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H2 international

THE E-JOURNAL ON HYDROGEN AND FUEL CELLS

→ ENORMOUS INTEREST IN H_2 TRUCKS BUT SUPPLIES ARE SHORT

→ CAN CRYOGENIC HYDROGEN (LH_2) STILL GET A LOOK-IN?

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IT MAY BE A JARRING CHANGE

Dear Readers!

The discussion about rising energy prices is taking on ever greater dimensions. Now, German economic minister Robert Habeck wants to grant the German competition regulation agency (Bundeskartellamt) new rights. Swift to oppose such alleged unconstitutionality is not only Handelsverband Deutschland (the general association for commerce in Germany).

The heated nature of this debate indicates what this is really about: power. The inherited political-economic power structures are being shaken up as a result of Putin's unspeakable aggression against Ukraine. And the rising inflation rate is fundamentally challenging established economic wisdom.

The federal government is trying to bring calm to the situation, but representatives of industry and business can sense that more is currently changing than just the European Central Bank's key interest rate.

More and more players are just realizing that energy has been far too cheap up to now. In times of oil and gas abundance, there was no real incentive for many to use fossil fuels sparingly. After all, environmental damage and pollutant emissions have hardly been taken into consideration.

This is now changing ferociously: Europe wants to become independent from Russian energy imports. Concurrently, the transition to cleaner energy supply is to be advanced. This means that, at the same time, the transport sector will be electrified as far as possible and, in addition, industrial businesses will switch to renewable energies.

Against this background, it is clear that energy will never be as cheap as it used to be.

This also applies to hydrogen. H_2 fuel was previously sold in Germany at a fixed price. This per-kilogram price for H_2 was set for many years by the federal initiative Clean Energy Partnership – initially at 8 euros, then 9.50 euros. To H2-international's inquiry, Kurt-Christoff von Knobelsdorff, managing director of the national hydrogen and fuel cell organization (Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie GmbH, NOW), explained, additionally at the start-up of Hannover Messe, "It may well be that this politically set price will have to go up for the time being, because it is moves in the convoy with all the other fuel prices."

And so it came to pass: Only one day later, H2 Mobility raised, for the first time since the company's founding, the price of H_2 fuel. As of June 7th, a kilogram of hydrogen will cost a uniform 12.85 euros at all fueling stations maintained by this industry consortium. According to information by the company, the cost of driving an H_2 car per 100 km will nevertheless "continue to be lower than that for comparable trips with conventional fuels or with a battery-electric car using a publicly accessible fast-charging station."

For e-fuels, prices as high as 5 euros per liter were discussed at Hannover Messe. However, these would then only apply to those who wish to use e-fuels. No doubt the Porsche 911 drivers, for which Porsche is currently building a power-to-gas plant in Chile.

For pure, green hydrogen, Ulrich Vögtle, vice president of MAN Energy Solutions, prefers to calculate long-term with a production price of 1.50 USD for 1 kg by 2030. The hope is to be able to generate sufficient green electricity with a rapid expansion of solar and wind power plants, in order to be able to provide enough green hydrogen for all sectors so that prices fall.

The will for it is there – both in industry and in politics; numerous large corporations have announced investments of billions in hydrogen technology (Bosch, MAN, Schaeffler, Siemens – see p. 8 and 9). To provide investors with planning security, the framework conditions are currently being adjusted. This naturally leads to strong reactions (see above), because not everyone is well enough prepared for this much-talked of "turning point" in history.

It's "jarring," according to German economic minister Habeck – and it may be as well. In view of the current challenges, it's more than understandable that not everything is running smoothly. It would also be surprising if no one were to get upset in the face of impending famine because millions of tons of wheat had rotted nonsensically in warehouses.

So it is very understandable that energy prices are rising, because energy is an expensive commodity – that has finally become clear. What is not understandable, however, is partisan political games being played on this terrain. When global emergencies are exploited for image enhancement, it can only backfire – as it has with the recent Tankrabatt (a tax reduction whose benefits did not extend past the fuel suppliers).

Energy is valuable. Therefore, it should be used with care. Short-term gifts for commuters are out of place here. Moreover, in the end, the wrong people profit from it. More effective would be honest communication and societally appropriate financial relief.

It would make more sense to rapidly expand public transit, instead of inviting the overcrowding of regional trains, which has a deterrent effect rather than encourages a switch from car to train.

More advisable is to finally say goodbye to the Otto and diesel engine than to get upset that the EU Parliament has voted in favor of a ban on combustion cars from 2035 onwards.

Long enough has there been hesitation and hitting of the brakes. Now, in a time of transformation, in which quite a few changes are coming anyway, we can actively participate in shaping them. Can leave the old behind and try something new. The new will not work perfectly right away. That doesn't matter. It will straighten itself out. ||

Sincerely,

Sven Geitmann
Publisher of H2-international

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Source: PaulGroup

Source: Afrikaverein/Fabian Hammerl

HERDAN NOW DEVELOPING E-FUEL PROJECTS

Fig.: Thorsten Herdan [Source: HIF EMEA]

Thorsten Herdan has worked for the German economic ministry for 8 years. Now, he's moving to HIF Global. The mechanical engineer's foray into politics lasted until January 2022. Mid-May, the e-fuel development company appointed Herdan the managing director of HIF EMEA.

President of the newly created business unit is Armin Schnettler, who previously worked at ABB, Siemens and Siemens Energy and was a research director at technical university RWTH Aachen for more than 18 years. From the office in Berlin out, the two gentlemen are to represent the American company in, now, Europe, the Middle East and Africa. The company HIF Global, in which Porsche has secured a 11.5 percent share, already has wholly owned subsidiaries in Chile, Australia and the USA.

César Norton, president and CEO of HIF Global, explained: "HIF EMEA, under the leadership of Armin Schnettler and Thorsten Herdan, will focus on providing carbon-neutral, (green) electricity-based synthetic fuels, also known as e-fuels, for the EMEA region, to accelerate decarbonization and improve the security of energy supply." HIF stands for "Highly Innovative Fuels" based on hydrogen.

Thorsten Herdan said: "With HIF EMEA, we are preparing for the delivery of e-fuels to Europe in the course of 2022, after we have launched operations at the Haru Oni plant currently being built in Magallanes, Chile (see photo on p. 4). The expansion of e-fuels into European, Middle Eastern and African markets will supply renewable energy to millions of existing vehicles, ships and aircraft, without requiring infrastructure changes."

Herdan's successor in the energy policy department of the Germany ministry for economics and climate protection is Christian Maaß, until then managing director of research institute Hamburg Institut. ||

CALL ITZ DUISBURG "TRHY"

The center for fuel cell technology in Duisburg (Zentrum für BrennstoffzellenTechnik Duisburg, ZBT) used Hannover Messe as a platform to announce the name of the new ITZ center (Innovations- und Technologiezentrum für Wasserstoff, see H2-international Feb. 2022) planned for location in Nordrhein-Westfalen: TrHy. For the time being, Joachim Jungsbluth, head of fuel cell testing at the ZBT, stands ready in a three-member team as the contact point.

German transport minister (BMDV minister) Dr. Volker Wissing explained: "With this, we can now go on to the implementation. The BMDV is providing 290 million euros to be distributed among the four ITZ locations as start financing, and the federal states want to give the centers additional support."

Originally, 90 million euros was to go to Bayern alone. In the interest of fair treatment of all the locations, however, the Ampel Coalition (federal administration) decided that the other innovation centers should receive equally ample funding from the federal government. TrHy, with its nucleus in Duisburg, is receiving in addition to the 72.9 million euros, likely 50 million euros from the state of Nordrhein-Westfalen.

For the time being, however, everything is still subject to funding restrictions. After that, the official founding of TrHy, with satellite locations in Aachen, Essen, Jülich and Neuss, could maybe take place this autumn. The goal of the total of four ITZ centers is to create a development, research and testing environment particularly for start-ups, founders and small and medium-sized enterprises in the hydrogen industry. ||

Fig.: The name TrHy, according to ZBT managing director Peter Beckhaus, stands for the many aspects involved in dealing with hydrogen technology: Training, Transfer, Technical Research, Transparency

DEUTSCHE ZENTRUM MOBILITÄT CANCELED?

The future of the DZM, a national center for future mobility, is more than unknown. The homepage currently only states: "The Deutsche Zentrum Mobilität der Zukunft (DZM) will be restructured and expanded in accordance with the agenda of the new federal administration."

In the summer of 2021, there was a festive founding ceremony in Munich with many prominent figures from Bavarian state politics. At that time, amidst the campaigning efforts for seats in the German parliament, it is said that around 500 million euros was invested in this project by the federal government. DZM was to function as the umbrella organization for the four ITZ centers (see H2-international Oct. 2021).

Now, things are looking very different. The answer from the German transport ministry to H2-international's in-

Fig.: German transport minister Volker Wissing

quiry was: "The concept of the Deutsche Zentrum Mobilität der Zukunft (DZM) is currently being revised. For now, this process is taking place at the Bundesministerium für Digitales und Verkehr (BMDV, German transport ministry). Since no founding office is required for the period of concept revision, this has been temporarily replaced by a contact point."

The newspaper Handelsblatt had previously reported that the DZM founding committee has meanwhile ceased its work. It went on to say that the attempts by the previous federal transport minister, Andreas Scheuer, to shield the DZM from the grasp of future ministers by creating a type of "Treuhand-Stiftung" (fiduciary trust) did not help. His successor, Volker Wissing, has distanced himself from the DZM, because there has not been anything worthy of being called a concept so far. There's at most a vague sketch.

The BMDV notified H2-international, however: "Further remarks regarding the content and orientation of the DZM are therefore only possible after the revision phase. The budgetary appropriations have also been adjusted accordingly." That all tranches up to 2026 have already been cancelled, as, according to Handelsblatt, BMDV parliamentary secretary Daniela Kuckert is to have reported, has not been confirmed by the BMDV as of yet. ||

LOHSCHELLER MOVES TO NIKOLA

Former Opel CEO Michael Lohscheller has changed companies and moved to Nikola. At the end of February 2022, the US commercial vehicle manufacturer announced that Lohscheller had been appointed president of the company. So after just four months as managing director of Vietnamese automaker VinFast, he resigned from this office. Prior to that, he had spent four years running Opel Automobile GmbH.

Fig.: Michael Lohscheller [Source: VinFast]

CEO Mark Russell explained: "Michael Lohscheller brings several decades of direct automotive industry expertise to our already successful leadership team at Nikola. Its role will be immediately critical as the Nikola Tre BEV enters production and we continue to achieve development milestones for the Nikola Tre FCEV."

Lohscheller said, also in English: "It goes without saying that hydrogen fuel cell and battery-electric zero-emission vehicles are the future of mobility, and I am extremely proud to be joining a company that is paving the way for this global transformation." ||

HANS SANDLASS HAS DIED

On April 15th, 2022, a longtime champion for green hydrogen left us. Dr. Hans Sandlaß had been campaigning for the use of regenerative energies since 1983 in the former East Germany. In 1990, he founded the energy engineering firm IEE Ingenieurbüro Energieeinsparung GmbH and was committed to the use of hydrogen at an early stage. Until the end, he fervently participated in the social and political discussion. Dr. Hans Sandlaß died in Berlin at 90 years of age. ||

MOVING SUMMIT IN ROTTERDAM

There was an endless lineup of who's whos in the global hydrogen industry at the World Hydrogen Summit that took place May 9th through 11th, 2022. And 6,000 participants via live stream and on location speaks for itself. It is clear to all participants that the existing plans to build a global hydrogen economy require enormous investments and that a number of the already existing plans need to be massively expanded. Thinking "big" is required, and it seems the world is doing that.

Example: The EU recently increased its plans for the ramp-up of electrolyzer capacity from 1.7 GW per year to 17.5 GW per year in 2025. It's about decarbonizing entire industries, it's about energy security, it's about climate change and replacing fossil fuels. And, of course, it is also about reducing dependencies. It is unclear how the oil price will develop in all this, since demand for black gold is unlikely to fall, when the basic demand is set to rise medium-term.

All this plays into the hands of green hydrogen production. So far, however, green hydrogen accounts for only one to two percent of global hydrogen production – a long way from the 500 million tonnes of it that are to be annually produced 30 years from now. Green ammonia is now well below gray hydrogen in terms of price. The transport costs for this come out as manageable in view of the large quantities involved. And there are new technological solutions to produce ammonia more cost-effectively.

Rotterdam was also about increasing planning security on the part of policymakers. Because the industry wants to invest, but needs clear guidelines and also incentives. It is, however, apparent that politicians will accompany these future markets in a more open and constructive manner. Also with regard to the advancing shortage of skilled workers.

Particular attention was paid to the initiative H2Global, whose aim is to bring green hydrogen from all over the world (outside the EU) to Germany at a subsidized price. New technologies will come into use that massively raise the efficiency of hydrogen production. There will be many collaborations. Electrolyzers will become more powerful and, at the same time, cheaper in price. Even if, due to unfavorable prevailing conditions, the hydrogen is not produced in Europe, but imported instead. ||

HAMBURG GAINS H_2 DEMO CENTER

All across Germany, more and more sites that focus on hydrogen are popping up. In addition to real-world labs (see p. 16), HyLand Regions (p. 18) and ITZ satellites (p. 6), there are so-called centers where hydrogen research and development is being driven forward. An additional contact point is now to be created in Hamburg: a demonstration center for sector-coupling and hydrogen technologies. At the new demo center, the expertise of the Competence Center für Erneuerbare Energien und EnergieEffizienz (CC4E), which is the renewables research center at applied science university HAW Hamburg, is to be joined with that of Fraunhofer IWES (Fraunhofer-Institut für Windenergiesysteme).

The aim is, together with other partners from industry and science, to research the development and implementation of hydrogen technologies, in order to ensure a climate-neutral and independent energy supply within each of the individual sectors. For this, 5.9 million euros from the European Regional Development Fund (ERDF) as well as resources from the state of Hamburg will be provided.

Professor Werner Beba, director of CC4E, explained: "The global competition for climate protection technologies has already begun. With the goal of energy technology autonomy, German companies are to become leaders in modern hydrogen technologies... Through its research and development projects, the demonstration center aims to accelerate the clean energy transition and at the same time function as a stimulus program that promotes sustainable innovations in the economy on the way to effective climate protection." ||

SIEMENS ENERGY IS BUILDING IN BERLIN

Fig.: Thomas Bagus (left) will manage the industrial production in Berlin [Source: Siemens Energy|

The German capital is also becoming increasingly important for hydrogen activities as an industrial location. Siemens Energy announced at the end of March 2022 that the manufacture of electrolyzers will be occurring at its location on the Huttenstraße in Berlin-Moabit. Starting 2023, electrolysis capacities on a gigawatt scale are to be produced there. Siemens Energy is making use of existing infrastructure for this purpose. In an already existing 2,000-square-meter hall (22,000 sq ft), new production lines for PEM electrolyzer cells are to be built, for around 30 million euros. The individual cells will then be combined into stacks on site, before they are assembled at the Mülheim location, in the final production step, into finished units. Christian Bruch, chair of Siemens Energy, explained, "With our new production facility, we are helping to make hydrogen economically competitive more quickly." ||

CHANGAN STARTS MASS PRODUCTION

Changan Automobile announced in early June 2022 that it was building the infrastructure for mass production of the SL03. Under the auto brand Deep Blue, the SL03 is to be immediately obtainable in China for, translated, 30,000 USD. The e-car is based on the electric drive platform EPA1 and is offered in three variations: purely electric, with range extender and with fuel cell. With hydrogen, a range of 700 km (400 mi) should be possible. However, it is not yet clear when exactly the H_2 model will be available and how many of the units will be produced. Technology partners for the SL03 are CATL and Huawei. ||

REUTHER STC INSOLVENT AGAIN

The steel construction company Reuther STC GmbH from Fürstenwalde, Brandenburg is bankrupt once more. On June 1, 2022, insolvency proceedings were opened – for the second time. As the state broadcaster, Rundfunk Berlin-Brandenburg (RBB), reported, Reuther had already been "as good as bankrupt before the pandemic," since, in 2019, a 7-million-euro order from Senvion for over 15 towers for wind turbines had been dissolved because of its insolvency. "We then went to court and filed for bankruptcy," recalled sales manager Christian Klingelstein. With support from the region, the company was able to save itself by using its know-how additionally for the construction of hydrogen containers from now on. So 165 of the previously imperiled jobs were saved.

What broke the company came as a result of the war in Ukraine. The 150-year-old traditional company in East Brandenburg used to purchase steel from the works in Asow, Russia. This steel is now missing. They had been looking for a buyer for the company but had not found one, it was said, and that's why 160 employees and managers received their terminations of contract in the beginning of June. ||

Category: Trade fairs | **Author:** Sven Geitmann

H2FC EUROPE MAKES FURIOUS COMEBACK

Looking grim for Deutsche Messe

There it was again – Hannover Messe. Although significantly smaller than before the corona pandemic, there was great relief on both the presenter and visitor side that the industry show from May 30 to June 2, 2022 could take place in person. The Hydrogen + Fuel Cells Europe event was very lively and busy at times – especially on the Tuesday and Wednesday. A sure sign that hydrogen will play a truly important role in industry as well as energy supply in the future. Otherwise, the view of Hannover Fairgrounds was rather dismal.

Fig. 1: German economic minister Robert Habeck conversing with Ove Petersen, managing director of GP Joule

It already started on Sunday. During the opening ceremony for Hannover Messe, every speaker, including German Chancellor Olaf Scholz, uttered the word "Wasserstoff" (hydrogen). Therefore, a sure sign – from politics as well as industry – that at this time there is no getting around the topic. Predictably, federal economic minister Robert Habeck visited the stand of GP Joule, of his old friends from Schleswig-Holstein, for a long while (see Fig. 1).

Impressive to see was how large the area inside hall 13 was, which had been laid with an orange carpet – a signature of Hydrogen + Fuel Cells Europe. This H_2 and FC fair within Hannover Messe was, with a gross area of 10,000 m² (108,000 ft²), nearly twice as large as before the pandemic, when it had usually stretched 5,000 to 6,000 m² (54,000 ft²). Accordingly good was the mood there – both of the exhibiting businesses and of the guests. The fact that only eleven halls were occupied on the exhibition grounds this year, and that not all of them were really full, took a back seat. For the operators of Hannover Messe, that is Deutsche Messe AG, however, the question arises of how to proceed next year.

Tobias Renz, who, like before, had professionally prepared the hydrogen fair with his small but efficient team, seemed accordingly satisfied. He had attracted 220 exhibitors to the fairgrounds of Hannover Messe, who all exhibited enthusiasm.

RAMP-UP OF PRODUCTION Right at the start with the press conference to kick off the fair, it was clear how much is to be invested in the following days to build up the production capacity of H_2 stations. Ulrich Vögtle, vice president of MAN Energy Solutions, confirmed that his company will provide 0.5 billion euros for the manufacture of electrolysis stacks at its 99% subsidiary H-Tec Systems. He said: "Now is the time to invest in order to move from manufacturing to large-scale industrial production... Our goal is to produce around 1,000 MW by 2025 and then be able to achieve a turnover of a billion euros with the electrolyzers around 2030."

Comparable statements were also made by other major industry representatives. Bosch had already announced at the beginning of May 2022 that it would also invest 0.5 billion euros for electrolyzer components by the end of the decade. Dr. Stefan Hartung, chairman of the board at Robert Bosch GmbH, explained, "We want to support the rapid development of hydrogen production in Europe with Bosch technology." In this, the focus is on the development of electrolyzer stacks that Bosch wants to equip with a control unit, power electronics and sensors to form so-called smart modules.

