where the price of filling up a tank of hydrogen will be less than filling up an SUV with gasoline. With the California Fuel Cell Partnership's goal of 1 million FCEVs and 1,000 hydrogen stations by 2030, in the near future being a hydronaut on California's roads will no longer make you stand out of the pack. That's a future I, along with many others, welcome and work every day to make a reality. ||

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CALIFORNIA TO ELIMINATE EMISSIONS

Emission-free until 2040 in public transport

California continues to move the needle in adopting more and more ambitious climate, energy and transportation goals, to improve air quality and reduce health impacts from emissions, and to develop a strong clean energy economy in the state that creates sustainable jobs.

One major development in this regard is the adoption of the Innovative Clean Transit (ICT) Regulation in December 2018. The ICT will seek to eliminate emissions from transit buses by mandating California transit agencies to purchase zero emission buses (ZEBs) in ever increasing numbers, with 100 percent zero emission bus procurement by 2029, only 10 years from today, and completely zero emission by 2040!

To be compliant with the ICT Regulation, transit agencies will develop ZEB Rollout Plans, which are due on June 30, 2020 for large transit agencies (100 or more buses) and June 30, 2023 for small transit agencies (fewer than 100 buses). Once ZEB Rollout Plans are approved, annual ZEB procurements for large agencies will require 25 percent by 2023, 50 percent by 2026, and 100 percent by 2029. Small transit agencies will need to procure 25 percent by 2026 and 100 percent by 2029.

California Air Resources Board (ARB) Chair Mary D. Nichols stated "a zero-emission public bus fleet means cleaner air for all of us. It dramatically reduces tailpipe pollution from buses in low-income communities and provides multiple benefits especially for transit-dependent riders". Tony Brasil, chief of the ARB transportation and clean technology branch added "regulations are required to provide that certainty for the market, provide market signal, long-term goals, and get the investments made to meet the goals".

The regulation gives transit agencies a deferral option to request an extension or exemption from the ZEB purchase requirements if conditions outside of the agencies control restrict their ability to comply. Industry insiders have stated that the high costs of ZEBs and infrastructure are one such condition.

"Meeting the mandates of the ICT Regulation will be a heavy lift for the transit agencies across the state while bringing significant benefit to the public," said Jeff Serfass, California Hydrogen Business Council Executive Director. "Education of the available ZEB options and the associated infrastructure options will be critical for this regulation to be successful. Battery buses work well in some scenarios, fuel cell electric buses (FCEBs) work well in all scenarios. Transit agencies need to make sure to study both to see the best value for their investment to meet the mandate."

Transit agencies have access to a variety of funding programs to assist with the high cost of FCEBs and BEB, most notably the Federal Transit Administration's Low or No Emission (Low-No) Program and the California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). In addition to these programs, funding could be obtained through the California Low Carbon Transportation Program (funded through the Cap-and-Trade auction proceeds), the Air Quality Improvement Program, and the Volkswagen Environmental Mitigation Trust. Many organizations and industry players are assisting transit agencies

Fig. 1: SunLine-Bus in Palm Desert, California [Source: CHBC]

in the development of project proposals, most notably the Center for Transportation and the Environment (CTE) and New Flyer, a leading zero emission bus manufacturer.

Hydrogen fuel cell electric buses have been in operation in California for over 15 years. FCEBs are a scalable solution for up to hundreds of buses per depot without stressing electrical infrastructures and perform very similar to diesel buses, including range. With high fuel economy, low maintenance costs, and lower weight than other ZEB options, which allows increased passenger capacity and refueling time similar to convention fueling, FCEBs are a perfect replacement technology, especially for larger transit fleets.

AGE OF CO_2-FREE ELECTRICITY California established GHG emissions reduction goals of 40 percent by 2030 and 80 percent by 2050. In addition to these goals, in September 2018, the state passed SB 100 which will usher in 100 percent carbon-free electricity by 2045. Former Governor Brown also issued Executive Order B-55-18, committing California to total, economy-wide carbon neutrality by 2045.