Schaeffler, who likewise exhibited in hall 13, is another major German automotive supplier that is making its mark in the hydrogen industry. Almost an affirmation, the Nürnberg-based technology company announced shortly after the fair that it wanted to found a globally active 50:50 joint venture with Symbio, a cooperative venture of Faurecia and Michelin, for the production of metallic bipolar plates. The new company is to be named Innoplate and situated in Haguenau, France, where it is to produce 4 million bipolar plates per year starting 2024 and around 50 million starting 2030. The first customer will be Symbio, which has received a contract for a project by a leading global car manufacturer.

Despite all these investments, it may still take years before significant H_2 volumes can be generated with the help of renewable energies, because, first, solar and wind power has to be expanded and, then, electrolyzer capacity has to be built up. In answer to H2-international's inquiry, Ulrich Vögtle of MAN Energy Solutions said, "We assume that around 2030 will be the time when you can expect significant quan-

"Nothing's going on this time. This used to be a really big industrial fair."

Parking attendant at Hannover Fairgrounds

tities of green hydrogen or renewable fuels." According to the state of Niedersachen's environmental minister Olaf Lies, however, this is too late. He told H2-international that there would be "significant quantities of carbon-neutral hydrogen 2025."

FERVENT PARTICIPATION BY COMPRESSOR MANUFACTURERS It was interesting to observe that numerous compressor manufacturers now offer complete fueling stations. Whether at the stands of Hexagon, Maximator, Neuman Esser or PDC, complete solutions were offered everywhere. Hexagon, who now wants to invest over 20 million euros in the Wystrach location, additionally intends to expand the business field in the direction of cryogenic storage technology, as Wystrach's managing director Wolfgang Wolter confirmed to H2-international. For this, on April 21st, 2022, the Norwegian company acquired 40 percent in Cryoshelter GmbH, an Austrian manufacturer of LH_2 tanks.

Maximator Hydrogen GmbH used the industrial show to introduce, together with Bosch Rexroth and Maximator Advanced Technologies, a new device development: the MAX Compression 2.0. This two-stage reciprocating compressor is equipped with automatic seal exchange technology. This is a further development of the "revolver solution" that Maximator had previously presented in 2018 (see H2-international July 2018).

Fig. 2: Presenting of MAX Compression 2.0 by Guido Hettwer, industrial hydraulics manager at Bosch Rexroth AG

Fig. 3: Integrated mobile autonomous hydrogen fueling station of BTE Inc.

Because of the considerable stresses as a result of the high pressures and temperatures, H_2 fueling stations that use such dry-running (oil-free) compressors must have the piston seals changed out at regular intervals. So that a technician does not need to drive out each time and disrupt operation during maintenance, Maximator and Bosch Rexroth designed an automatic seal exchange system (ASX).

René Himmelstein explained to H2-international, "Compared to its predecessor, the MAX Compression 2.0 achieves up to five times higher throughput while taking up the same amount of space." Himmelstein has been with Maximator since 2002, and has been head of business development at Maximator Hydrogen, the subsidiary he co-founded, since January 2022. "Our goal is to build 400 fueling stations for hydrogen by 2025," he said. Planned is to equip 4,000 fueling stations around the world with the technology of the Nordhausen-based company by 2030. Matthias Kurras, managing director of Maximator Hydrogen GmbH, added that the public transit company Wiener Linien is to be one of their first pilot customers. Starting 2030, city buses in the Austrian metropolis of Vienna are to run exclusively on green hydrogen.

NUMEROUS NEW DISCOVERIES It was striking that a very large number of companies that have barely been noticed up to now exhibited at Hydrogen + Fuel Cells Europe for the first time. For example, EVS Hydrogen presented in Hannover something completely new. Its H_2 combustion engine is based on the Wankel principle, because the thermodynamics of a rotary engine are better suited for hydrogen than a reciprocating piston engine, according to the Niederbayern-based company. This Wankel engine is particularly suitable "as a diesel alternative" for CHP applications as well as for construction vehicles.

A discovery outside the orange area was the mobile refueling unit of BTE Inc. The hydrogen refueler is an automated all-in-one solution and has its own cooling unit, a compressor, an intuitive user interface, various sensors and a nozzle. According to information from the manufacturer, "the device can also be used without knowledge of the water pressure and pneumatic pressure." It could be used as a charging device for various fuel cell applications, such as H_2-powered drones, forklifts and bicycles.

That such flexible tank solutions are gaining more and more importance was also evident by another supplier competing in this market segment. Namely, Maximator, with a double-axle H_2 trailer.

Having similar dimensions to the BTE unit is the system of EODev (Energy Observer Developments), although the GEH_2 is a power generator (see Fig. 4), not a fueling station. EODev was founded in March 2019 in the wake of the project in which the renewables-run vessel Energy Observer sailed around the world (see H2-international Nov. 2017 and July 2019). The technology installed and tested out on this solar-H_2 catamaran is now being brought by EODev to market. In this way, this fuel cell unit will be put into application in the module of technology partner Toyota.

The 88-kW power generator was presented for the first time in 2021. In addition to the PEM FC system, it has a lithium iron phosphate battery with a capacity of 44 kWh. So far, 30 units have already been launched onto the market. In the future, there is to be 20 per month.

H2ECO AWARD GOES TO FAUN One highlight was the giving out of the newly created H2Eco Award. The German hydrogen and fuel cell association (Deutsche Wasserstoff- und Brennstoffzellen-Verband, DWV) and Deutsche Messe AG had put this contest together for the H_2 sector – somewhat of a counterpart to the highly backed Hermes Award that's been granted at every Hannover Messe since 2004. The chosen winner was the Bluepower project of the Faun Group (see p. 30). ||

Fig. 5: (Left to right) Werner Diwald, DWV, with the nominees Clean Logistics SE, Infotec GmbH/Faun Gruppe and eFarming GmbH, as well as Arno Reich, Deutsche Messe

Fig. 4: In addition to this stationary FC system, there is Hynova for maritime applications

Category: Building energy | **Author:** Sven Geitmann

BECOMING AN H_2 DISTRICT PAYS OFF

Concrete plans to build an example

Fig. 1: The analyzed residence spaces of the housing co-op
[Source: Bauverein, Tim-Online]

So far, H_2 has comprised only a tiny slice of the German gas grid. And the suitability of increasing this share to up to 30 percent is currently only being tested within the framework of individual, time-limited demonstration projects. H_2 "micronets," that is city districts or regions running 100 percent on hydrogen, are yet to exist. But Lennart Lohaus has recently demonstrated that H_2-based solutions can already be economically attractive today. As part of his master thesis, he developed an optimization model for designing regenerative supply solutions with hydrogen as energy carrier for the coal district Rheinisches Revier.

As Lennart Lohaus has found out, a climate-neutral energy supply is already feasible today through an optimal interplay between regenerative energy carriers, energy converters and storage systems. His market research yielded the result that there are already numerous products suitable for stationary hydrogen applications available.

First, photovoltaic systems and heat pumps as well as energy storage systems are in principle required. While batteries are suitable for short-term storage, large amounts of energy can be stored over long periods in the form of hydrogen.

To the frequent argument that the use of electrolyzers and fuel cells is inefficient, he had an answer. However, it relies on the waste heat generated by the hydrogen components, which is sufficiently high in temperature for the building sector and other sectors, being used.

CENTRALIZED ENERGY SUPPLY OF THE DISTRICT Lohaus first studied electrical engineering for his bachelor degree, then got a master degree in energy management at Hochschule Osnabrück. In an interview with H2-international, he made clear how important being energy-efficient and sustainable are to him. For this reason, he also went through further training to become an energy consultant and explicitly chose "Design of regenerative supply solutions with hydrogen as energy carrier" (original "Auslegung von regenerativen Versorgungslösungen mit dem Energieträger Wasserstoff") as the topic of his master thesis.

Lohaus' project was a thorough analysis and detailed recommendations for real-world implementation by the local housing cooperative, and it involved the preparation of a comparison of alternatives with subsequent sensitivity analysis. It looked at 38 existing units in the co-op, which were to be expanded by 34 units, thus offering space for 180 residents. In the future, this residential district could be supplied by a technical control center (see Fig. 2).

The engineer's market research showed that commercially available electrolyzers and fuel cells can each guarantee an overall efficiency of 80 percent. The H_2 could optionally be stored as gas, liquid or metal hydride in the respective container, which could

Fig. 2: Technical control center with energy convertors and storage units
[Source: L. Lohaus]

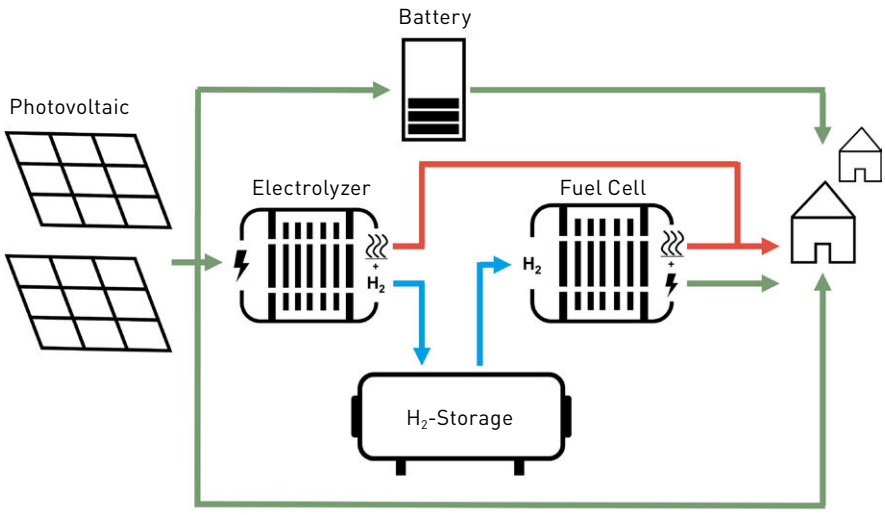


Fig. 3: Technical control center with energy converters and storage units [Source: L. Lohaus]

be set up so that the entire area is supplied with electricity and heat relatively efficiently. Depending on system variant, Lohaus calculated that the investment cost amounts to 7.5 to a little under 11 million euros.

Lennart Lohaus summarized: "Even if the investment costs of the whole systems are currently higher compared to fossil energy systems, solutions exist that make implementation of a climate-neutral energy supply convincing from an economic point of view. Also, it is important that policy-makers create appropriate support measures and framework conditions for this purpose. The introduction of a subsidy for offsetting fossil fuels, for example, would be a good way to do this."

He further explained: "For projects being implemented today, an average service life of 15 to 25 years can be expected for the installed technology. In the future, fossil fuels will become scarcer and the subsequent technology conversion to 100 percent renewable energies will be very cost-intensive. Therefore, it is advisable to set up a regenerative energy supply today."

Even after his studies, the dedicated engineer wants to continue working on this idea. Together with numerous supporters, he is already planning further projects to inform about the wide array of possibilities with hydrogen technology, to excite more people about it and to realize mapped out projects. ||

Literature:

Lohaus, Lennart; Auslegung von regenerativen Versorgungslösungen mit dem Energieträger Wasserstoff, HS Osnabrück, 2021

Category: Associations | **Interview Partner:** Thorsten Kasten, Tilman Wilhelm

SIGNIFICANT QUANTITIES OF HYDROGEN FROM ABROAD

Interview with Thorsten Kasten (DWV) and Tilman Wilhelm (DVGW)

Membership of the German hydrogen and fuel cell association DWV is going up and up. Not only that, the difficult energy policy situation at the moment means the association is gaining in importance too. For several years the DWV has been evolving into a central industry association alongside the German gas and water industries association DVGW. In order to further improve cooperation between the two organizations, in spring 2021 the DWV executive committee selected Thorsten Kasten, at the DVGW's suggestion, to become its second chairman (see H2-international, August 2021). H2-international spoke to Kasten during the Hannover Messe about his first year at the DWV and to Tilman Wilhelm, who from April this year has headed up the regulatory policy, press and public relations work of the DVGW, about the challenges in the energy space.

Fig. 1: Thorsten Kasten [Source: DWV]

H2-international: Mr. Kasten, you have been co-chairing the DWV with Werner Diwald since April 22, 2021. How did you find your early days in the role?

Kasten: The three years before I joined the DWV were all about developing new business areas at VNG AG, including neighborhood solutions, as well as about collaborating with startups – in other words the innovation space – with a view to transforming the energy sector. Under my leadership we were able to notch up a number of successes, among them partnerships with startups which have focused on pyrolysis as a means of hydrogen production. After spending many years working in energy supply companies, the responsibilities at an association such as the DWV are, as you would expect, much more general and varied in nature. Being in charge of infrastructure and education areas as well as the association's general organization and development means I can actively bring many things from my previous positions as well as my expertise in energy sector transformation.

H2-international: What exactly is the goal of the cooperation agreement between the DVGW and the DWV?

Wilhelm: Both associations presume that, as the energy supply system evolves, we will need gas molecules in similar proportions to what we do today – it's just that increasingly they will be green and renewable. The DVGW represents a major part of the value chain in terms of today's natural gas grid and the future hydrogen grid. This part has now started converting to hydrogen – for instance, the upstream and downstream areas of production and application. The DWV and the DVGW pursue the same goals and represent the same positions which is why we are working together.

H2-international: How are responsibilities divided between the associations?

Wilhelm: The DVGW has a very strong scientific and technical foundation, not least with regard to the scientific institutions that make up the DVGW group. This also naturally provides the basis for engagement with the political establishment. What's more, the DVGW creates technical standards which means it's very close to what is happening down on the ground, making it a good intermediary between the political sphere and industry.

Kasten: The DWV's primary focus is on policy work. Here, our main emphasis is on areas and commercial fields that want to ramp up hydrogen in Germany and Europe so as to safeguard future energy supplies.

H2-international: As a natural gas trade association, the DVGW has traditionally represented the fossil fuel industry. What does the DVGW stand for now?

Wilhelm: The role of the DVGW has been clear for over 160 years: Within the energy sector, it stands for the grid-bound supply of gas molecules and it sets technical standards for the grid, which in Germany comprises over half a million kilometers of pipework and supplies energy for heating, industrial processes and so forth to 19 million homes and 1.8 million commercial and industrial companies. 96 percent of this network is already suitable for handling the supply of pure gaseous hydrogen. And it's precisely here, in this conversion of networks to the new energy carrier – hydrogen, where the DVGW sees one of its main roles right now and in the years ahead.

Fig. 2: Tilman Wilhelm [Source: DVGW]

H2-international: Where's the proof that the DVGW isn't just interested in preserving the value of natural gas assets and is actually encouraging a move toward green hydrogen?

Wilhelm: Firstly, the pipelines are the assets, not what they carry. Of course, pipelines retain their value by being used to convey an energy carrier. The fact that this energy carrier will be hydrogen in future is absolutely clear to everyone. It's also clear that we are talking about green hydrogen as the ultimate goal. I'll give you two specific examples of how the DVGW is already helping to shape this energy vision: In order to start repurposing the current natural gas grids, the DVGW is leading

the H2vorOrt initiative as part of which regional gas distribution network operators, representing around 55 percent of the German gas distribution network, are currently working together to draft a data-based transformation plan which will then be put into practice. Plus, in 2020 the DVGW set up a hydrogen innovation program using 15 million euros of association funds. An example project is the collaboration with Avacon, a grid operator from E.ON, in which 20 percent hydrogen is being injected into a section of the grid and which is backed by funds from the DVGW innovation program.

H2-international: What's your opinion when it comes to blue hydrogen? Should there be investment in this technology, something which would then inevitably result in lock-in effects?

Kasten: At the DWV we have a clear position regarding the hydrogen color spectrum: Green hydrogen will play a major part in a secure and defossilized future energy industry. Hydrogen will ideally be produced from renewable energy sources and the expansion of these renewable sources still needs to be substantiated and prioritized. Nevertheless, in order to meet the urgent need for hydrogen in the ramping-up phase as things shift to a green hydrogen market economy, carbon-neutral hydrogen from other sources can also be a temporary option. This approach crops up time and again in current European solutions which we are seeing in the new RePowerEU proposal from the EU Commission.

H2-international: Now let's turn to policy: Back in the spring, the German economy minister Robert Habeck unveiled his Easter Package [of energy policy amendments]. What's your take on it? What's good, what's bad?

Kasten: The government's Easter Package already sets out that things will be made easier for the expansion of renewable energy production. That's a good thing and it makes us feel positive about the Summer Package that's been signaled. That said, there are still a lot of question marks that remain within industry, particularly in relation to investment security. Greater work needs to be done in this area. We need to act now and not let any more time go by. The aim should be to pass specific measures before the year is out so that industry can make well-informed and targeted investments, and for this to happen we need a reliable policy framework.

H2-international: You've already mentioned the Summer Package. What are your hopes there?

Kasten: The trio of energy policy objectives – economic efficiency, environmental sustainability and security of supply – was thrown out of balance when Russia started waging war against Ukraine, if not before. The government must seize the opportunity to use its Summer Package to put in place effective incentives by creating a technology-neutral regulatory framework for ramping up hydrogen and expanding infrastructure – incentives that will make for a secure, affordable and sustainable energy supply in a new set of circumstances. Ideological debates, such as the one sparked recently by state secretary Patrick Graichen, do not help the cause any further. In order to ensure the security and affordability of our energy supply in the future, all the options for producing, acquiring, storing and distributing hydrogen need to be explored in full. Hydrogen derived from natural gas and the existing infrastructure must definitely be involved too.

H2-international: Could you please be a little more specific: What exactly are the most pressing areas or challenges that you believe now need to be tackled as a matter of urgency?

Kasten: The key message is: We need clear regulations or rather a binding level playing field for the creation and design of the necessary infrastructure. And for this we urgently need to ensure that no sectors or industries are excluded or disadvantaged from the outset when it comes to using hydrogen. All players need to be pulling together from the get-go. Ultimately, as numerous studies have proven, we will have enough hydrogen to reach the majority of end consumers – consumers which have traditionally been supplied with molecules.

H2-international: What are the specific projects that you would like to tackle? What have you perhaps managed to get underway during your first year?

Kasten: Infrastructure is one of the key issues that needs to be clarified if hydrogen is actually going to be ramped up at all. Without a network, hydrogen will be a fine wine that goes to waste. The fact is that hydrogen will be available in sufficient quantities in the future. We now need to act as the key pacemaker in the political arena. The energy transition and the ability to meet climate targets shouldn't be allowed to fail because Germany and Europe haven't continued to involve their existing asset, by which I mean the gas grid of the distribution network operators and transmission system operators, in the shift to different energy carriers. Carbon-neutral molecules can have a big role to play in climate change mitigation through the reuse and repurposing of existing infrastructure. A dedicated technical commission on the transformation of gas infrastructure with various parameters from the relevant sectors is being set up – involving hydrogen producers, network and storage operators right through to consumers of carbon-neutral molecules.

H2-international: What are your plans for further projects – possibly with the DVGW and DWV working in partnership?

Kasten: Industry needs to become very clearly carbon neutral in its process and value chain. That is the intended goal and there shouldn't be a move away from that. Different pieces of the puzzle are needed to get there, such as carbon capture, in order to make hydrogen production and, especially, supply pathways carbon neutral. So as to gain a coherent overall picture, the DWV and the DVGW will start a suitable initiative and will work together to ensure that this initiative leads the way by acting as a bridge between industry and the political establishment. The aim is, first and foremost, to make sure that midsize companies are also brought on board.

H2-international: Final question: When do you think significant quantities of green hydrogen will become part of the energy supply?

Kasten: The first significant quantities will likely come to us from outside Europe. The first deliveries will arrive in 2024. Domestic production in Germany and in European countries such as Bulgaria, Romania, Greece but also Portugal and Spain currently depends on how the framework being worked out in Brussels will look. At present, we are in proactive dialogue with EU institutions and ministers in Germany and are optimistic that we will have the key framework conditions in place before the coming winter. The networks are there, and analyses of the potential have shown that renewable energy and therefore electrolytic hydrogen can be produced in the countries mentioned. Now it's a matter of moving the molecules produced to central Europe. Something that we'll also achieve together.

H2-international: Gentlemen, many thanks for talking to me.

Category: Funding | **Author:** Sven Geitmann

FIVE OUT OF 10 HYDROGEN LIVING LABS UNDERWAY

Many industry players favor IPCEI due to better opex funding

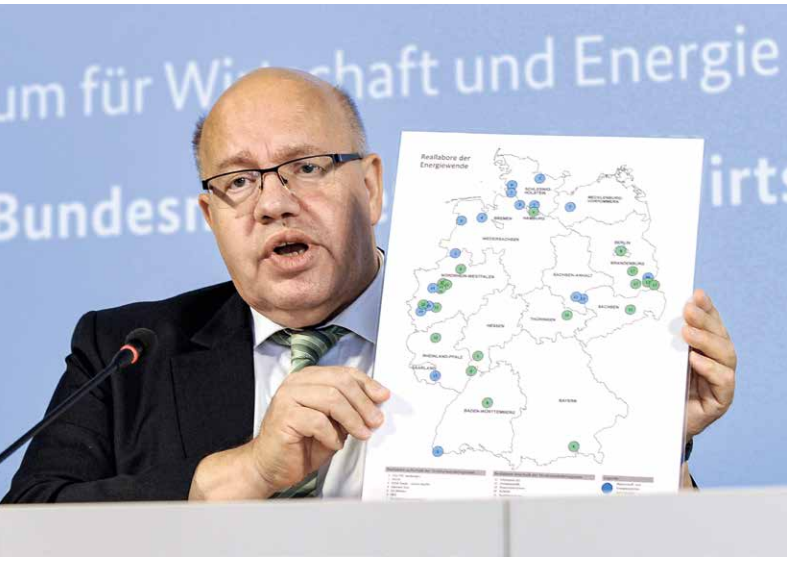


Fig. 1: Former German economy minister Peter Altmaier at the living labs presentation in 2019 [Source: BMWi]

Here's a sobering statistic: Out of a total of 10 hydrogen living labs, only five have actually been rolled out. Peter Altmaier, economy minister in the previous German government, had enthused grandiosely about the practical relevance of the projects he was supporting and went to great lengths to rebut any criticism of them. Even during the selection process, a fair number of voices could be heard complaining that the time for demos had passed. And yet Altmaier used the full force of his authority and sailed on. Today the reality is that the majority of these field trials have yet to swing into action, hampered by excessive bureaucracy and onerous conditions.

A sum total of 20 projects were chosen as part of an ideas contest by the ministry which was, before the latest government shake-up, officially known as the Federal Ministry for Economic Affairs and Energy. The aim of the 7th Energy Research Programme was to initiate projects in various regions of Germany. These, it was hoped, would act as incubators that would give fresh impetus to the energy transition and help the government reach its climate targets.

In summer 2019, the economy and energy ministry proudly announced that a grand total of 90 proposals has been submitted involving over 500 participants from the industrial and research sectors. This was narrowed down to the 20 best schemes, half of which were focused on hydrogen while the other half concentrated on energy optimization. Each federal state (with the exception of Bremen) was awarded at least one project. These proposals were due to receive grant funding of up to EUR 100 million in the runup to 2022 (see H2-international, July 2019).

As it happens, things turned out rather differently, with most Living Labs for the Energy Transition still not out of the starting blocks. In 2021, half of the schemes entered the project phase which will last until 2025. Only Westküste100 managed to get going in 2020.

CONSIDERABLE BUREAUCRACY Way back at the bidding phase, concerns were raised as to whether it was still prudent to stump up subsidies for further demos and research projects or whether it would be better to provide more support for market entry. Reservations were also openly expressed straight after the winners' presentation about whether all the schemes could actually be carried out in the way they had been intended.

For a long period there was a lot of fuzziness surrounding what exactly was eligible for funding. Not only that, it was clear from early on that the funding regulations would be stringent. This is something that many industry players have since confirmed to H2-international. "The demands are considerable," "it's a rough ride" – are among the comments from various corners.

One key issue is that living labs are not entitled to receive funding for their operating expenses, an aspect that has been criticized time and again on numerous sides. The drawback

REFLAU

The RefLau model power plant that is due to be built in Schwarze Pumpe industrial park in Lusatia, as detailed in the May edition of H2-international, is based on the original project outline that was submitted and subsequently selected as part of the Living Labs for the Energy Transition ideas contest. However, since it is still at the approvals stage, it's not classed among the five living labs that are already underway. LEAG, a regional energy company, withdrew from the project because it is only possible to obtain full financing of research activities if a project involves only university facilities.

GREENHYDROCHEM

The GreenHydroChem proposal is not going ahead as previously planned but instead several ideas have been carried over and are now being pursued in other projects. For example, individual elements have found their way into subsidized schemes such as the Hydrogen Lab in Leuna as well as into leading hydrogen projects H2Wind and H2Mare, the latter also forming part of the NRL living lab in northern Germany.

HYDROHUB FENNE

The HydroHub Fenne proposal is another project that was chosen in the ideas contest, but has so far failed to get started. A spokesperson for the consortium stated that an attempt is currently being made to include the project in an IPCEI program as the regulatory conditions for the living lab are not yet such that a financial commitment of the necessary magnitude has been forthcoming on the part of its industry partners. The original intention had been: "If everything happens in the way we imagine it, the HydroHub will be finished in the second quarter of 2023." The project is now expected to be commissioned in early 2026.

is that funding for a proportion of the capital expenses often does not provide an adequate basis on which to create a business model. It's for this very reason that some companies have decided to take a different approach.

Many bidders are now increasingly looking to apply for support under the Important Project of European Interest or IPCEI strategy, since this European Union funding program also gives grants to cover opex. Some organizations have applied to other subsidy schemes. Nevertheless, not enough living labs are reconsidering their approach to finance. That's not to say that the ideas on which the original project outlines were based have fallen by the wayside.

A number of projects are now getting off the ground albeit in a different environment. However, this does also mean that it is impossible to access the full state funding that was originally promised to the living labs. Consequently, if you added up all the state funding that was previously allocated you would get the false impression that far more taxpayers' money is being spent than is actually the case. As it stands, a total of EUR 200 million is being channeled into the current five living labs over the program's lifetime until 2025.

Even so, the necessary finance could be increased further as the "lid of the living lab has been lifted" according to Trans4ReaL (see below). This means that "many more project outlines are eligible for submission as part of the 7th Energy Research Programme." The homepage of the new German economy and climate ministry, known as the BMWK, states: "On July 1, 2021, the BMWK published a new subsidy concept for the Living Labs for the Energy Transition. The concept has no thematic restrictions and can therefore include living labs that focus on all areas of research considered under the BMWK subsidy scheme within the energy research program."

TRANS4REAL – SCIENTIFIC SUPPORT Since April 2021, the Trans4ReaL transfer research project has been providing scientific support to the living labs with the aim that findings from the labs can be used to supply policy ideas for integration into the German government's hydrogen roadmap. The hunt for a suitable project to aid this knowledge transfer was itself the subject of an ideas contest that was launched by project management agency Jülich in April 2020. In all, 11 consortia applied and the award went in favor of Munich-based Trans4Real.

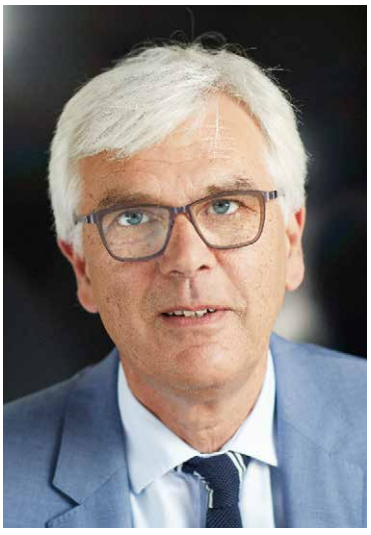


Fig. 2: Ulrich Wagner, Trans4ReaL spokesman [Source: Trans4ReaL, Enno Kapitza]

Ulrich Wagner from the FfE research institute for energy economics, acting as spokesman for Trans-4ReaL, said: "The overarching aim of Trans-4ReaL is to ensure that the findings from the living labs on sector coupling and hydrogen technologies are widely shared and can be used extensively. In the next five years we would like to link up the Living Labs for the Energy Transition and consolidate their individual knowledge about specific hydrogen technologies and innovations in relation to sector coupling. This will enable us to draw generalized conclusions about how a sustainable hydrogen economy can be established in Germany."

Simon Pichlmaier, a leading light in hydrogen and synthetic energy carriers at Trans4Real, told H2-international: "Regulatory learning is one of the most important points." The objective is "to convert results and experience into knowledge that can be generally applied." This would require "at the moment definitely still funding" so that policy options can be ascertained and approvals procedures simplified. ||

WE ASK – THE MINISTRY ANSWERS

"The Living Labs for the Energy Transition are a key element in the energy research program and serve the purpose of demonstrating several innovative energy-related technologies and how they interact in a real-life environment and on an industrial scale. Producers, developers and users of innovative technologies should be put in a position in which they are able to test out these technologies to a greater extent than would otherwise be possible without subsidy support. This approach should also generate cost effects through scaling and achieve quicker progress. The projects play a significant part in engendering the technological advances necessary for the energy transition as well as putting research results into practice and helping promising ideas reach market maturity. The intention is to fund broadly purposed projects that seek to investigate the systematic and cross-sector interaction of individual technologies on an industrial scale in addition to the interlinking of various processes and infrastructures. The Living Labs for the Energy Transition are therefore pioneering in their approach toward transforming the energy system.

By introducing this new format, which straddles both research and market domains, BMWK energy research has created an important foundation for large industrial investment in sustainable technologies. In doing so, the subsidy scheme leverages extensive corporate investment and cushions entrepreneurial risk.

The living labs have a major role to play in providing further impetus to the hydrogen economy which will enable the ramping up of the market in Germany. At the same time, there are still investment constraints in relation to European Union framework conditions. The BMWK looks to proactively support the ramp-up of the European market and to adopt criteria that will not obstruct market ramp-up."

"So far 10 living labs have been approved under the Living Labs for the Energy Transition subsidy format. Five Living Labs for the Energy Transition have a specific hydrogen remit.

Bad Lauchstädt energy park, H2Stahl, H2-Wyhlen, NRL living lab, Westküste100

Two further living labs will get underway this year, one of which is related to hydrogen."

Federal Ministry for Economic Affairs and Climate Action BMWK

Category: Funding | **Author:** Sven Geitmann

WHERE WE ARE IS WAY AHEAD

Transport minister Wissing starts second HyLand round

Fig. 1: HyStarters and HyExperts of round 2

On May 12th, 2022, German transport minister Dr. Volker Wissing set off the next round of the HyLand program. Representatives from each of the 15 HyStarter and HyExpert Regions came to Berlin to hear the funding decisions from the ministry for transport and digital infrastructure (Bundesministerium für Digitales und Verkehr, BMDV). In addition, Wissing announced another call for HyPerformer Regions – also for this year.

The start of the second HyLand round was a chance to take a glance back as well as to look at what is likely taking form ahead. In the first round of the HyLand program, three regions with an already established hydrogen strategy, called HyPerformer Regions, were each given up to 20 million euros in investment grants to implement their hydrogen concept. The total for the projects was 195 million euros, distributed as part of the national program for hydrogen and fuel cell innovation (Nationales Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie, NIP).

Meanwhile, HyExpert Regions have each received up to 400,000 euros in grants in order to commission consulting, planning and other services needed to create an implementable comprehensive plan for a regional hydrogen economy. The HyStarter Regions have each received one year of support in the technical and organizational development of a region-tailored hydrogen concept and network focused on the use of hydrogen in transport.

> "With the regional approach of HyLand, we're bringing hydrogen all throughout the country and helping 30 more regions work out concepts for a local hydrogen economy. I'm especially pleased to announce that we've approved a second round for the category HyPerformer and thus will be able to support more regions through investment grants in the future."
>
> *Dr. Volker Wissing, German transport minister*

> "Insufficient vehicle availability not only aggravates costs but makes the initiation of a market harder, especially in the case of trucks."
>
> *Eva Stede, HyWays for Future*

It was said by the organizers that the supported approaches "depicted the entire hydrogen value chain in the transport sector of the region, from the production to the storage and distribution infrastructure, to the various transport applications: buses, municipal vehicles, trucks, cars, etc."

Kurt-Christoph von Knobelsdorff, the managing director of the national organization for hydrogen and fuel cells (Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie GmbH, NOW), said in his welcoming speech, "HyLand is a blueprint and grassroots work at the same time." He further compared the HyLand Regions to the Hydrogen Valleys that are currently being established at the EU level. He said that the participants could rightly proclaim, "Where we are is way ahead!"

MANY LEFT IN THE DUST The response in the second round was equally high to the first (see H2-international Feb. 2020), when in the end many more "winners" had been chosen than originally envisaged and so there were 13 instead of the planned 5 HyExperts and 3 instead of 1 HyPerformer. In 2019, there were 138 applicants for the 9 HyStarter spots. Now, in the second running, 116 applications were submitted (see H2-international Aug. 2021), out of which 15 HyStarters and 15 HyExperts were chosen. Five of these HyExperts were previously HyStarters and are now in the next development stage.

A great deal of praise, in the presence of the federal ministry, went out to the project management group Projektträger Jülich (PtJ) for the complication-free cooperation and good support. The program "HyLand – Wasserstoffregionen in Deutschland" (Hydrogen Regions in Germany) is again being coordinated by NOW GmbH.

WHAT'S MISSING ARE VEHICLES The major shortcoming, however, was and still is that there are not nearly enough vehicles available so far. This also became more than clear during the opening ceremony for the second round. The actual objective of the funding body, to put as many H2 vehicles as possible on the road, cannot be reached as a result. Blame should not be put on the federal government, but rather the automotive industry, who took to electrification much too late and not vehemently enough.

Extremely long delivery times exist for both hydrogen- and battery-powered vehicles. In the case of H2 vehicles, the situation is aggravated by the fact that the infrastructure is still not nearly all there. A HyLand participant boiled it down for H2-international: "The lack of available vehicles is dooming the program. Therefore, not many vehicles will come out of HyLand, but rather filling stations." The answer as to why the supply is so meagre is simple: "Because of the OEMs."

For years, almost all automobile and also some commercial vehicle manufacturers have had their research and development work in the H2 sector subsidized with taxpayer money, yet hardly any marketable products have emerged from this so far. Fuel cell trucks are therefore only available in minimal numbers (see p. 27). In the case of FC buses, there are now potential suppliers, but only with extremely long delivery times.

This has also led to the HyPerformer Regions from the first round of tenders achieving much less than envisioned. The millions in funding were supposed to put H2 vehicles into service in these three geographic areas. But with the lack of supply, the plan is as good as doomed.

HyPerformer Region Nordwest were originally full of promise: "HyWays for Future serves as a market activation program for the establishment of green hydrogen in the transport sector of the metropolitan region Northwest Germany and as a pioneer for a cross-sectoral and cross-border hydrogen community. The aim is to open up the transport sector as a sales market." Now, the tone is: "The applications have been submitted. We know who it should go to." Since the term for this project (2020 to 2023) is nearly three quarters of the way over and only 64.2 million euros is still available, this is a sad yield.

Players from the second HyLand round therefore have better chances of perhaps obtaining the vehicles within the project term. That the start of the second HyPerformer round would be delayed was foreseeable. Kurt-Christoph von Knobelsdorff had hinted already in November 2020 that a second running would only occur once the HyExperts had advanced enough that they could apply to become HyPerformers.

HIGHER SUBSIDY RATE FOR HYPERFORMERS It may help that the conditions for HyPerformer Regions are to improve. The subsidy rate is expected to raise from 40 percent of the additional cost to purchase hydrogen vehicles over diesel to 80 percent.

Finally, von Knobelsdorff, head of NOW, was thoroughly pleased that through HyLand "implementation expertise" would be generated. In addition, he proposed – initially still rather vague – that in the future there could possibly be a "banding of H2 Regions." Such a grouping could pool the knowledge and experience acquired and then, perhaps through a seat in the national hydrogen council (Nationaler Wasserstoffrat), bring these to the political stage, is his idea. ||

REGIONS SERIES IN H2-INTERNATIONAL

To give an impression of what is actually happening in the numerous Hydrogen Regions that now exist in Germany, Hydrogeit Verlag is publishing a series of articles. In each, H2-international introduces readers to one of these Regions, which could be a HyLand project or a real-world lab. See also pages 16 and 32.

Fig. 1: Hydrogenious' demo system for hydrogen storage and transport in Finland [Source: HySTOC]

Category: Energy storage | **Author:** Niels Hendrik Petersen

LOHCS AS A PROMISING ALTERNATIVE?

Development of an LOHC fuel cell

A startup from Erlangen, Germany is advancing the development of a liquid organic hydrogen carrier. With various corporations like Bilfinger und Schaeffler, the technology company is trying to make the innovative solution for green hydrogen more economical worldwide. At the end of 2023, the largest storage and release plant thus far is to appear in Chempark Dormagen, near Cologne. It should be able to produce and store 1,800 tonnes of hydrogen annually. Demand is widely abundant.

The automotive and industrial supplier Schaeffler is talking of a milestone for its own hydrogen strategy. "Hydrogen technology will play a key role in CO_2-neutral, sustainable mobility, including energy supply and is for Schaeffler of strategically significant importance," confirmed Uwe Wagner, member of the research and development managing board.

Schaeffler is working with Erlangen-based company Hydrogenious LOHC Technologies and the Helmholtz renewables research institute (Helmholtz-Institut Erlangen-Nürnberg für Erneuerbare Energien, HIERN). The partnership is to accelerate the development of an H_2 fuel cell. Specifically, a fuel cell that uses a liquid organic hydrogen carrier (LOHC). According to information by the company, Schaeffler wants to bring its expertise in industrialization and know-how in materials, forming and surface technology to the new alliance.

The starting situation: Hydrogen is usually stored and transported in special vessels in gaseous form at a high pressure of 700 bar or in liquid form at extreme sub-zero temperatures of minus 253°C. Both ways are technically complex and expensive. LOHCs offer themselves as an attractive alternative here. "The direct use of LOHCs in fuel cells for power generation makes the handling of hydrogen as a gas unnecessary," describes Daniel Teichmann, the CEO and founder of Hydrogenious. This technology therefore allows a particularly cost-effective and secure supply of hydrogen to mobile and stationary energy users.

SCHAEFFLER DRIVES LOHC TECHNOLOGY FORWARD This alliance benefits from the extensive prior research work done by Hydrogenious and HIERN. They also hold several patents. Then, Schaeffler comes into play. The corporation is developing together with HIERN a suitable fuel cell technology for the direct use of LOHC-bound hydrogen. The fuel cell construction must also be adjusted for this purpose. Schaeffler is manufacturing, for example, the bipolar plates for these. The know-how for the necessary catalysts and membranes, on the other hand, lies with the researchers at HIERN.

In the process developed by Hydrogenious, benzyl toluene comes into use. This is an oil-like, organic substance that chemically binds the hydrogen and allows it to be transported under normal ambient conditions. Unlike the classical system, there would be no molecular hydrogen in an LOHC fuel cell nor in the supply chain. The liquid carrier material can be used in this way multiple times, which makes the technical solution particularly sustainable.

"With its properties, LOHC technology based on benzyl toluene enables a safe and cost-effective hydrogen infrastructure," says Dr. Tim Hosenfeldt, the head of research, innovation and business technology at Schaeffler. He clearly sees the use of LOHCs in fuel cells as complementary to the classical hydrogen technologies.