The ICT Regulation is one of many new and developing regulations that the Air Resources Board has adopted to improve the state's air quality and address global climate change. Other mandates are currently being considered for the trucking industry and light duty transportation. While hydrogen may not be the first thought that comes to mind for policy makers to meet those mandates, the 100+ CHBC members believe that this is the most important and are prepared to deliver hydrogen fuel cell solutions with the right mix of mandates and incentives. ||

During the month of June, the California Hydrogen Business Council (CHBC) and California Transit Association (CTA) will conduct a series of four webinars to provide transit agencies, local and state government officials, and environmental justice organizations the opportunity to learn about the fuel cell electric bus option. Details on the webinar series, which is free of charge, are available at www.californiahydrogen.org/the-other-electric-bus-meeting-the-ict-regulation-with-hydrogen-fuel-cell-technology-webinar-series/

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FROM PIONEER TO LAGGARD

Iceland holds on to hydrogen and fuel cells

Iceland was quick to recognise the opportunities offered by hydrogen and fuel cells for the transport sector – but has unfortunately made little of them to date. At the end of the last millennium, the Nordic island was regarded as a pioneer in the field of hydrogen, because it considered the vision of a sustainable hydrogen economy to be quite feasible. For decades, the country's energy supply with heat and electricity has been covered by the country's existing renewable energy sources of hydropower and geothermal energy. Only Icelandic transport, including shipping, is still dependent on fossil fuels, which have to be imported at high cost. Electric mobility is struggling, although Icelanders have been working with fuel cell vehicles since the end of the 1990s. Reykjavik was one of the first twelve cities in the world to use fuel cell buses in public transport as part of European demonstration projects in the early 2000s and to produce and supply hydrogen from renewable sources.

Abb. 1: Bohrloch für Geothermie in Island [Quelle: ON Power, Island]

But then the financial and economic crisis came in 2008, and in Iceland not one stone was left unturned. Although politics has never abandoned the topic of hydrogen and fuel cell mobility, the island state has had to realign itself following these radical changes and see to it that the country can cope with its horrendous debts and get back on its feet.

Iceland's renewable energies were and are the best way to grow with them. Geothermal energy and hydropower supply 80 percent of the country's required energy around the clock, regardless of the weather. The remaining 20 percent of the energy requirement is covered by imported fuels for transport by land, sea and air.

Iceland made a name for itself at the end of the last century by fully announcing the conversion of its energy supply to hydrogen. After a few initial demonstration projects, however, the Nordic country has now become quiet about this issue.

MANY CO_2 EMISSIONS Although Iceland's energy supply is predominantly based on renewable energies, the small Nordic country is nevertheless one of

Iceland took its first major step towards a sustainable energy economy between 1945 and 1970 by using geothermal energy as a source of electrical energy and heat and shutting down the last coal-fired power station. Twenty years ago, one kilowatt hour of electricity from hydropower cost just under three cents. Icelanders nevertheless cover around 30 percent of their annual energy consumption with mineral oil. More than half of the total 850,000 tonnes per year are consumed by the fishing fleet, the other half by road (three out of four Icelanders own a car). However, the required oil must be imported. The government under Prime Minister Davíd Oddsson (1991-2004) wanted to change this and therefore planned to switch to the hydrogen economy. By the year 2050, the island state should transform itself into a self-sufficient hydrogen society that would cover its entire energy requirements from its own regenerative resources. The first hydrogen filling station was opened in Reykjavik in April 2003. The project was part of the Icelandic ECTOS project (Ecological City Transport System), a sister project of CUTE (Clean Urban Transport Europe). The station was used by three fuel cell buses used by the local bus company on the streets of Reykjavik.
In addition, in 2003 the North Atlantic island state signed a Memorandum of Understanding on cooperation with the Canadian province of Manitoba to implement the hydrogen plans. Manitoba has large quantities of hydropower available that should be used to produce hydrogen. It was also planned to convert the entire fishing fleet to quiet, environmentally friendly FC operation in the long term, so that, in addition to reducing oil consumption and the associated pollutant emissions, an increase in fishing yield could also have been achieved. But for several years now it has been quiet about these plans. (sg)

the largest per capita CO_2 emitters in the world. The reasons for this are the extreme increase in the number of tourists in recent years with a corresponding increase in air traffic and the three large aluminium smelters that have settled on the island with strong support from Icelandic politics thanks to low electricity prices. They consume large quantities of graphite in the production process, which is used as an electrode material in fused-salt electrolysis. This results in large quantities of CO_2 emissions.

Since these two major CO_2 emitters cannot simply be shut down due to their outstanding economic importance for the country, the government at least wants to decarbonise the mobility sector. This is precisely where Iceland's newly awakened soft spot for hydrogen and fuel cells comes in. The use of hydrogen-powered vehicles and ships would make CO_2 free mobility possible. At the same time, the nation of 340,000 inhabitants could reduce its dependence on fossil fuel imports to a minimum. Nevertheless, the country has not yet gone beyond a few hydrogen and FC demonstration projects.

In contrast to Norway, for example, battery electric mobility does not play a significant role either. Until now, there has been no consistent political strategy or even funding instruments that would favour the acquisition or operation of electric vehicles and ships. It was not until the spring of 2017 that the Icelandic government actually initiated the energy turnaround in the transport sector. Its goal is to increase the share of renewable energies in transport to 10 percent by 2020 (starting from 6 percent in 2016) and to 40 percent by 2030. At the same time, the share of renewables in the fleet for fishing is to rise from 0.1 percent in 2016 to 10 percent by 2030. How exactly this is to be achieved, however, remains unclear.

In the meantime, the country is involved in various European H_2 and FC projects in order not to lose touch. Iceland is part of the Scandinavian Hydrogen Highway Partnership (SHHP) alongside Norway, Sweden and Denmark. In addition, the capital Reykjavik is involved in the hydrogen activities of the business initiative of the European regions of the FCH JU. As part of the JIVE 2 project, five new fuel cell buses are to be deployed in Iceland's capital until 2023.

As a partner in the Hydrogen Mobility Europe project (H2ME, see p. 37), three hydrogen filling stations have now been set up and commissioned in Reykjavik. (The vehicles that refuel with this hydrogen, however, are scarce on Iceland's roads.) It is planned to produce the hydrogen for the filling stations in Iceland's largest geothermal power plant Hellisheidi of the energy supplier ON Power (Orka náttúrunnar) by means of water electrolysis. For this, too, subsidies from European funding sources flow to Iceland. ||

SELF-SUPPLIER

Today, Iceland produces more than 18 terawatt hours of electricity from geothermal and hydropower – far more than its own population needs. Although there are discussions about connecting Iceland to Great Britain via a submarine power cable in order to be able to export electricity, as long as the financing of such a project is not in place, there can only be further speculation about the possibilities. Meanwhile, the country is trying to consume the energy itself – either by establishing energy-intensive industries or, more recently, by producing electrolysis hydrogen from renewable electricity.

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ORGANIZERS (EVENTS)

CeMAT ASIA — October 23-26 2019 — Shanghai New Int'l Expo Centre Shanghai, PR China

HANNOVER MESSE — April 20-24 2020 — Hall 27, C66 Exhibition Grounds Hannover, Germany

Hydrogen + Fuel Cells ASIA, October 23–26, Hydrogen + Fuel Cells Europe, Hannover Messe 2020, April 20–24 Tobias Renz FAIR, *tobias@h2fc-fair.com, www.h2fc-fair.com*

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STORAGE

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

Hexagon Purus GmbH, Otto-Hahn-Str. 5, 34123 Kassel, Germany, Phone +49-561-58549-0, Fax -29, *www.hexagonxperion.com*

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

Kessels Prüfwerk Gmbh & Co. KG, Lehmkuhlenweg 13, 41065 Mönchengladbach, Germany, Phone +49-(0)2161-65907-0, Fax -68, *www.kessels-pruefwerke.de*