EU PROJECT HYSTOC Hydrogenious LOHC Technologies has also been involved in the HySTOC project, which started in 2018. The project name stands for "Hydrogen Supply and Transportation using Liquid Organic Hydrogen Carriers." The aim of the EU project was to establish and test an efficient H_2 value chain, from production to use, in Finland (see also p. 62), in order to transnationally learn from it.

The company's container-based LOHC systems have now survived the field test: "Using our LOHC material, around two tonnes of hydrogen have been stored and released," summarized Stefan Naser, chief operating officer at Hydrogenious. Valuable results from the demonstration project could be taken that are useful for scaling and building larger systems in the future.

Particularly important was the last phase of the EU project, which began just over a year ago. In spring 2021, the gas company Woikoski Oy put the hydrogen storage plant StorageBox 10 from Hydrogenious into operation at the H_2 production site in Kokkola – at minus 23°C. Woikoski produced the hydrogen and stored it in the liquid carrier material. The system was also operated by state-owned technical research company VTT, located in Espoo, for more than 2,000 hours, and the quality of the released hydrogen was scientifically tested. The project participant obtained satisfactory results with regard to the purity of the hydrogen and the operating of the plant.

The easy transport of hydrogen as the LOHC liquid was confirmed between the test sites in Kokkola and Espoo, a distance of 500 km (311 mi). The analysis of the H_2 quality showed that on average the respective limits of the ISO standard were met. With that, a central objective of the HySTOC project was fulfilled.

Also demonstrated was the positive effect of a pressure swing adsorption technology from project partner HyGear, a service provider for industrial gases. This ensured that the hydrogen released from the LOHC was purified so that it met H_2 quality standards, a requirement before its use in cars or trucks with fuel cell engines. The purified hydrogen met the purity criteria.

Furthermore, during full operation of the hydrogen release plant ReleaseBox10, a hydrogen yield of more than 90 percent was measured. Particularly successful was the employment of a new LOHC material that is even more suitable for cold environments and has an improved H_2 release rate.

BILFINGER ON BOARD AS A PARTNER Another of Hydrogenious' strategic partners is the German corporation Bilfinger. The two have been cooperating since the end of 2021 to make green hydrogen economically available on a large scale and throughout Europe. A turnkey plant with storage and release facilities as well as installation, operation and maintenance are to be offered from a single source. Industrial services provider Bilfinger was the partner of choice, affirms Daniel Teichmann of Hydrogenious.

The start of construction of an industrial-scale LOHC storage plant at Chempark Dormagen is planned for year 2023/24. According to the company, this will be the world's largest plant for H_2 storage in LOHCs. It is to produce and store about 1,800 tonnes annually. During the project, Bilfinger will assist in the planning of the technical aspects as well as in the application for permits for operation in the chemical park.

MAN Energy Solutions and the Netherlands-based Frames Group are also involved in the plant construction. Trucks will load the H_2-carrying oil and transport it by road to LOHC release facilities and hydrogen consumers in Europe, for example to Rotterdam.

MORE H_2 EXPORTS FROM THE MIDDLE EAST Additionally, startup Hydrogenious entered into a joint venture with the company Emirates Specialized Contracting & Oilfield Services (ESCO), from the United Arab Emirates, at the end of 2021. ESCO, with office in Abu Dhabi, is an optimal supplier of solutions for realizing the storage and transport of hydrogen in the Middle East, the Erlangen-based company can rejoice.

The portfolio of the new joint venture includes the construction of turnkey hydrogenation (storage) and dehydrogenation (release) plants as well as operating and maintenance services. In order to accelerate the H_2 market ramp-up, the joint venture will develop benchmark projects with regional partners. Hydrogenious LOHC Emirates wants to source low-cost, clean hydrogen locally and establish efficient LOHC-based supply chains worldwide, expressed Andreas Lehmann, chief strategist and CEO at Hydrogenious. However, Germany remains, according to Lehmann, a key market. Other potential markets, including Japan and South Korea, are already in the company's sights. ||

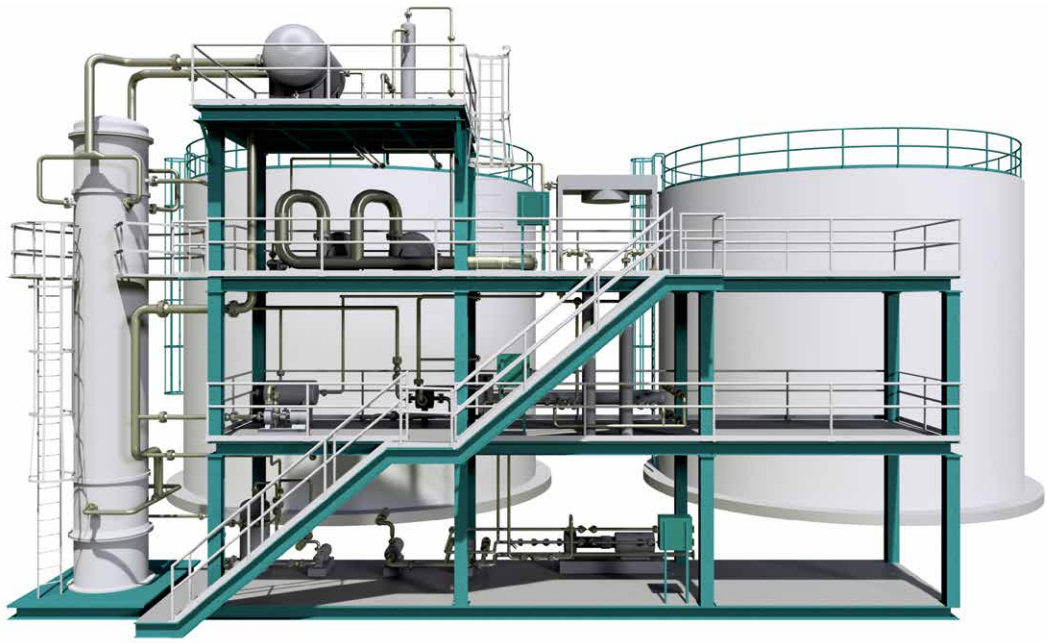


Fig. 2: Model of the planned LOHC plant to operate in Dormagen, which is to generate 1,800 tonnes of H_2 per year
[Source: Frames Group]

Category: Energy storage | **Author:** Eva Augsten

PHOTOVOLTAIC FIRMS DISCOVER HYDROGEN

Inverter manufacturers now build rectifiers

Fig. 1: The MVPS 40: a 40-ft station with two electrolyzer converters (EC-UP) – up to 8 MVA output [Source: SMA Sunbelt Energy GmbH]

For an electrolyzer to work with electricity from the grid, it needs a rectifier. The rectifiers work, in essence, like a photovoltaic inverter – but the other way around. Several companies from the solar industry are now active in this area. Positive side effect: Your technology is inherently network friendly.

By 2030, 10 gigawatts of electrolysis capacity is to be connected to the grid in Germany alone. This is a challenge for the manufacturers of all the components. From the water preparation to the membranes and pressure vessels, the task now is to quickly scale up production. Rectifiers have hardly been in the public spotlight so far. Maybe it has to do with the fact that electrolysis is explained in the physics books similar to this: direct current and water go in, hydrogen comes out. The fact that there is no direct current coming out of the socket at all is neglected in this short formulation.

SOLAR INVERTER THOUGHT BACKWARDS

For the manufacturers of photovoltaic inverters, this is opening up a new market. "Basically, a rectifier is like an inverter – but backwards," says Iñigo Uriarte of the Spanish manufacturer Ingeteam. Fabian Jochem, Head of Strategy at SMA Sunbelt Energy GmbH, explains, "Some adjustments are of course necessary with both the hardware and the software. However, we use the same platform as for our inverter solutions."

Austrian inverter manufacturer Fronius also manufactures rectifiers for electrolysis. This carries a great advantage for PV companies. They can enter the relatively young market right away with devices manufactured in large quantities. For comparison, the installed photovoltaic capacity in Germany is expected to grow from the around 60 gigawatts today to 200 gigawatts by 2030, so an average 18 gigawatts per year. This offers a lot of potential for synergies, including in the production of the corresponding power electronics. Conversely, this also means that photovoltaics and hydrogen are competing for the same raw materials and value chains.

However, the green electricity and hydrogen industries are growing closer together anyway, as was shown during the trade fair The smarter E Europe on May 11th through 13th, 2022 in Munich. This joint event has emerged from the solar fair Intersolar and now also includes the topics of electrical energy storage, electromobility and energy services. Hydrogen technologies were also to be found in various forms at the stands of the solar and power storage companies.

REACTIVE CURRENT COMPENSATION AS A SIDE EFFECT

The PV inverters bring not only scaling effects, but also a technical change to the new rectifier application. For many years, rectifiers based on thyristors were used to convert alternating current from the grid into direct current of the required voltage. Thyristor technology is well established, robust and comparatively inexpensive to purchase. But it has a disadvantage: it generates reactive power in the AC circuit.

To ensure that this does not have a negative impact on the power grid, the reactive power must be compensated. However, this would significantly increase the cost of the hydrogen produced. Solar inverters are based on IGBT (insulated-gate bipolar transistor) technology. This is a more expensive investment, but it can actively compensate reactive power.

The electronics specialist AEG has not settled on pure IGBT technology, but has instead developed its own type of rectifier – a hybrid of thyristor and IGBT technology. Whereas IGBT solutions first reduce the voltage strongly and then

increase it again slightly, the hybrid from AEG implements a gradual reduction of the voltage. This limits the current intensity on the DC side to the minimum necessary. This in turn reduces losses and also the cable diameters needed – and thus costs. Both in terms of investment and capabilities, the hybrid technology falls between IGBTs and thyristors, according to Andreas Becker. "It does not compensate foreign reactive power, but does not generate any on its own either," says the AEG product manager.

Whether a targeted compensation of "foreign" reactive power brings an additional benefit depends on the use case. If during an industrial operation, for example strong motors or other devices that lead to high reactive power are in use, this is reflected separately on the electric bill. These costs can be reduced by compensation of the respective reactive power directly during operation. An IGBT rectifier can handle this task at the same time. When there's nothing extra to compensate, AEG's hybrid rectifier can do the job of power correction. Theoretically, it could also be interesting to offer reactive power compensation as a service to grid operators. Based on available information, this is, however, not yet the plan of many manufacturers.

DECENTRALIZED H_2 PLANS FOR BUSINESSES AND COMMUNITIES Solar inverters are manufactured in all power sizes. This means that rectifiers of various power ratings can also be offered. However, for home energy systems, the kilowatt class is omitted for hydrogen, since PV systems with battery storage can address this power range for a majority of the year. Solely the Berlin-based company Home Power Solutions (HPS) has been active in this market so far, with its solar-hydrogen energy supply system Picea.

On the scale of commercial and small industrial systems, much more is going on. With the devices from AEG, for example, a number of projects in the single- to lower double-digit megawatt range are currently being implemented. A 100-MW project is to follow in France next year. "For this year, we have orders for about 80 modules," says Becker. On module can deliver – depending on the output voltage – 500 kW of power.

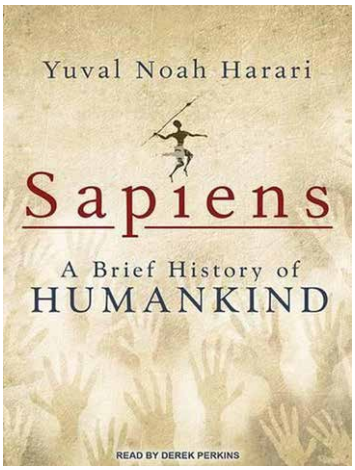
From the modular construction, AEG expects two advantages. On the one hand, different sizes can be covered with one device, which increases the producible quantities and reduces costs. On the other hand, the many small devices can be operated in alternation, each with a high workload. And so a partial load operation with mediocre efficiency can be avoided.

Rather unusual is the offer of the Austrian electronics company Fronius, which offers complete on-site hydrogen solutions. Its Solhub contains everything, from the rectifier to the cylinder bundle, that is needed to store energy in the form of hydrogen. The solution is primarily intended for municipalities or medium-sized commercial enterprises that want to use it to, for example, operate their own hydrogen fueling station.

Ingeteam and SMA, on the other hand, are focusing on larger projects, for example in combination with photovoltaic systems on a power plant scale. They sell their rectifiers to electrolyzer manufacturers, who in turn configure complete systems for project developers – so the EPC (engineering, procurement and construction) businesses. "It is quite possible that in the future, the EPCs will also purchase the components directly. Perhaps it will no longer be PV EPCs, but rather companies from plant construction or the gas industry," forecasts Fabian Jochem of SMA. ||

Fig. 2: Around 65,000 visitors flocked to The smarter E in the Messe München exhibition halls with over 1,300 exhibiting companies from 46 countries. That's a third more visitors than at the last regular event, in 2019 [Source: Eva Augsten]

A SHORT HISTORY



You don't need to be a history buff to be drawn into this book. "Sapiens – A Brief History of Humankind" is neither a historical novel nor a tedious history book. Instead, this work by Yuval Noah Harari features a well-researched narrative that seeks to explain why we humans behave the way we do.

This book isn't an internationally acclaimed bestseller for nothing. Harari is not only able to present the entirety of human development in a highly engaging way but also makes it an entertaining read. Despite it first appearing in 2015, this book has lost nothing of its freshness. In fact, it could be said that it's even more relevant today, offering answers to the urgent questions of our time.

Priced at EUR 14.99 for 528 pages, it's a worthwhile investment – both financially and for the ideas it contains, even if it doesn't explicitly delve into the subject of hydrogen. And if you liked this book, which has so far been translated into 40 languages, then you'll certainly enjoy the other publications by this Israeli history professor. ||

Harari, Yuval Noah, Sapiens – A Brief History of Humankind, Harper, 2015

Category: Energy storage | **Authors:** Tetyana Raksha, Luis A. Martinez B.

REFLECTION AND PERSPECTIVE ON PtX

Overview of PtX activities in Germany and Europe

The progression of PtX technologies within the last two decades, starting in Germany, seems to have developed into a success story, with currently more than 900 projects worldwide. At this time, a transition from small laboratory-scale pilot projects to large-scale commercial use can be observed. The PtX activities up to now have been followed and analyzed by LBST, who will continue to in the future.

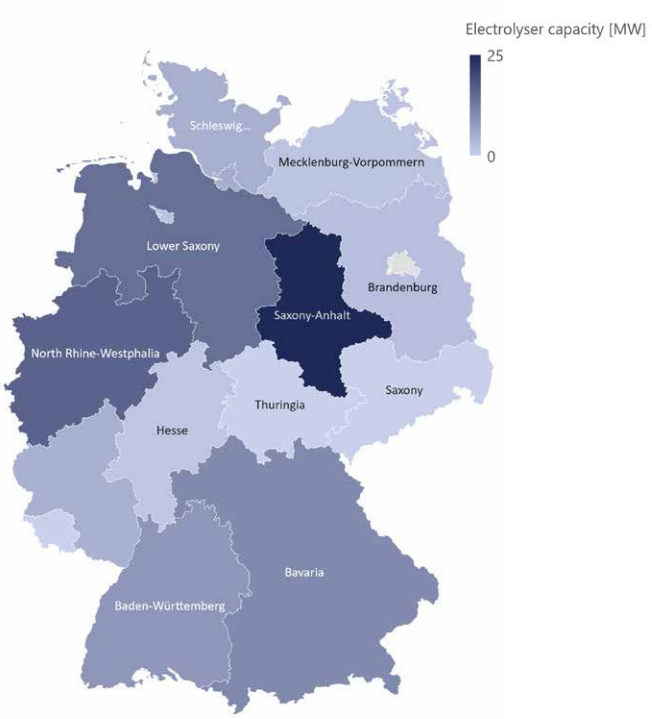


Fig. 1: PtX landscape in Germany (stations in operation or being constructed) [Sources: LBST]

With the coupling of electricity, gas and transport as part of the clean energy transition, a new technical infrastructure is emerging in which the power-to-X concept (PtX), as a sector-coupling technology, can make a major contribution to the decarbonization of industry. Under the term PtX are systems that use electrical energy to generate hydrogen and, as needed, convert that hydrogen, with addition of carbon, into gaseous or liquid hydrocarbons.

Since 2011, the engineering firm Ludwig-Bölkow-Systemtechnik (LBST) has been following the development of relevant PtX activities and maintaining a database, which currently contains 900 projects from around the world. While initially only smaller systems with electrolysis capacities in the kilowatt range for research purposes were listed, more recently projects with electrical outputs of several megawatts have been realized. Even larger plants in the gigawatt range are currently in various stages of preparation for various countries. Drivers of this are the rising pressure to reduce greenhouse gas emissions, the extensive public as well as private funding, and not least the Ukraine conflict, which has accelerated the need to diversify the energy supply.

SITE OF GERMANY From April 2022, in Germany alone are located around 200 research and demonstration units in various stages of implementation, from "announcement" to "planning," to "construction and operation." The total installed output capacity of PtX stations in the Federal Republic currently amounts to nearly 55 MW. For comparison, in May 2012, the total capacity lay under 50 kW. This corresponds to a thousandfold increase within ten years.

The largest hydrogen electrolysis plant in Germany, which is equipped with polymer electrolyte membrane (PEM) technology, has an output of 10 MW and was brought into operation mid-2021 as part of the project REFHYNE. The station constructed by ITM Power and operated by Shell produces 1,300 tonnes of hydrogen per year for Rheinland Raffinerie in Wesseling. Building on this experience, ITM Power is currently developing a design for a 100-MW PEM station.

Other frontrunners in installed output in Germany are the 10-MW alkaline electrolyzer from Sunfire that is to be installed in Lingen in 2023 and the 20-MW PEM electrolyzer Trailblazer in Oberhausen that will be built by Air Liquide and whose start of operation is likewise planned for 2023.

The following map shows the distribution of the in total 60 stations in Germany that are currently either already in operation or in the construction process.

Thus, in almost every federal state are now stations that operate and produce and store renewable gases in accordance with the principle of sector coupling. With two current major projects under construction, 10 MW in Zerbst and 24 MW in Leuna, Sachsen-Anhalt has assumed the role of trailblazer in renewable hydrogen production in Germany. In total, 14 major projects in the construction phase adding up to about 100 MW of electrolysis capacity are to go into operation within the next two years.

Attributable to changes in the energy sector, the total output of announced PtX projects are correspondingly increasing. Initial project designs or project outlines for stations for production of green hydrogen are also entered in the LBST database. In total, currently more than 4 GW of "announced" electrolysis capacity related to PtX are to be operative in Germany by 2030.

On the one hand, this reflects the increased dynamics in the area. On the other hand, not all announced projects reach their implementation phase. Financing approvals or operating licenses can take years to obtain. For example, the project partners Gasunie Deutschland, TenneT and Thyssengas intend with the project Element Eins (element 1) to construct a PtG (power-to-gas) station in the 100-MW class with planned start of H_2 production in 2022. The application for investment submitted to the federal networks agency (Bundesnetzagentur, BNetzA) in 2019 was declined in 2021 (see H2-international Apr. 2021). This delayed the original planning work. Now, the project Element Eins is merging with the Clean Hydrogen Coastline project. The targeted goal is, in an initial expansion stage, to integrate 200 MW of H_2 production capacity in the area of Bremen into the European energy system by 2026.

FRAMEWORK CONDITIONS AS INFLUENTIAL FACTOR Evaluation of the PtX data of LBST shows that the majority of large projects, in Germany as well as Europe-wide, are dependent on approvals of public funds. Among other things, numerous business consortiums have sent an IPCEI notification (important project of common European interest) involving hydrogen to the European Commission, for the possibility of a high level of national funding. Such major projects include:

HYTechHafen Rostock, DE: Construction and operation of a 100-MW electrolyzer for the production of green ammonia. Long term, a hydrogen production capacity of up to 1 GW is to be created.

- GreenMotionSteel, Duisburg, DE: 120-MW water electrolysis plant for climate-neutral steel production.
- Wasserstoff für Maasvlakte, NL: 500-MW production plant for green hydrogen from electricity generated at North Sea wind parks with connection to the national hydrogen pipeline.
- Green Fuels for DK: Construction of an electrolysis station with a total capacity of up to 1.3 GW before 2030.

The IPCEI process requires close transnational cooperation between the project partners. Over 400 projects from 18 EU countries, including Belgium, France, Italy, Poland, Portugal and Sweden, were registered at EU level. In the course of 2022, the grant offer letters are expected to be sent and, dependent on this, the final investment decisions reached.

PTX IN EUROPE The LBST database contains nearly 600 Europe-wide PtX activities. A large majority of European countries participate in these projects. By number, Germany has the largest share of completed projects. The expertise and experience thus gained in this country in the areas of PtX technology and plant operation are to be successfully utilized in the construction and operation of plants beyond the border.

The following map (Fig. 2) gives an overview of the distribution of the 150 European PtX stations that are either already in operation or near completion of construction. The installed electrolysis capacity amounts to about 90 MW, and nearly 300 MW more by 2024 has been announced. Of the stations, 14 have an electrolysis capacity between 5 and 10 MW, and already 9 stations have between 12 and 50 MW. Most of the plants in the megawatts range were put into operation in the last two to three years or are to be in operation by year 2023/24.

The largest electrolysis plant in the EU, with an output of 50 MW, is to be realized end of 2023 in Denmark by Siemens Energy. The operator European Energy is planning the production of e-methanol, with the maritime transport company Maersk as a reliable major customer.

Alkaline electrolysis technology is also being used in large-scale projects. For example, P2X Solutions is erecting a production facility for green hydrogen in Harjavalta, Finnland (see also p. 62). The high-pressure alkaline electrolyzer has a capacity of 20 MW and is to be delivered by Sunfire in

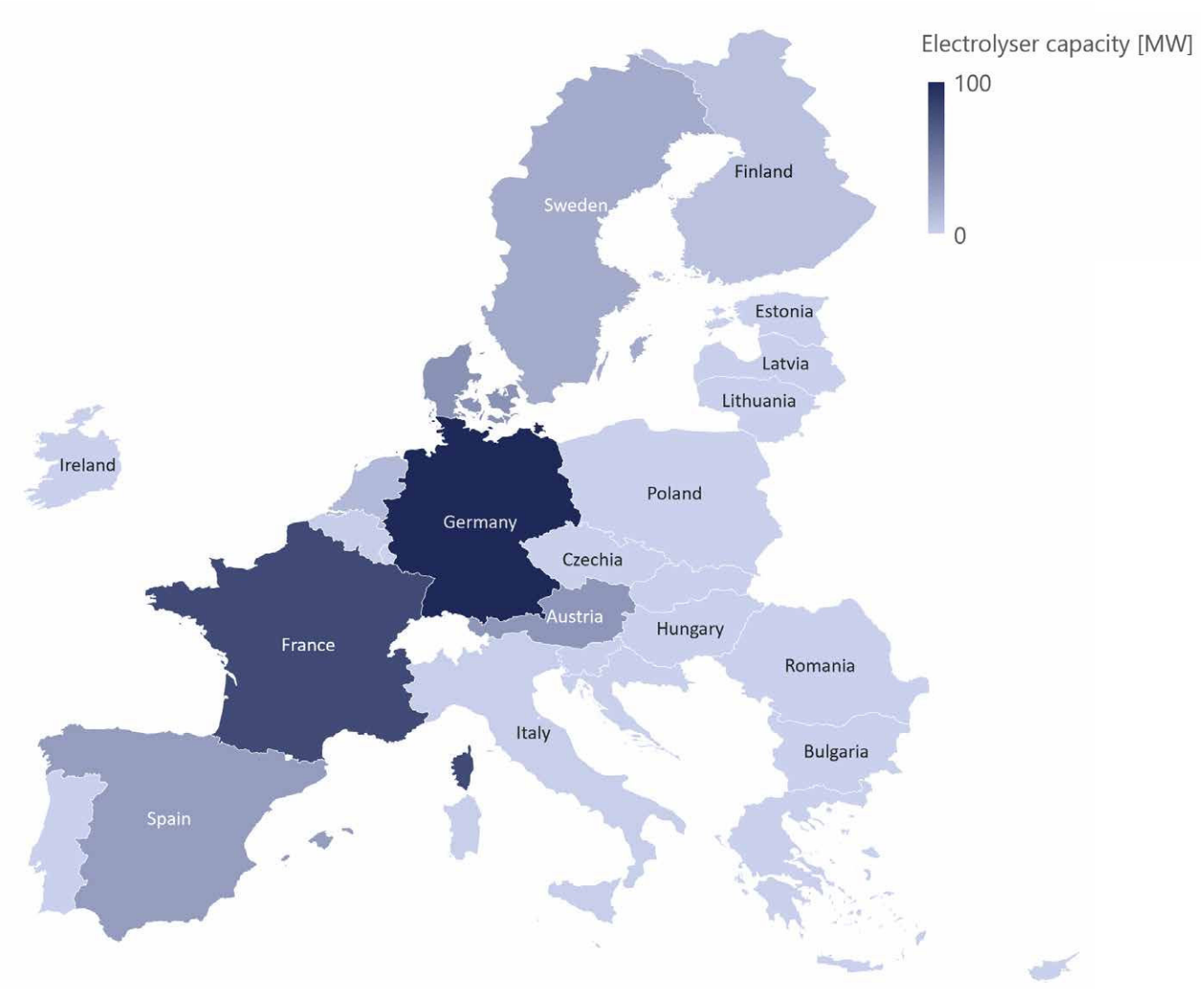


Fig. 2: PtX landscape in EU-27(stations in operation or being constructed)

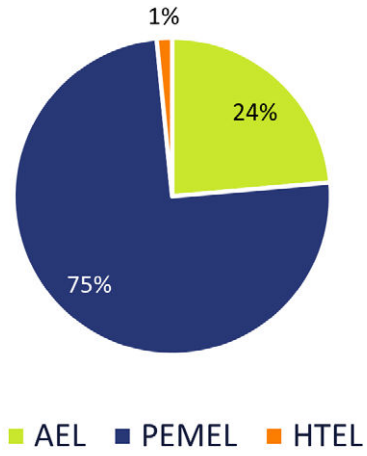


Fig. 3: Breakdown of the applied electrolysis technologies (stations in operation or being constructed, April 2022)

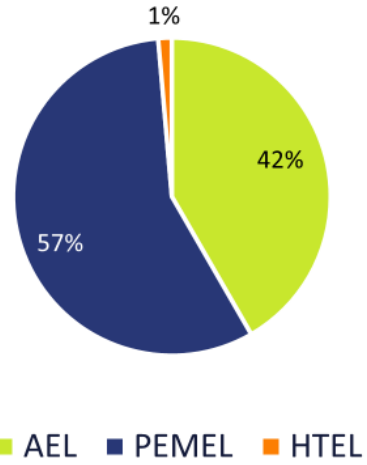


Fig. 4: Breakdown of the applied electrolysis technologies used in PtX plants in EU-27 (April 2022)

2023. As part of Danish green hydrogen company Everfuel's project HySynergy, a 20-MW alkaline electrolyzer from Nel is to go into operation in the course of 2022. Expansion of the station to produce 300 MW in a second phase is planned.

THE ELECTROLYZER IS KEY Both PEM-based (PEMEL) and alkaline electrolysis (AEL) have proven themselves as deployable technologies for the large-scale production of hydrogen from renewable electricity. When looking at the installed and in-construction PtX stations in Europe, PEMEL (205 MW) is currently dominating over AEL (150 MW). Figure 3 shows the percent breakdown of the electrolysis technologies in PtX applications in Germany and in the EU. For several of the announced PtX projects with electrolysis output in the tens of gigawatts range, the technology has not been decided on.

If glancing over at China, it seems that there the alkaline technology has prevailed over PEM. A 150-MW AEL plant started hydrogen production at the end of 2021 (Baofeng Energy) and another AEL plant, with over 200 MW capacity, is under construction (Sinopec).

One technology that is in the early stages of commercialization is high-temperature electrolysis (HTEL) with a solid oxide as electrolyte. It is currently being tested in eight projects within the EU. This technology has not been utilized on a large scale yet. The registered outputs of the HT electrolyzers installed in Europe reach 5 kW to 1 MW, with the total capacity at nearly 5 MW. The largest 1-MW high-temperature electrolyzer has been under testing at Hydrogen Lab Leuna since June 2021 as part of the project e-CO2MET.

Currently, no construction of significant HTEL output capacity has been announced in Germany. However, there are some activities outside Germany to list. For example, in the Netherlands mid-2022, a 2.7-MW high temperature electrolyzer is to go into operation to demonstrate the production of green hydrogen for refinery processes (MULTIPLHY). In 2023, construction of a 20-MW HT electrolyzer is to start in Norway (Norsk e-fuel). In most of the analyzed projects with high-temperature electrolysis, the technology of German manufacturer Sunfire is being used.

RENEWABLE ELECTRICITY AS AN ENERGY SOURCE FOR PTX To produce green hydrogen, renewable energy sources must be used in the preparation of the electricity. At most of these stations, wind power, photovoltaics, hydropower or perhaps a combination are utilized. At present, the (offshore) production of hydrogen in connection with offshore wind power is increasingly being considered. Large-scale projects have already been announced. An example is the initiative AquaVentus, which aims to provide 10 GW from offshore wind power in the European North Sea area for hydrogen production by 2035. However, no large-scale stations for hydrogen production from offshore wind have yet been realized.

The next projects that focus on an electrolyzer integrated into offshore wind energy production start in the less than 10 MW range (H2Mare, OYSTER, PosHydon). Floating wind and photovoltaic technologies for offshore hydrogen production are to be investigated in the Spanish research project OCEANH2 and also on the French Atlantic coast in the Lhyfe project "Offshore renewable hydrogen." The future promises to also be more diverse in the integration of intermittent energies. ||

Literature: LBST Power-to-X Datenbank

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VOLKER BLANDOW IS DEAD

A longstanding member of the H_2 community died in May 2022 after a serious illness: Volker Blandow. The former employee at Ludwig-Bölkow-Systemtechnik GmbH (see also report on p. 40) had a major hand in the fact that LBST has made a name for itself as a hydrogen engineering firm far beyond the borders of Germany. With his great wealth of knowledge and his conscientiousness, he has made a fundamental contribution to advancing the energy transition and the transformation now taking place in the direction of a hydrogen society. Condolences were expressed from the many institutions for which Blandow had so diligently worked over the years – LBST, Green City AG, TÜV Süd. The passing of Volker Blandow has left a great hole.

Category: Electric transportation | **Author:** Sven Geitmann

HYDROGEN TRUCKS FOR HIRE

Hylane, H2 Delivery and Next Mobility to offer rent-a-truck service

The idea of carmakers running their own car sharing enterprises has been around for years. But an insurance company leasing hydrogen-powered trucks is something completely new. Indeed at first glance the plans put forward by hylane, a subsidiary of German insurer DEVK (historically an insurance fund for railroad employees), seem rather unconventional. During the course of the company's press conference on April 11, 2022, however, the partners involved made it clear that unusual times occasionally call for unusual measures. The same applies to the H2 Delivery brand which began marketing its rental concept in December 2021.

Fig. 1: In all, 44 of these hydrogen trucks will be rented out across Germany by 2023 via hylane [Source: hylane]

The company hylane GmbH was founded in 2021 by DEVK in order to drive forward the transition to more sustainable forms of transport. As a climate-friendly mobility provider, the subsidiary plans to only hire out vehicles that are green. The current focus is on hydrogen-propelled trucks with various fixtures and superstructures – with cargo vans and buses expected to be added at a later date.

The goal is to offer potential users the highest level of convenience without them having to run any risks themselves. As such, hylane has ordered 44 tractor units as well as complete tractor-trailer combinations from various manufacturers which will in future be made available to customers on a pay-per-use basis. The company said: "The risk for technical breakdowns therefore lies not with users, but with hylane. All services (not including fuel and the driver) are covered by the rental fee."

Sara Schiffer, who is director of Cologne-based hylane, explained during the press conference: "We have already concluded rental agreements for the initial vehicles. Our first customer is the global logistics service provider DB Schenker."

STARTING OUT: FIVE VEHICLES AT FOUR SITES The first five vehicles are due to be made available at the end of 2022 and are expected to be Hyundai semi-trailer trucks. Eventually it is hoped that these will be complemented by vehicles produced by Hyzon Motors. The company also plans to use Daimler Truck tractor units that have been converted to hydrogen propulsion by Clean Logistics Technology. Further additions to the lineup are set to be MAN Truck & Bus swap body trucks that have been refitted by Framo eTrucks with a Robert Bosch fuel cell.

Some of the vehicles are oversized, with an excess length of around 24 inches (60 centimeters) due to the placement of the hydrogen tanks behind the cabs. This overlength requires approval, hence DEVK is working on obtaining the appropriate permissions.

The first four sites where these vehicles will be deployed will be Hamburg, Munich, Stuttgart and the Ruhr region. These locations already have hydrogen refueling stations, although most of the existing stations are not set up for commercial vehicles. This is why hylane is also at pains to sort out the infrastructure network. Schiffer stated: "We would like to build more hydrogen sites and are in talks with Line AG about this." Commenting on the carbon footprint, she said: "In the longer term the hydrogen will be green, but not right away."

The startup also has its sights set on incorporating other vehicles and manufacturers with the aim of quickly increasing its range so as to be able to offer its customers a wide and varied choice of vehicle options. The current plan is to increase the number of trucks to 44 by spring 2023, with 18 of those vehicles being provided by Hyzon. CEO Craig Knight said: "Hyzon recognizes that, as with any new technology, customers need the chance to utilize our fuel cell electric vehicle in their regular operations. From past experience, we are confident that once fleet owners have experienced our vehicles, they will be motivated to hasten their transition to zero-emissions."

Dirk Graszt, director of Clean Logistics, foresees hylane reaching "four figures from 2024" across Europe. In his opinion, the demand is there "because road charges will be further increased in the coming years."

Hylane is working on the premise that hydrogen trucks are already competitive even now, thanks to state subsidies.

Founded in 1886, DEVK has its origins in the rail industry. Over many decades, the company, which is headquartered in Cologne and financed by members, developed into a large car insurer. Three quarters of its business is now no longer within the railroad sector; instead 20 percent of its dealings are today either international or related to reinsurance.

"At the moment, commercial vehicles and particularly heavy-duty transport cause around a third of greenhouse gas emissions in the German transportation sector."

Fig. 2: Sara Schiffer, founder and director of hylane, advisor to the board at DEVK [Source: hylane]

Fig. 3: In Berlin, Müller and Hellenthal (right) sign the agreement for using the EUREF Campus in Düsseldorf which is currently under construction

According to its calculations, the financial outlay on hire fees and fuel is lower than that for a comparable diesel vehicle – assuming an annual mileage of 100,000 miles (160,000 kilometers), a leasing period of 96 months and hydrogen costs of EUR 4 per kilogram.

New customers will be initially offered a leasing period of 24 months, with shorter timeframes subsequently possible upon request. The level of investment in the vehicles alone has been put at EUR 24 million, since the purchase price is "roughly six to seven times greater than a conventional diesel vehicle."

Hylane's mantra of "environmentally responsible mobility" places sustainability front and center. For this reason the company is undertaking several environmental endeavors, including a collaboration with Bosch on a method of recycling the fuel cells.

H2 DELIVERY ROADSHOW A similar type of pay-per-use model was also revealed some months previously by H2 Greenpower & Logistics during its tour through 13 towns and cities and seven states across Germany. At Berlin's EUREF Campus in December 2021, managing partner Ludger Hellenthal presented a Hyundai hydrogen truck and announced the company's intention of making an entire fleet of trucks of this type available for rental. In Hellenthal's words, the company is looking to become the "Sixt for the truck sector."

Joining him at the press call were Nikolas Iwan, managing director of Berlin-based H2 Mobility Deutschland, and Reinhardt Müller, director of EUREF AG. On Dec. 7, the EUREF Campus, recognizable for its large gasometer in the center of Berlin, formed the stop-off point for H2 Green Power & Logistics as part of its nationwide roadshow, and it was also here that the Hyundai Xcient Fuel Cell and the "H2 Delivery" format were unveiled.

Up until now, the fuel cell truck in Europe was earmarked only for the Swiss market. However, Hellenthal now wants to bring it to Germany, too. Beat Hirschi, CEO of Hyundai Hydrogen Mobility, commented: "We are looking forward to the partnership with H2 Green Power & Logistics and its H2 Delivery brand."

The investor, which has roots in the real estate sector, kicked off initial discussions about the project in August 2020. Nevertheless, the idea behind it dates back 10 years.

The H2 Delivery venture will see various types and makes of commercial vehicles – including vans and buses – being made available and supplied with green hydrogen. On his roadshow, Ludger Hellenthal met 300 potential customers, 50 of whom quickly showed serious interest. In terms of the German government, a total of EUR 1.6 billion is being invested to support light- and heavy-duty commercial vehicles with alternative planet-friendly power systems and their associated fueling and charging infrastructure.

GREEN HYDROGEN FOR 350-BAR FUEL STATIONS The necessary hydrogen is expected to be produced entirely from renewable energy sources. In order to do so, H2 Green Power & Logistics, situated in Münster, is planning to build photovoltaic plants that float on artificial lakes. Hydrogen refueling would then occur at filling stations built on private business premises that would be both accessible by the business and the general public.

An initial refueling station is already located in the company's Mittelelbe industrial and commercial park at the Magdeburg truck stop where H2 Mobility Deutschland created a facility in 2018. The station allows motorists to fill up on hydrogen, CNG or LNG as well as offering rapid charging. The location is also home to the company's own H2 Delivery Truck Pool enterprise. What's more, Hellenthal confirmed to H2-international that H2 GreenPowerLog is also involved in importing hydrogen via Wilhelmshaven and in 2021 was awarded the tender to supply the inland waterways vessel Elektra with green hydrogen.

Nikolas Iwan said: "We are currently adding the 350-bar option to our public hydrogen refueling station network in line with demand in order to also supply hydrogen to trucks such as the Hyundai Xcient, and this includes the filling station at the Magdeburg truck stop, opened in 2018, in cooperation with H2 GreenPowerLog. Commissioning is slated for the third quarter of 2022 and is planned to coincide with the arrival of the first Hyundai Xcient trucks from South Korea."

NEXT MOBILITY ACCELERATOR Another consortium is Next Mobility Accelerator. This collaboration sees two companies from Lower Bavaria – MaierKorduletsch Group and Paul Nutzfahrzeuge – teaming up with Shell Deutschland. On June 2, 2022, at the PIN21 Clean Trucking Conference, the consortium partners together showcased their own fuel cell truck which is based on a Mercedes-Benz Atego and has

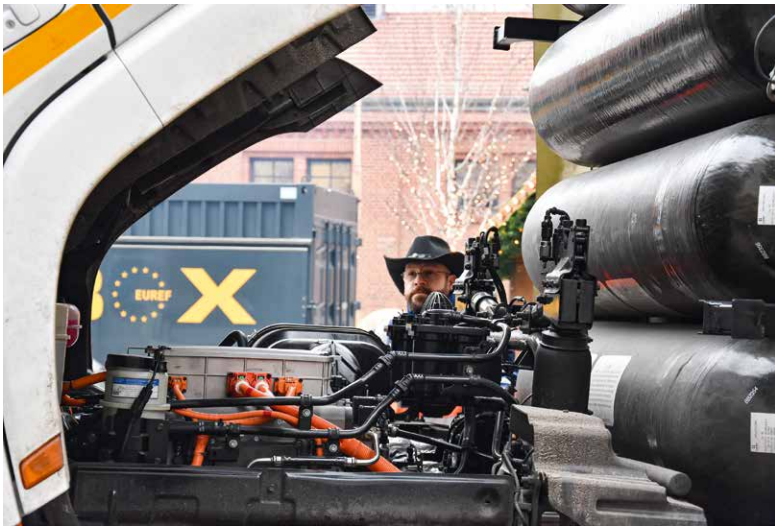

Fig. 4: Thomas Patzer, Hyundai development engineer and "hydrogen cowboy" drove the 36-ton truck at the roadshow

a gross vehicle weight of 24 metric tons. A prototype of the same truck had been presented the previous fall at the ITS World Congress in Hamburg.