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

Worthington Industries – Stako Sp. z o.o., 54 Poznanska, 76-200 Slupsk, Poland, Phone +48 598424895, *Sales-PL@worthingtonindustries.com, www.worthingtonindustries.com*

SUPPLIERS

Anleg GmbH, Advanced Technology, Am Schornacker 59, 46485 Wesel, Germany, Phone +49-(0)281-206526-0, Fax -29, *www.anleg-gmbh.de*

Borit NV, Bipolar plates and interconnects, Lammerdries 18e, 2440 Geel, Belgium, Phone +32-(0)14-25090-0, Fax -9, *contact@borit.be, www.borit.be*

ElringKlinger AG, Max-Eyth-Str. 2, 72581 Dettingen/Erms, Germany, Phone +49-(0)7123-724-0, Fax -9006, *info@elringklinger.com, www.elringklinger.com*

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

Kerafol Keramische Folien GmbH & Co. KG, Ceramic Electrolytes, Solid Oxide Cells, Glass Tapes, Koppe-Platz 1, 92676 Eschenbach, Germany, Phone +49-(0)9645-884-30, Fax -90, *www.kerafol.com/sofc*

Pajarito Powder, LLC,
3600 Osuna Road NE, Suite 309, Albuquerque, NM 87109-4427, USA,
Phone +1-505-2-935367, Fax -448040,
www.pajaritopowder.com

Sandvik High Precision Tube, ZN der SMT D GmbH, 33824 Werther, Germany, Phone +49-5203-91090, *info.hpt@sandvik.com,* H_2 Stainless Steel Tube Applications / Coil Container Service – On Site Tubing Solution

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

TESTING

JA-Gastechnology GmbH, Albrecht-Thaer-Ring 9, 30938 Burgwedel, Germany, Phone +49-(0)5139-9855-011, Fax -33, *www.ja-gastechnology.com*

Maximator GmbH, High Pressure Hydrogen Technology, Testing Equipment, Customer Testing Services, Lange Strasse 6, 99734 Nordhausen, Germany, Phone +49-(0)3631-9533-5107, *H2Team@maximator.de, www.maximator.de*

Resato International B.V., H_2-Pressure Testing, H_2 gas booster for refueling stations, high pressure technology, Duitslandlaan 1, 9400 AZ Assen, Netherlands, Phone +31-(0)501-6877, *h2sales@resato.com, www.resato.com*

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*

Zeltwanger, Leak and Functional Testing, Automated Lines for Laser Applications and Assembly Tasks, Maltschachstr. 32, 72144 Dußlingen, Germany, Phone +49-7071-3663-106, *a.nobel@zeltwanger.de, www.zeltwanger.de*

TEST STANDS

AVL List GmbH, Hans-List-Platz 1, 8020 Graz, Austria, Phone +43-316-787-0, Fax -400, *info@avl.com, www.avl.com*

DATES

November 5 to 7, 2019
Fuel Cell Seminar & Energy Exposition
in Long Beach Convention Center
in Long Beach, California, USA
www.fuelcellseminar.com

November 26 to 28, 2019
gat + wat
DVGW Congress in Cologne, Germany
www.gat-wat.de

2020
January 29 to 30, 2020
El-motion
9. Austrian Electric Mobility Congress in Vienna, Austria
www.elmotion.at

February 26 to 28, 2020
FC Expo
International Hydrogen & Fuel Cell Expo
Tokyo Big Sight, in Tokyo, Japan
www.fcexpo.jp

March 10 to 12, 2020
IRES
International Conference and Exhibition
for the Storage of Renewable Energies
in Düsseldorf, Germany
www.eurosolar.de

March 10 to 12, 2020
Energy Storage Europe
in Düsseldorf, Germany
www.eseexpo.com

March 17, 2020
Hydrogen and Fuel Cells
Powering the Future #CCSHFC2019
in Burmingham, UK
www.climate-change-solutions.co.uk

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Co-organised by: **Hydrogen Energy Systems Society of Japan (HESS)**
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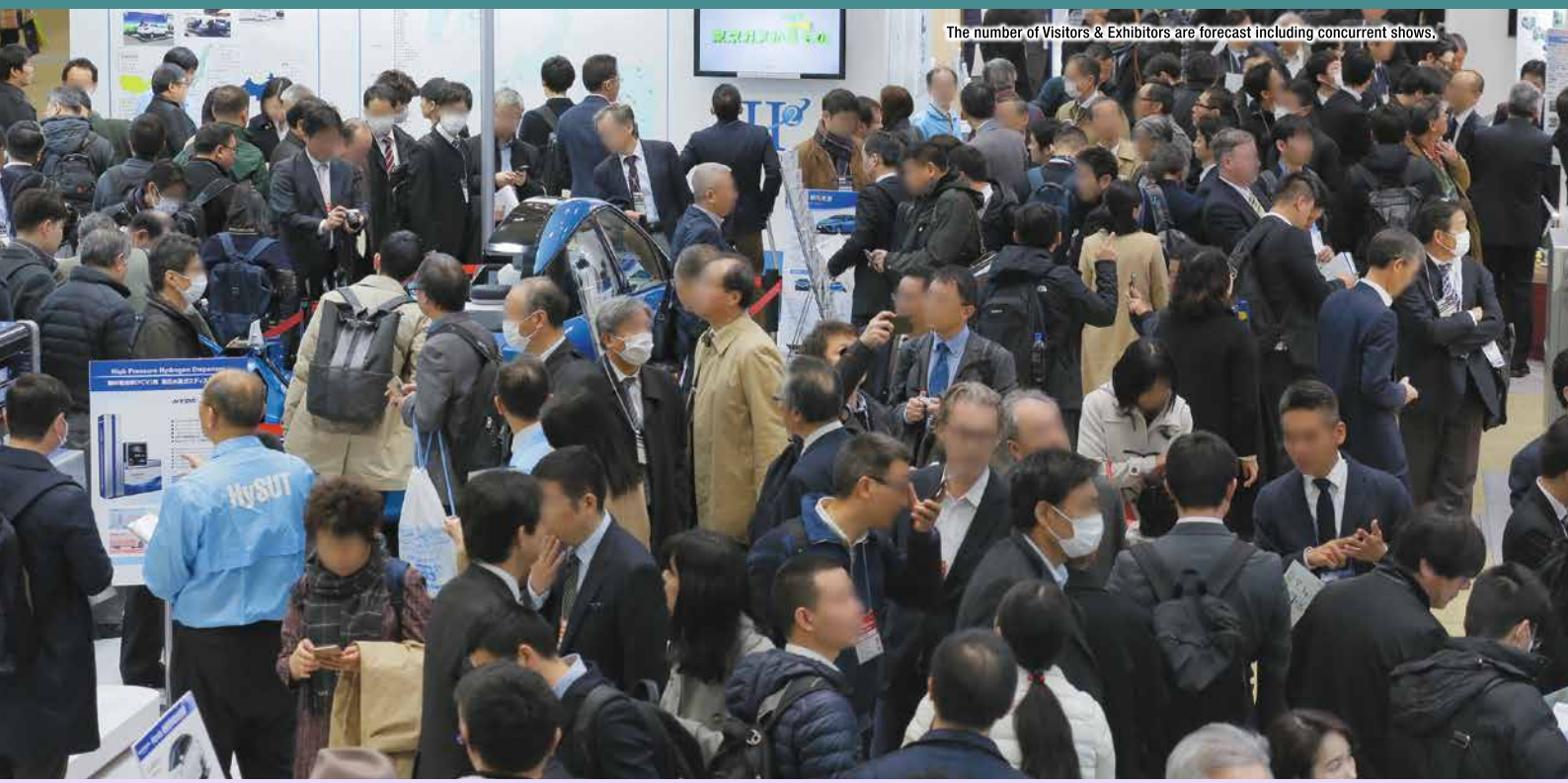

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