In terms of division of labor, Paul Nutzfahrzeuge is responsible for integrating the power unit in the Daimler glider (Atego chassis without engine), as well as providing servicing and maintenance. Meanwhile MaierKorduletsch is in charge of constructing the hydrogen refueling station for the initial trucks and Shell is supplying the green hydrogen. The enterprise will operate – just like hylane and H2 Delivery – on a pay-per-use basis.

The truck's first taker is Shell, which is hiring 25 vehicles. The arrangement is being supported by the German transportation ministry, having awarded Shell a grant of EUR 4.7 million for the lease at the close of 2021. The partnering companies are planning 2,500 fuel cell-powered trucks and up to 50 hydrogen filling stations by 2025 and 10,000 fuel cell trucks and 150 hydrogen stations by 2030.

The central electrical drive system (max. 300 kilowatts) is being sourced from Voith, the fuel cell from Toyota, the battery from Impact (60 kilowatt-hours) and the tank system from Paul, Hanwha Solutions and Anleg. System integration is being taken care of by pepper motion. The result is the PH2P truck, an electric truck with a gross vehicle weight of 24 tons including trailer and a range of 310 miles (500 kilometers) that is then to be offered subsequently with a variety of superstructure options.

The pre-series models 1 to 25 have already been sold to consortium partner Shell and will be delivered by the end of 2022 to regional customers from the Passau area. According to Bernhard Wasner, director of the Paul Group, the scheme will apply a back-to-base approach in which the vehicle is returned to its starting location every night.

Vehicle number one has just been secured by MaierKorduletsch. In a symbolic gesture during the presentation ceremony, Josef Paul, director of Paul Nutzfahrzeuge, handed an oversize key for the vehicle to Constanze Weinkum from Shell Hydrogen who then passed it to the beaming Lorenz Maier, director of MaierKorduletsch.

Shell, working in collaboration with MaierKorduletsch, plans to construct the first hydrogen refueling station in Passau in southeastern Germany in the next few months. As Lorenz Maier explained, the transport hub will get two dispensers for 350-bar refueling which will allow 10 trucks to fill up on 25 kilograms of hydrogen per hour. The hydrogen will be supplied by 380-bar pressurized trailers, with each container holding 1 metric ton of hydrogen. This gas will then be compressed to up to 1,000 bar using two Maximator compressors. Added to that, there is a stationary medium-pressure storage tank for 400 kilograms of hydrogen.

In 2026 it is anticipated that a further mobility hub will be created at the new A3/A94 autobahn interchange in Pocking. Located at the local enterprise park, the facility is to be fitted out with photovoltaic panels on all areas of roofing and will have a hydrogen capacity of up to 5,000 kilograms a day. ||

"The pay-per-use model is expected to eliminate customer's concerns about operating these vehicles. [...] We want to create proof of functionality."

Constanze Weinkum, Shell Hydrogen

Hyundai Xcient Fuel Cell

The hydrogen truck features two 95-kilowatt fuel cells which are mass-produced by Hyundai – and also used in its Nexo car model and stationary systems – as well as a high-voltage battery. In the course of this year it is understood that a new power generator will be deployed that can deliver more than 200 kilowatts.

The truck's powertrain comprises a 350-kilowatt engine with an Allison automatic transmission. The seven pressurized tanks each hold 5 kilograms of hydrogen at 350 bar, allowing the truck to travel 340 miles (550 kilometers) unladen or 250 miles (400 kilometers) with a trailer.

Since 2019, Hyundai has rolled out 49 examples of the Xcient Fuel Cell which between them have now managed to cover a distance of about 2.2 million miles (3.5 million kilometers). According to Hyundai, the response received has been resoundingly positive. The drivers were especially pleased not to be smelling of diesel at the end of the day. By the end of 2022, around 50 of these 36-ton trucks are due to be on the road, with numbers reaching three figures in 2023, according to Hellenthal.

Gebrüder Weiss, a Swiss transportation and logistics company, achieved an excellent record in March 2022 for its Hyundai Xcient Fuel Cell operating out of Altenrhein which is used to deliver packages and parcels on a daily basis. After a year of emission-free service in which the vehicle traveled 44,000 miles (70,000 kilometers), the company decided to deploy further hydrogen trucks in Austria and Germany. Its head of quality and environmental management Peter Waldenberger said: "The purchase was a worthwhile investment in resource-saving road freight transport. The truck has been well received by drivers and, above all, customers."

Fig. 5: Bavarian economy minister Hubert Aiwanger in the PH2P [Source: Paul Group]

Category: Electric transportation | **Author:** Sven Geitmann

NEW BRAND FOR HYDROGEN-RUN GARBAGE TRUCKS

Enginius wins new H2Eco Award

The kickstart for Enginius could hardly have turned out better. On May 16th, 2022, Faun Umwelttechnik GmbH & Co. KG introduced its new brand to the public in Bremen, and only two weeks later, the vehicle manufacturer from Niedersachsen was presented the first ever H2Eco Award during Hannover Messe (see p. 9). At the same time as the industrial fair, the subsidiary of the Faun Group also made a splash at IFAT 2022, the world-leading trade fair for environmental technologies, in Munich from May 30th to June 3rd.

Fig. 1: Dr. Johannes F. Kirchhoff at the Enginius presentation in Bremen – with the CityPower in the background

"Is that still a Faun?" With this question, Dr. Johannes F. Kirchhoff, managing partner of the Kirchhoff Group, greeted the numerous employees and visitors that had come to the presenting of the new brand at the Faun location in the far east end of the Hanseatic city of Bremen.

"No, that is something different." Referred to was the brand new Enginius truck standing behind and a little to the side of Kirchhoff. It was no Faun trash collection vehicle, but something deserving of a new name, a new brand, according to the mechanical engineer.

FIRST BLUEPOWER, THEN CITYPOWER As one of the first suppliers of municipal vehicles, the member of the Kirchhoff Group intends to build trucks with hydrogen drives in series. This will involve the Econic body manufactured in Bremen by Daimler Trucks. The body will be just the raw version of the vehicle – without the drive unit. Head of development Georg Sandkühler explained, "The vehicles are coming just the way we need them. Nothing will be thrown out."

> "With Enginius, we want to be the European market leader for short- and medium-haul hydrogen-powered trucks by 2030."
>
> *Patrick Hermanspann, CEO of the Faun Group*

Depending on the customer's needs, one to three 30-kW fuel cell systems from Hydrogenics and two to four hydrogen tanks from South Korea could be installed. Each 700-bar pressure vessel holds 103 liters of hydrogen, which is about 4 kg. Four tanks enable a travel range of about 240 km (150 mi).

"The first nudge to start the truck comes from the battery. It sits under the cabin," described Sandkühler. He stated a capacity of 85 kWh, but added that this is the end-of-life value. When new, it stores significantly more power. The energy supply runs on a 700-volt basis, since the cable cross-section required can be decreased with a higher voltage.

In answer to H2-international's inquiring of the production capacity, the head of development said that an initial production of 300 to 350 of the three-axle Bluepower model per year is planned. The price per unit, at 650,000 to 950,000 euros, is significantly more than double the price for a conventional vehicle. The second model planned by Faun is the somewhat smaller, double-axle Citypower, which is based on the Atego from Daimler Trucks and is currently still at the very beginning of its development. The Citypower might be available starting 2023.

Dr. Johannes F. Kirchhoff said in conversation with H2-international, "We could balance out the higher CapEx with the lower OpEx." Since in his experience "the customer wants nothing to do with all the bothersome details", he offers a comprehensive service package down to the H_2 refueling station. The purchase eventually pays for itself within a few years. "I achieve this through the bundling," said the CEO. With regular sales, the accompanying H_2 infrastructure will also pay for itself.

MANY YEARS OF EXPERIENCE The Northern German company has sufficient experience with hydrogen. Over sixteen years ago, Faun started its first work – at that time still with a fuel cell system from Heliocentris for the waste collection unit of a municipal vehicle for Berliner Stadtreinigung (BSR; see H2-international Jan. and Oct. 2010, and Oct. 2020).

Fig. 2: Georg Sandkühler explains which components will feature in the body

Since then, much has happened. According to the company that employs more than 2,000 people, already "in numerous cities, like Berlin, Duisburg, Bochum and Brus-

sels, hydrogen-powered waste collection vehicles are on the road that not only help remove waste and excess materials, but at the same time keep air in the city clean and noise pollution low." In June 2021, Faun, in the presence of then German transport minister Andreas Scheuer, ceremoniously handed two H_2 garbage trucks over to the BSR. The total number of units is to rise to twelve.

In order to be able to successively ramp up production capacities, Faun has involved itself in, among others, the Clean Hydrogen Coastline project in northwestern Germany with industry partners like ArcelorMittal Bremen, EWE, Gasunie, SWB and TenneT. The investment in these projects is to total up to 1.3 billion euros. The aim is to expand production in such a way that up to 12,000 vehicles can be put into service by 2026.

The need for market-ready H_2 trucks is large. In the call for commercial vehicles with alternative drive systems that NOW started in August 2021, proposals around 250 million euros were submitted. A further call is to follow in the course of this year. By 2024, 1.6 billion euros total is to be invested in climate-friendly commercial vehicles and infrastructure.

> "Doing a few battery electric trucks is easy; doing hundreds is near impossible. Doing a few fuel-cell trucks is a pain in the butt; doing hundreds is a walk in the park.""
> *Craig Knight, CEO of Hyzon Motors*

GIANT GLOBAL INTEREST IN H_2 TRUCKS Just how great the interest in H_2 commercial vehicles is worldwide is also shown by the many new players, cooperations and projects. In November 2021, more than 30 businesses in the state of Rheinland-Pfalz founded the network HyCoVe (Hydrogen-based Commercial Vehicles), to jointly advance the development and testing out of H_2 commercial vehicles.

The economic minister of the state, Daniela Schmitt, stated on the occasion of the founding ceremony: "Rheinland-Pfalz is a major land for the commercial vehicle industry. The industry is one that structures the state and is a decisive pillar in value creation, jobs and innovation. With HyCoVe, we are bundling the current activities and expanding them in a targeted manner, to enable the successful use of hydrogen technologies in practice." She publicized the goal of the western German state of becoming the leading site in the country for hydrogen-powered trucks and buses, but also agricultural and construction equipment.

Another network is H2Accelerate. Members of this European association are Linde, Shell, OMV and TotalEnergies, as well as Daimler, Volvo and Iveco. The aim of this partnership is to put hydrogen-powered heavy-duty vehicles on the roads. Concurrently, Shell is planning to put the needed refueling stations in operation. The oil corporation wants to erect several stations between Rotterdam, Cologne and Hamburg by 2024. The plan envisions 150 H_2 stations along these corridors by 2030.

OMV is also testing, together with Hödlmayr, the use of alternative drive systems in heavy transport. Hödlmayr wants to fortify its own vehicle fleet with fuel cell trucks over the next few years. CFO Robert Horvath stated, "We currently assume that hydrogen will be the most viable future option in the truck sector. Battery-electric quickly reaches its limits with us due to the heavy loads and long routes."

Daimler, meanwhile, is further developing its LH_2 trucks with Volvo. In addition, the Swabian company has taken drastic restructuring measures. At the end of 2021, the Stuttgart-based corporation completed the previously announced split-off of the commercial vehicle division from the passenger car division. The commercial vehicle division until then had more than 100,000 employees and designated itself the global market leader for commercial vehicles. The head of Daimler Truck, Martin Daum, stated, "In our factories, where transmissions, engines and axles are manufactured, 30 to 40 percent of the tasks and thus the jobs could be eliminated." Since then, the car and van business has been operating under the name Mercedes-Benz Group AG.

Fig. 3: Loop Energy presented its T505 system during Hannover Messe

The tanks for the liquid hydrogen could come, for example, from Faurecia, who in October 2021 signed a cooperation agreement with Air Liquide. Together, the companies want to advance the development and manufacture of liquid hydrogen storage systems, especially for heavy-duty applications.

Another supplier in the H_2 segment is Tevva. The Britisch developer of electric commercial vehicles ordered FC systems from Loop Energy in April 2022. The 50-kW power T505 modules (see Fig. 3) are to be installed as a range extender for 7.5-tonne lorries. The energy for the total range of 500 kilometers (310 miles) is to be stored half in the battery pack and half in the hydrogen tank.

Traton, truck subsidiary of competitor Volkswagen, in contrast, is set on the battery-electric drive in long-distance travel and plans to invest 2.6 billion euros in this technology until 2026. Hydrogen could only be a supplement in certain niches, Traton head Christian Levin told the newspaper Die Welt.

RETROFITTING OF FLEET VEHICLES Retrofitting solutions are a focal point for not only Clean Logistics (see p. 10) but also, for example, Proton Motor. The Bayern-based fuel cell manufacturer started a cooperation with automotive engineering firm Lauer & Weiss in November 2021. The Stuttgart-based engineering company specially founded a company, Green Power Systems GmbH, to be able to act as a system integrator for customer projects in the future.

"Customers often find it difficult to dimension the right fuel cell system with respect to the battery capability and in accordance with the overall vehicle design. This problem is to be solved by our business cooperation," explained Proton Motor sales manager Matteo Schmid. Walter Bollinger, member of the managing board at Lauer & Weiss, added, "With Green Power Systems, we're expediting the retrofitting of basic electric high-voltage vehicles with batteries or various alternative range extenders like biogas and LNG. Complete fuel cell vehicles too." ||

Category: Electric transportation | **Author:** Christoph Burkard

USING HYDROGEN IN FREIGHT TRANSPORT

Hydrogen Regions series: HyExperts Fulda

Fig. 1: From left to right, Christoph Burkard, Caroline Schäfer, from Landesstelle Wasserstoff of LEA Hessen, and Matthias von der Malsburg, also with LEA Hessen [Source: Region Fulda]

During a media-effective ceremony on May 12th, 2022 at the event hotel Titanic on the Chausseestraße in Berlin, NOW GmbH together with German transport minister Volker Wissing cheerfully presented the funding decisions for the new HyStarter Regions and the participants in the second round of the HyExperts program (see also p. 18). A good two years before, Martin Thaler, as the representative from the city of Fulda, likewise stood onstage in Berlin to accept funding from the federal transport minister, then Andreas Scheuer. It was 300,000, an outcome from the first call for HyExpert Regions. What has happened in the meantime? What is special about Hydrogen Region Fulda?

One thousand fuel cell trucks on the road by 2026, including service and refueling options for local and long-distance transport as well as buses, in East Hessen and the bordering regions is the ambitious goal of stakeholders in HyExpert Region Fulda. In a study within the corresponding program for hydrogen use in the transport sector in East Hessen, called HyWheels, commercial traffic flows in the region, possible locations for regenerative energy structures to produce green hydrogen, fueling station locations and the establishment of a management center were analyzed. At the same time, the first prototypes for fuel cell trucks were also presented.

The first preliminary result of this analysis was that four locations for hydrogen fueling stations in the district of Fulda could be considered: Hünfeld-Michelsrombach, Fulda-Nord, Eichenzell and Flieden. A multi-phase plan envisages the design and construction of the first two fueling stations and the deployment of 20 to 40 vehicles in 2023. The target of 1,000 vehicles with 10 to 15 fueling stations is to be reached by 2026. Suggested was also the creation of a central information and coordination office for hydrogen within the management organization Region Fulda.

Ten months after the end of the study, of course no fueling station has been built and no hydrogen truck is yet on the road. However, in the last call for tenders in January 2022, three investors applied to get funding for fueling stations in Hünfeld-Michelsrombach, Fulda-Nord and Eichenzell. A working group for hydrogen under the management of Region Fulda Wirtschaftsförderungsgesellschaft mbH made sure that the applications did not have any competing overlap. To each of the applications was attached a page that references the other proposals. In this way, freight transport companies should be given maximum assurance of energy supply for their H_2 vehicles.

Together, the submitted funding applications work out to a production of 500 tonnes of green hydrogen and 30 to 50 refuelings per day at three hydrogen fueling stations. If all the planned projects can be realized, the targets for year 2023/2024 set out in the HyWheels study will be exactly fulfilled.

CENTRAL COORDINATION OFFICE ESTABLISHED In addition, a central information and coordination office for hydrogen (Landesstelle Wasserstoff) at the economic development agency (Wirtschaftsförderungsgesellschaft) of Region Fulda, which operates it together with the city of Fulda, regional district of Fulda and the chamber of commerce of Fulda, has been established. Here, not only are inquiries about hydrogen answered, but the threads of a growing active H_2 network are being spanned. “At this point, we’re talking about H_2 Cluster Region Fulda,” said managing director Christoph Burkard.

What’s special about Fulda’s H_2 cluster is that it’s a union of two storylines that arose independently of one another, and both followed a bottom-up approach. The first starts back in 2015 with an initiative of the domestic shipping industry and ends up in the HyExpert/HyWheels study. So nearly all the members of H_2 Cluster Region Fulda had already been working here.

The second bottom-up approach came from the engineering industry. The Fulda-based engineering firm EDAG had parallel to the HyExperts study also applied to the federal ministry of transport's competition to become a hydrogen innovation center (Innovations- und Technologiezentrum Wasserstofftechnologie, ITZ, see H2-international Feb. 2022 and Aug. 2021) and had asked Region Fulda Wirtschaftsförderungsgesellschaft for support. Out of this came a working group that was busy building an H_2 fueling station in Fulda-Nord, directly near EDAG's office. Unfortunately, none of the tenders from Hessen were accepted in the ITZ competition in the end. What stayed, according to Christoph Burkard, was the momentum of the working group, "which was able to be preserved in H_2 Cluster Region Fulda."

CLOSE-WORKING NETWORK IS A FACTOR FOR SUCCESS With no additional personnel, the management of H_2 Cluster Region Fulda is essentially being handled by the standard members of Region Fulda GmbH. Managing director Christoph Burkard, however, has a lot of support from Caroline Schäfer and Oliver Eich of the Hessen state energy agency (LandesEnergieAgentur, LEA), which supports H_2 Cluster Region Fulda with not only expert knowledge and transregional contacts, but also financially. In addition, Fulda is linked through the governmental district of NordOsthessen (NOH) with Kassel, where the project of a HyExpert Region from the second round of tenders has recently started up. A major key to success, managing director Christoph Burkard states, is the engagement of an external expert to manage the project of the H_2 cluster. Namely, Dr. Volker Strubel and his company Innovationgreen from Denzlingen in Freiburg.

FEASIBILITY STUDY ON FC TRUCK PROCUREMENT What H_2 Cluster Region Fulda is now still missing are fuel cell trucks. Over 60 Hyundai Xcients are already moving about Switzerland. In Germany, however, only demo vehicles have been put into play. Hydrogen-run tractor trailers? Not a chance. For this reason, H_2 Cluster Region Fulda started in January 2022, with funding from the federal support program for electric commercial vehicles KsNI, a feasibility study on the procurement of fuel cell trucks, in cooperation with the LEA and Cologne-based engineering firm EMCEL.

An early high point was the celebration of "The Day of the Fuel Cell Vehicle" on March 22nd, 2022 in Technologiepark Fulda-West, together with LEA Hessen. Caroline Schäfer, from LEA Hessen, was truly pleased: "More than 80 participants were able to test out, as passenger or driver, the Hyundai Xcient as well as test drive the two passenger car models Hyundai Nexo und Toyota Mirai. To finally experience the technology for themselves was everyone's goal on this day. And as you can see, the feedback from all involved was extremely positive."

In separate events the following weeks, representatives from Hyundai and Clean Logistics, who retrofitted Hyundai's diesel semi-trailers with hydrogen drives, took questions from the shipping and logistics division of the H_2 cluster. As part of the feasibility study, the shippers will be guided along far enough that they will be able to apply for funding to order fuel cell trucks with the next KsNI call for tenders this summer. Subject to the approval of the applications for funding, the envisioned 20 to 40 H_2 trucks in operation by year 2023/24 in the detailed plan of the HyExperts study could become a reality.

GOAL: ESTABLISHMENT OF A REGIONAL VALUE CHAIN Throughout all of our efforts, H_2 Cluster Region Fulda has the clear goal of a complete regional value chain, from the regenerative energy generation to the production of green hydrogen, to the provision of fuel cell trucks operated by domestic haulers with readily available fueling and service stations. We're also now thinking about how to work public transportation in for not only the city and intercity buses, but also the non-electrified tracks Vogelsbergbahn and Rhönbahn as well as Fulda's City-Bahn. A feasibility study is currently being prepared. And why all this? "Our motivation is clear," said Christoph Burkard in closing, "We're supporting the important to us industries of freight transport and engineering, and at the same time creating the basis for improving quality of life, the most precious commodity in our region." ||

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Category: Electric transportation | **Author:** Michael Nallinger

THE FUEL CONUNDRUM FOR H_2-TRUCKING

What the future holds for compressed gas, liquid hydrogen and cryogas

Fig. 1: This type of trial refueling station could potentially fill cryogas storage systems [Source: Cryomotive]

Gaseous or liquid hydrogen? It's a dilemma facing everyone involved in the refueling of heavy-duty vehicles. It makes no difference to the power system whether the fuel is a gas or a liquid as the fuel cells can process the hydrogen regardless. In infrastructure terms, however, it's another matter. The consensus among experts is that it's not economically viable for fuel station operators to support every available technology in the long run. One alternative is cryogas, which is produced by cooling pressurized gas to extremely low temperatures or by directly compressing liquid hydrogen. Work is currently underway to deliver cryogas tank systems that will give a range of around 620 miles (1,000 kilometers), the CryoTRUCK project and the Salzburger Aluminium Group initiative being prime examples.

The most popular way to store hydrogen in vehicles is in the form of compressed gaseous hydrogen, otherwise known as CGH_2, at 700 bar. Despite this high pressure level, at ambient temperature it's still not enough to compress the gas to a density that will allow 80 kilograms of hydrogen to be stored within the installation space available in today's long-haul trucks, says Tobias Brunner. According to the director of startup company Cryomotive, the high storage pressure also leads to high costs for the carbon-fiber tank reinforcement. Added to this is the considerable amount of energy required to pressurize the hydrogen and precool it during refueling.

Another option for commercial vehicles is the storage of liquid hydrogen, LH_2 for short, in vacuum-insulated low-pressure vessels. These have the advantage of allowing a high physical density which is inherent in the liquefaction of hydrogen. On the negative side, a substantial amount of energy is needed during liquid hydrogen production in order to cool hydrogen gas to ultra-low temperatures of around -250 °C. The risk of evaporation and the associated hydrogen losses caused by warming are also additional drawbacks. In order to prevent hydrogen boil-off, a high level of insulation is crucial.

This means that the two vehicle storage techniques that are available today for hydrogen, namely compressed gas or liquid hydrogen, are subject to a number of technical challenges. Enter cryogas. A cryogenic gas at pressures of up to 400 bar and with temperatures ranging between -240 °C to -100 °C, this alternative means of hydrogen storage can be arrived at in one of two ways: through the cooling of compressed gas to ultra-low temperatures or through the direct compression of liquid hydrogen. "Cryogas marries the benefits of gaseous and liquid hydrogen while also avoiding most of the disadvantages," says Cryomotive boss Brunner.

TWO WAYS TO MAKE CRYOGAS

The production of cryo-compressed hydrogen, abbreviated to CcH_2, is able to draw on both gaseous and liquid distribution and refueling infrastructure.

- CcH_2 can be produced using a cryopump at a filling station with a LH_2 supply through the direct compression of LH_2. Here the pump energy requirement is less than 0.5 kWh/kg.
- CGH_2, delivered by tube trailer at present or supplied via pipelines in the future, can be compressed at the refueling station by a high-pressure compressor and then subcooled in a cryogas cooler to about -200 °C. This process consumes much less energy and is far less expensive than full-scale liquefaction, with low temperature and pressure combining to achieve an equally high density to that of liquefied hydrogen.

620-MILE RANGE PER REFUEL Cryomotive is cooperating with manufacturer MAN Truck & Bus, commercial vehicle refitter Clean Logistics, test experts IABG and the Technical University of Munich as part of the CryoTRUCK consortium. The group is developing a cryo-compressed hydrogen gas tank with a refueling system for long-distance fuel cell trucks. The aim is to achieve a range of 620 miles with each fill-up and a refueling time of around 10 minutes.

Brunner is convinced of the advantages the technology brings: "As well as the extremely high storage density, components are lighter, safer, more compact and more robust when in operation. Less energy is needed to fill cryogas storage tanks and they can be filled more quickly, without incurring losses and at a lower cost." This is why he believes they

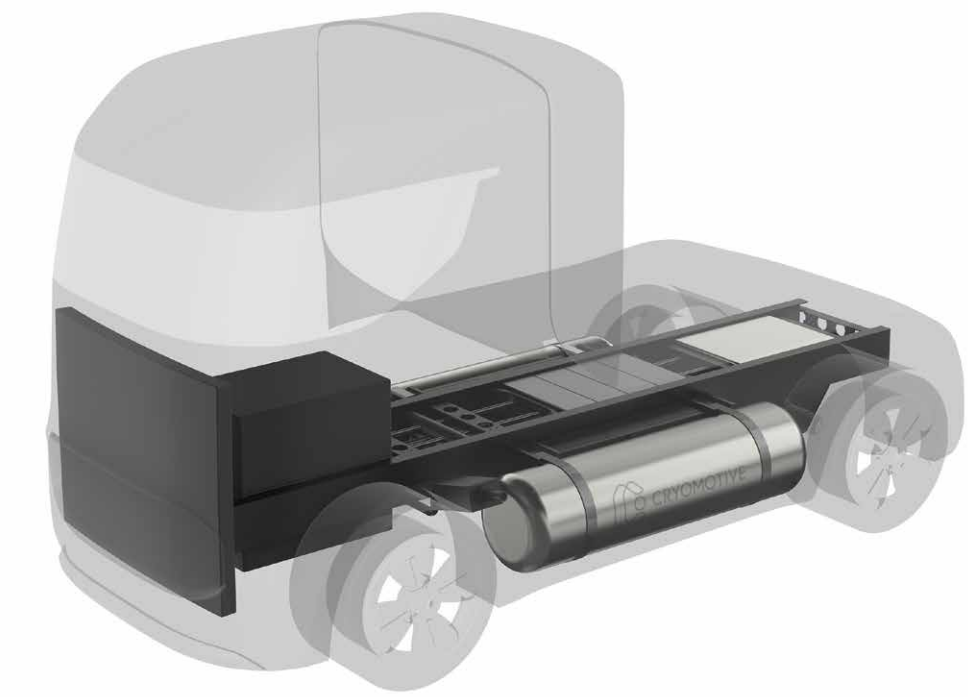

Fig. 2: The compact design fits two vessels along a truck's frame where diesel tanks are currently located [Source: Cryomotive]

are particularly suited to long-distance commercial vehicles but are also an appropriate choice for special vehicles such as mining trucks, dump trucks and small aircraft intended for urban air mobility applications.

Cryomotive lists a variety of specific plus points for cryo-compressed hydrogen, or CcH_2, in terms of its use in long-range commercial vehicles:

- It is nearly twice as dense as hydrogen pressurized to 700 bar. It also exceeds the density of liquefied hydrogen, which is already very dense, by up to 20 percent.
- It is impossible for cryogas to evaporate either during refueling or when stored on board.
- A minimum pressure level of 10 bar to 15 bar is sufficient to supply a fuel cell system with a high power density or a supercharged hydrogen combustion engine.
- Refueling can occur at extremely high flow rates of up to 800 kg/h without the need for energy-intensive precooling.

The CryoTRUCK project has been devising a system design for initial prototype tank systems comprising two interlinked vessels with an approximate storage capacity of 80 kilograms. That's the equivalent of roughly 2,600 kilowatt-hours of stored chemical energy (see fig. 2). Further component development is ongoing. According to the Cryomotive chief, the first generation of cryogas refueling stations is also now at the design stage.

And the next phases of the project have already been scheduled, too: This year and next year will see the first prototype tests for the components, with system testing planned to start in 2024. Brunner then also envisages the integration and commissioning of tank systems within the truck. Filling station commissioning (see fig. 1) and experimental truck tests are lined up for the first half of 2025.

YEARS OF TESTING AT BMW Commenting on the challenges that need to be overcome, Brunner doesn't foresee any "fundamental technology showstoppers." After all, he says, the technology has been proven in cars for a number of years at BMW. The relevant requirements for use in trucking are much less stringent than for automobiles, he claims. What's more, the company director points out that using the technology in commercial vehicles has significantly greater benefits than its deployment in cars which only require small storage capacities. Nevertheless, the integration of a cryogas tank system comprising several vessels has yet to be demon-

Fig. 3: Tobias Brunner [Source: Cryomotive]

strated in large commercial vehicles. Brunner is, however, certain that the cost objectives are achievable.

In order to make that possible, the development program aims for prototype testing to be carried out as soon as possible. It also foresees incorporating design-to-manufacturing and design-to-cost techniques at the prototype development stage. Here, Brunner is confident of hydrogen's future in heavy-duty vehicle transportation: "Rising energy and raw material prices are pushing the balance of power between battery and hydrogen fuel cell propulsion systems in favor of hydrogen since this can be manufactured and distributed globally and at off-peak times." He estimates that the market in the European Union for hydrogen trucks will reach up to 100,000 vehicles by 2030.

LIQUID HYDROGEN CRYOTANK SYSTEM FOR TRUCKS Similarly optimistic are the people at Salzburger Aluminium Group, otherwise known as SAG. "Hydrogen is very well suited to use as a fuel in heavy-duty transport. In particular the range and refueling time are comparable to diesel trucks. Two factors that are hugely important for profitability in long-distance transportation," says Thomas Stepan. The cryogenic engineer from the R&D team at SAG makes the assumption that liquid hydrogen trucks will be hitting the roads by 2025 at the latest.

A family-run company based in Austria with around 1,100 employees worldwide, SAG is currently busy developing a liquid hydrogen cryotank system for trucks. Forming the basis for the tank system (see fig. 3) will be a double-skinned, vacuum-insulated stainless steel vessel that should offer the greatest amount of capacity in the existing installation space. It is understood that a special valve system that is designed for extremely low temperatures will ensure safe refueling and provide a reliable supply of hydrogen to the fuel cell.

The liquid hydrogen tank has been under development for around three years. In the fourth quarter of 2021 the first certifiable prototype was rigorously tested with liquid hydrogen. At the moment, trials are being carried out that focus on integration with regard to the vehicle and powertrain. The findings have been overwhelmingly positive: "The results thus far have been very promising and provide an excellent basis for further optimization of the tank design," reports Stepan.

The next step is to obtain unconditional approval for operation on European roads which it is hoped will be achieved by the end of 2022. Thereafter, SAG will concentrate on industrializing and standardizing its manufacturing process – something which is a necessity for series production in the automotive sector. In addition, the tank must undergo to an extensive product validation procedure to provide assurances about the product's service life. The hydrogen expert also believes it's vital that customers put the tank through its paces on the road. The timeline for this testing is scheduled to take place between 2023 and 2025 and will be followed by the buildup to series manufacturing.

EXCELLENT VACUUM INSULATION STOPS BOIL-OFF SAG can rely on its many years of experience in the large-scale manufacturing of cryotanks for liquefied natural gas. Even so, the cryogenics engineer is well aware of the new challenges: "The significantly lower storage temperature of LH_2 raises the requirements for the tank components considerably," states Stepan, adding that material compatibility with hydrogen is also an issue. Another huge challenge he mentions is the prevention of hydrogen boil-off. This, he explains, requires excellent vacuum insulation as well as highly specialized tank design, for example in terms of line routing.

However the biggest task is making the liquid hydrogen cryotank technology practicable and, above all, economically competitive while at the same time meeting customer expectations with regard to maximum performance, functionality and capacity. How these goals will be met is illustrated by Stepan using material compatibility as a case in point:

Due to the low storage temperature and the risk of hydrogen embrittlement, high-alloy stainless steel is the most suitable material for liquid hydrogen tank production, he says. The disadvantage, on the other hand, is most of all the price and the weight of the construction. "In order to find an appropriate balance between the diametric requirements for the tank design it's important to clarify things in detail with the customer," the hydrogen expert confirms. The need to take such an approach applies equally to the collaboration with a large number of highly specialized suppliers so as to seamlessly integrate a variety of components into the tank system. "Teamwork that extends beyond our own company is by far our most important strategy for solving the challenges that lie before us," he declares.

STUDY ON DIFFERENT SUPPLY PRESSURES As part of the next step on the development journey a SAG team of experts is currently researching storage solutions that work with different supply pressures and that can be deployed in trucks regardless of whether they are equipped with a fuel cell or an internal combustion engine. The technical requirements have been compiled by the researchers in a compatibility study. The background to this is that different hydrogen power systems require different supply pressures. These pressures range from less than 10 bar for battery-powered fuel cells to up to 300 bar for high-pressure direct injection in an ICE vehicle.

The study's findings show that, for direct hydrogen supply from a liquid hydrogen tank, the nominal working pressure of the PEM fuel cell or the hydrogen combustion engine should be as low as possible and under 15 bar so as to minimize the weight of the tank and ensure adequate storage capacity and holding time.

For high-pressure applications up to 300 bar, gaseous compression at the vehicle is inefficient and not practical, the study reveals. In this case, the use of a cryopump appears to

be a sensible option, it says. However, the study goes on to state that this type of pump is not yet available and is the subject of applied research.

WIDENING SCOPE Cryomotive, which is based in Taufkirchen near Munich, is also focused on making further developments to refueling technologies. The company strongly believes that 350-bar CGH_2 tank technology for back-to-base transportation will become more established and in the medium term will be expanded to include storage and refueling technology that is suitable for long-haul vehicles. Nevertheless, Brunner is eager to emphasize that: "For long-distance applications, 350-bar CGH_2 isn't viable. And it seems that 700-bar CGH_2 isn't viable for reasons of cost on the refueling side."

In his view, subcooled liquid hydrogen, or sLH_2, and cryo-compressed hydrogen are the most promising options with the potential to provide a complementary technology that is suitable for long-distance trucking. The use of subcooled liquid hydrogen not only presupposes cooled and thus liquefied hydrogen, but also a higher pressure level compared to ambient pressure. It's this process that Daimler and Linde seem to be keenly pursuing. A huge challenge exists for both sLH_2 and CcH_2 processes in terms of their ability to allow sufficiently rapid loss-free refueling as well as the costs involved. "That's why we see excellent opportunities for CcH_2 in the competitive environment in the future," Brunner elaborates.

And how do things look from a cost perspective? In the Cryomotive director's opinion, compressed gaseous hydrogen at 350 bar remains the cheapest option for return-to-base truck operations. By contrast, it will be costs and availability that will be decisive for green liquid hydrogen in the future. As Brunner summarizes, "So long as it's not possible to offer green LH_2 for much under 10 euros per kg at the fuel station, it will potentially continue have a considerable disadvantage in comparison with CGH_2." As an alternative to CGH_2, cryogas produced by cryo-cooling CGH_2 could also continue to be cheaper than liquid hydrogen, he says. These variables prompt a clear conclusion on Brunner's part: "The search for tank and refueling technology for long-distance trucks is open-ended." ||

"A DEFINITE DECISION IS URGENTLY NEEDED"

H2-international spoke to Thomas Stepan, cryogenics expert from the R&D team at SAG, about the alternative possibilities for refueling long-range trucks:

Fig. 4: Thomas Stepan [Source: SAG Innovation]

How do you rate the chances of liquid hydrogen in comparison with other high-pressure gas storage?
Stepan: Cryogenic storage of hydrogen makes sense whenever the benefits of this storage solution, especially higher energy density and lower costs, outweigh the disadvantages of its application, for instance hydrogen loss if standing times are long. Liquid hydrogen is therefore inevitably destined for use in cost-driven applications that have a high energy requirement and where there is little idle in operating cycles. The additional energy input and the higher costs that are incurred when hydrogen is liquefied can also be justified where higher energy density leads to a significant cost reduction, for example in long-haul transportation.

What opportunities do you see for cryogas to act as a kind of link between the two technologies?
With cryogas, there's potential to further increase the energy density of the storage system in comparison with liquid hydrogen. Also hydrogen loss through boil-off is a much smaller issue since the pressurized tank is designed to withstand up to 350 bar. This is offset by the combined requirements of the system with regard to thermal insulation and high-pressure application. The ability to produce a high-pressure tank that not only can be vacuum insulated but that can also meet the requirements of predominantly motive applications is an enormous challenge.

In your opinion, how do the costs of the various technologies stack up?
The relative costs of gas and liquid hydrogen storage systems have been evaluated by the machinery and vehicle specialist CNH. In their assessment the liquid hydrogen system came out on top. Of course, in order to gain a holistic view, you also need to take into account the costs involved in manufacturing the stored medium as well as the transport costs. There is consensus on the target price: If prices start at 4 to 5 euros per kilogram of hydrogen, a hydrogen-powered truck will be able to run on the same costs as current diesel vehicles.

What impact does the existence of several alternatives have on the hydrogen refueling station network? To what extent is it sensible and economically feasible to depend on a number of different technologies for the refueling of heavy-duty trucks?
Even in the transitional phase we'll see both storage systems and hence also both alternative refueling possibilities for heavy-duty trucks. As time goes on, the technologically superior but above all more cost-efficient option will prevail. From an economic perspective it makes no sense to have two different approaches. For hydrogen to succeed as a fuel it's therefore crucial that the political establishment quickly sets the course to allow the build-out of fuel station infrastructure – at least on major transport routes.

What signals are you getting from the political establishment and industry in terms of a decision?
A definite decision is urgently needed. It would be important to create more incentives generally to encourage the switch to sustainable energy carriers, in a similar way to what has happened for e-mobility. Both scenarios require large-scale investment to repurpose infrastructure. In addition to the great deal of risk already attached to such projects, the lack of a political framework is leading to further delays and consequently to further increases in carbon dioxide emissions.

In your view, when will a decision need to be reached?
The targets that have been put in place to limit global warming are barely being met as it is. Therefore these kinds of fundamental decisions are better made sooner rather than later.

Fig. 1: A view of how the new cellcentric site should look. The design incorporates special green spaces, including on the factory roofs. [Sources: cellcentric]

Category: Electric transportation | **Author:** Michael Nallinger

CELLCENTRIC OVERCOMES MAJOR OBSTACLE

Fuel cells for heavy-duty transport and stationary applications

A positive result in a community poll has apparently cleared the way for cellcentric to press ahead with its plans to mass-produce fuel cells in the German town of Weilheim an der Teck. Cellcentric – a 50-50 joint venture by Daimler Truck and Volvo – is expected to start building its new factory in the course of the year. Preparations for the highly automated manufacturing facility have "already come a very long way," H2-international was informed.

In all, 70 percent of the 8,100 eligible voters living in the Swabian municipality of Weilheim an der Teck, which is situated to the southeast of Stuttgart, chose to support the official designation of the industrial park as the site of the factory. Participation was high with a 60.7-percent turnout. Winfried Kretschmann, minister president of Baden-Württemberg, had made particular efforts to encourage the new manufacturing facility. The Green-party politician was therefore suitably pleased with the result. He now anticipates this positive outcome will give the project a major boost, particularly as there was a large turnout.

The community is hopeful that locating the factory in the Rosenloh industrial park will bring opportunities for development, especially for local businesses. It's a view that's echoed by cellcentric. The company reports that it intends to not only develop and produce tomorrow's sustainable transport solutions but that it also wants to create added value in the area. It is expected that the company will generate up to 450 extra jobs.

The new factory building itself will also have eco-credentials of its own. Green spaces designed especially with ecology in mind will be created across the site in various locations, including the roofs, in order to offset the land lost through construction. What's more, waste heat arising from the production of green hydrogen, which is needed to test the fuel cell systems, will be used in the Rosenloh industrial park and in neighboring areas, according to the plans. The hydrogen will, however, not be produced by cellcentric itself, the company has told H2-international. Instead, the infrastructure required will be put in place by a third party from which the hydrogen and the excess heat will be obtained.

DAIMLER TRUCK AND VOLVO STILL RIVALS Provided that all permissions have been granted, building work is scheduled to start during 2023, reports CEO Matthias Jurytko in response to H2-international's inquiry (see fig. 2). When Daimler Truck and Volvo entered into their joint venture about a year ago, the companies announced that they would be initiating customer trials of fuel cell trucks in approximately three years and starting series production in the second half of the current decade. Despite their cooperation, the two companies take great care to emphasize that all their vehicle-related activities take place separately from one another and that they remain competitors. This independence, they say, extends across their entire vehicle and product portfolio and particularly applies to the integration of fuel cells within vehicles.

According to Jurytko, his company is currently creating prototypes for commercial vehicles and also for the Power

Fig. 2: Matthias Jurytko, CEO of cellcentric: "The challenge is to develop highly automated systems that meet rigorous requirements while minimizing cycle times."

Systems business unit of Rolls-Royce which intends to deploy cellcentric-manufactured fuel cell systems in its applications. "We are cooperating with Rolls-Royce on stationary fuel cell generators as a means of providing carbon-neutral emergency power generation for security-critical facilities such as data centers," explains the cellcentric CEO. The intention is that these generators will offer emission-free alternatives to the diesel engines which are currently used for supplying backup power or for covering peak loads.

PRE-SERIES PRODUCTION FACILITY BY END OF 2022 The cellcentric site in the Pliensauvorstadt quarter of Esslingen is the planned location for a pre-series production facility which is due to be established by the close of 2022. "Series manufacturing processes are already being applied there on a smaller scale," confirms Jurytko. "For the next stage it's a matter of bringing together mass production at the new site and transferring expertise."

One particularly challenging aspect is the large number of cells that need to be bundled together to form stacks. The CEO describes the current situation: "At the moment we're in a semiautomated production situation. In order to manufacture the quantity of fuel cells required we'll need our manufacturing to be fully automated." The challenge is to develop highly automated systems that meet rigorous requirements while minimizing cycle times, which in turn has an impact on costs, he says. Nonetheless, the company chief is optimistic: "We're working flat out on this issue and we've already come a very long way."

He's equally positive when it comes to the main application area for the manufactured stacks, in other words heavy-duty vehicle transportation. In addition to the high energy density of the hydrogen, he points out, the low weight of the fuel cell and the short refueling time are qualities that indicate their use in fuel cell power systems. Both aspects are comparable with conventional diesel engines, he says. ||

Category: Development | **Authors:** Jan Michalski, Christopher Kutz, Ulrich Bünger, Michael Ball

GREEN HYDROGEN FOR EMISSIONS-FREE STEEL PRODUCTION

Findings from a metastudy of the LBST

Green hydrogen is the future of German steel industry, which is currently facing major pressure to change due to the challenges of climate protection and increasing international competition. Through H_2-based steel production by direct reduction (DR), on the one hand, greenhouse gas emissions (GHG) in the steel sector can virtually be avoided and, on the other, German industry can once again demonstrate its innovative technology strengths. The energy consultancy Ludwig-Bölkow-Systemtechnik (LBST) has presented an analysis in the form of a metastudy on behalf of the German Hydrogen and Fuel Cell Association (Deutscher Wasserstoff- und Brennstoffzellen-Verband, DWV) in cooperation with DWV's special advisory group HySteel on the role of green hydrogen in the steel industry.

The core task of the study was a detailed discussion of the questions how the H_2 demand of German steel industry may develop by 2045 as well as discuss the technical, economic and ecological parameters for sustainable crude steel value chains in Germany. For this purpose, most relevant studies of the last years were screened and evaluated, complemented by in-depth technical and strategy discussions with representatives of the HySteel Commission.

TECHNOLOGY PATHS FOR STEEL PRODUCTION Today, crude steel production in Germany is based on integrated bituminous or metallurgical coal-based smelting of pig iron in a conventional blast furnace (BF) with subsequent oxygen blowing (basic oxygen furnace, BOF) for fine-tuning the carbon content. A large part of the studies examined assumes that annual crude steel production in Germany will maintain its current annual level of about 40 megatonnes (Mt) of crude steel. In 2018, steel production is responsible for about seven percent of Germany's CO_2 emissions.

Moving away from the use of coking coal to an alternative use of (green) hydrogen as reduction agent is a prerequisite and unavoidable in the long term. In the short term, another option is direct reduction of iron ore based on the use of natural gas (CH_4-DR), constituting an option for a partial GHG emission reduction. In fact, a large part of the approximately 108 Mt of direct reduced iron (DRI), or sponge iron, was produced this way worldwide in 2019.

Further processing of the sponge iron to produce crude steel takes place in a suitable melting unit, which today is usually an electric arc furnace (EAF). To achieve the climate protection targets by 2045, the crude steel production will then be carried out using green hydrogen (H_2-DR), with further processing of the sponge iron in an electric arc furnace operated with renewable electricity.

The German steel industry, comprising crude steel production and plant construction, has already adapted to this alternative, i.e. has presented fully integrated process technology partially based on highly innovative and integrative concepts. A successive replacement of the conventional BF-BOF route by 2045 can enfold in three phases (see Fig. 1): setting the course up to 2030 with the first pilot plants for CH_4- and H_2-DR, consolidation of the market by 2040 and an establishment of a market for green steel by 2045/50. In this way, more than 1 Mt of crude steel should be produced annually in CO_2-reduced or -free mode in first pilot plants already by 2025.

In addition to these three main production routes, another option is the import of sponge iron produced from CH_4- or H_2-DRI overseas is. But this route would only be taken if highly efficient conversion of sponge iron into crude steel in an integrated process were not possible in Germany for economic or strategic reasons. I.e., a switch to the import alternative would lead to energy losses and possibly an undesirable change in the quality of the crude steel. Furthermore, the studies indicate that in the future, the percentage of steel produced from recycled scrap metal using electric arc furnaces may rise from today's 30 % to ≥ 50 %.

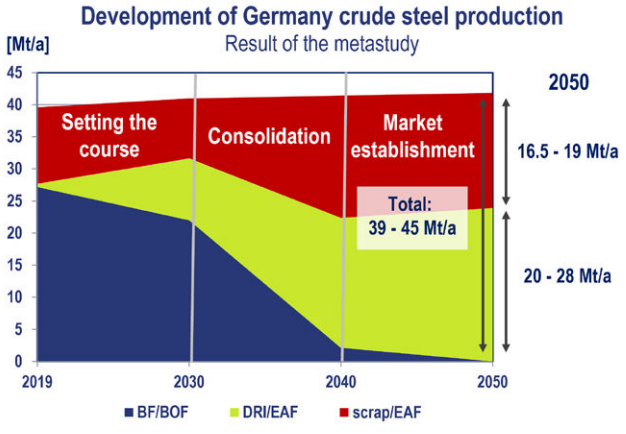

Fig. 1: Possible development of German crude steel production until 2050 [Source: LBST]

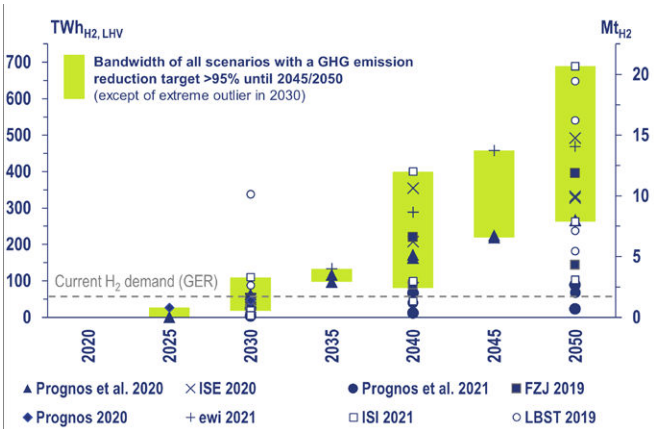

Fig. 2: Development of green hydrogen demand in Germany as predicted by other studies [Source: LBST]

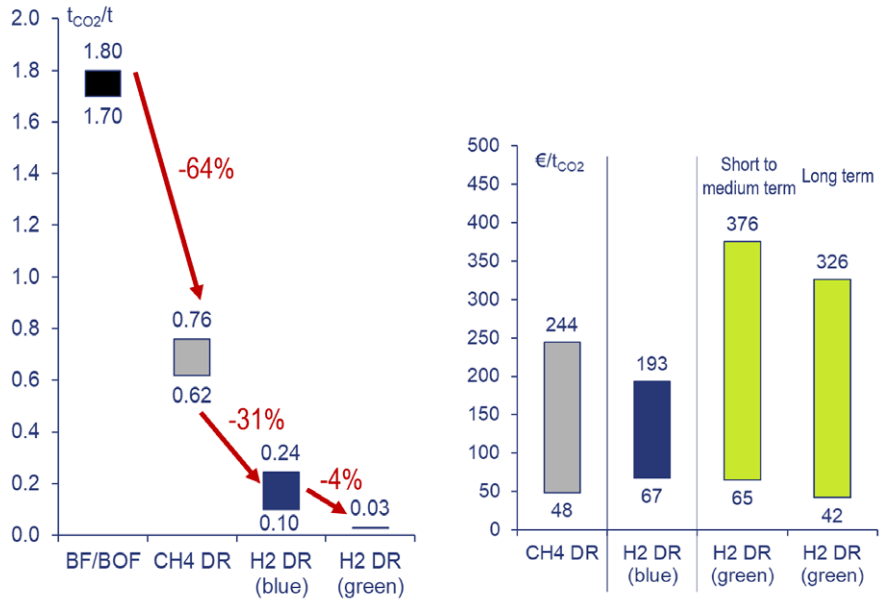

Fig. 3: Comparison of specific CO_2 emissions (left) as well as CO_2 avoidance costs (right) for the different steel production technology paths [Source: LBST]

DEMAND DEVELOPMENT AND SUPPLY OF GREEN HYDROGEN The development of the future hydrogen economy in Germany is being driven by the high pressure to reduce GHG emissions in all sectors. The narrowing of German and EU climate protection targets in recent years is also reflected in the results from an analyses of Germany's future energy supply. Figure 2 shows an overview of the evaluated studies regarding the respective predicted demand development for green hydrogen in Germany. As obvious, the H_2 demand will multiply from about 50 TWh today to 300 to 700 TWh by 2050.

The industrial sector, and in particular the steel industry, has a major role to play, particularly in the transformation during the early phase of up to 2030. All in all, the studies indicate a total H_2 demand, as energy carrier and base chemical, for the iron and steel industry of up to 34 TWh/yr by 2030, or 70 to 100 TWh/yr by 2050. This corresponds to a short-term share of 20% to 40% of the total H_2 demand across all industries, which will lower to 8% to 16% with an increasing H_2 demand in the other industries.

Regarding the origin of the hydrogen, almost all the studies examined assume that Germany will continue to rely on energy imports to cover a large part of its hydrogen demand in the future. Along with the availability potential of renewable electricity and its future costs, including transport and distribution, will determine future energy and hydrogen supply structures. Optimistic cost reductions until 2030 may even result in hydrogen supply costs of as low as 2.5 EUR/kg.

HYDROGEN AS A MAJOR COST DRIVER The current costs of conventional steel production, i.e. by blast furnace and electric arc oven route, lie within a range of 390 to 450 EUR per tonne of crude steel and depend on raw material and energy costs to a large extent accounting for 60 to 80 percent of the total production costs. While in the case of CH_4-DR, similarly to the BF-BOF route, iron ore costs also strongly influence production costs, high hydrogen prices may be the dominating factor for H_2-DR, especially in the initial phase.

In the case of H_2-DR, the additional costs of crude steel production, for example with a hydrogen requirement of 70 $kg_{H2}/t_{crude\ steel}$ and H_2 prices of 1 to 7 EUR/kg_{H2}, amount to respectively about 70 to 490 EUR/$t_{crude\ steel}$. To the purchase cost of a mid-range passenger car, this would only result in a price increase of about one percent, and only two percent for an onshore wind turbine.

The investment requirements for a successive conversion of blast furnaces in Germany to direct reduction technology are estimated to be 10 to 30 billion EUR in various studies. However, it needs to be taken into consideration that a large share of the existing blast furnaces will reach the end of their service life in the coming years anyway, thus creating a favorable time window for new investments in H_2-DR plants.

Figure 3 shows the specific CO_2 emissions along with the corresponding range of CO_2 avoidance costs for the various technology paths. Compared to the conventional blast furnace route, a reduction in emissions of more than 60 percent can already be achieved with CH_4-DR. For real climate protection with a reduction of more than 90 percent, however, H_2-DR will be inevitable.

The large bandwidth of CO_2 avoidance costs is mainly driven by the current uncertainty of the prices of natural gas and hydrogen. Particularly, with very high gas prices and reduced production costs for green hydrogen steel production based on green H_2 can become significantly cheaper than from direct reduction with natural gas or blue H_2, in long term even to below 70 EUR/t_{CO2}.

GREEN HYDROGEN AS "NO REGRETS" OPTION In the overall evaluation of the results, the short- to medium-term perspective until 2030 proposes the conventional blast furnace route and CH_4-DR as the main available paths due to the respective technical maturity and high economic efficiency (see Fig. 4). While the application ofCH_4-DR technology can already significant lower CO_2 emissions, even in the transition phase, it is limited for the conventional blast furnace route. H_2-DR, on the other hand, is not yet technically mature in the first phase and must prove itself with green hydrogen becoming available in sufficient quantities and at favourable prices.

In the long term, the conventional blast furnace route will lose its dominating role, both from an ecological and economic perspective. Also, natural gas-based DR will become less significant in the long run because of the residual yet unavoidableCO_2-emissions and the costs to compensate them. As a consequence, green hydrogen-based DR remains as sole relevant technology path in the long term. Both steel production with blue hydrogen and DRI important will be less relevant options in the long term, both from an ecological and politico-economic point of view.

SUMMARY In conclusion, the meta-analysis shows that the steel industry is aware of the art and consequences of the fundamental requirements for innovation in crude steel production. A concerted effort by the business community with politics is required to achieve this conversion supported by a reliable framework conditions. In principle, it

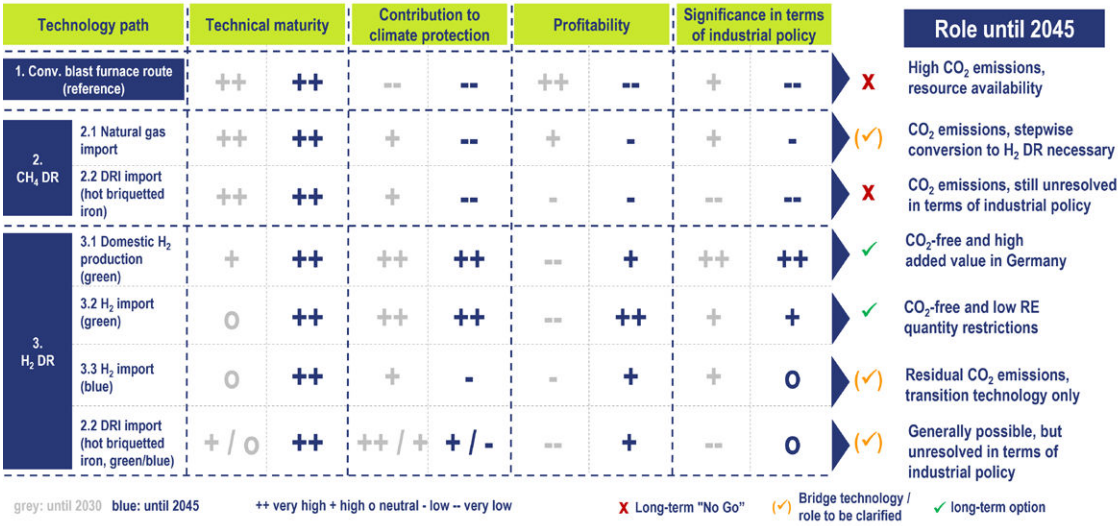

Fig. 4: Evaluation and role of technology pathways in the short-term (gray) and long-term perspective (blue)

helps that DR technology has been internationally commercialized and that German plant builders have established a knowledge base in good time. The steel industry, inevitably a major "no regrets" consumer of hydrogen, is one of the key drivers for the necessary market ramp-up and expansion of a future German hydrogen infrastructure.

This is due at present, on the one hand, to the fact that, likewise for other sectors, alternatives for the conversion to emissions-free steel production are not foreseeable. Furthermore, the large volumes for steel industry locally concentrated will consecutively allow other H_2 users to connect to an existing H_2 infrastructure at low cost. On the other hand, from a broad economic view, the high CO_2 avoidance potential for conversion from the blast furnace route is something to be considered in an early phase of market ramp-up, even with possible supply bottlenecks for low-emissions hydrogen. Setting the course for the future development of direct reduction technology in the steel sector and provision of the industry with green hydrogen therefore is an urgent and immediate task. ||

Note: The present study was conducted between October 2021 and February 2022 as a meta-analysis of relevant literature. The war between Russia and Ukraine that began February 24th has triggered a paradigm shift in German and EU security, energy and industrial policy. With this background, some of the results presented in the study also need reevaluation, particularly regarding the role of natural gas-based transformation paths in steel production, namely methane-based direct reduction (CH4-DR) and the use of blue hydrogen as a bridging technology. Accordingly, an accelerated conversion of the domestic steel industry to domestic green hydrogen-based direct reduction has gained additional importance. In the long-term, it will be the only sustainable option for emissions-free, energy-secure steel production with a corresponding value for the national economy.

This study, funded by the German ministry for environmental protection (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, BMU, currently BMUV), was commissioned by the HySteel cluster of the German hydrogen and fuel cell association (Deutscher Wasserstoff- und Brennstoffzellen-Verband, DWV) in August 2021 and completed in March 2022.

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Category: Development | **Authors:** Thomas Jungmann, Alexander Dyck

HOW STANDARDS CHANGE THE WORLD

Twenty years of fuel cell norms

The importance of hydrogen and fuel cells, both at the national and international level, is strongly growing. Not only through the multitude of national roadmaps toward energy change but also by more and more companies entering the market with promising products is the maturity of the technology becoming increasingly clear. In order to offer safe products to as many regional markets as possible, it is vital to establish globally recognized norms, guidelines and harmonized standards.

For many years, topics under the heading Regulations, Codes and Standards (RCS) have been arriving at the international standards organizations IEC and ISO via a large number of voluntary experts. In the publications of the IEC, the International Electrotechnical Commission, can be found all the safety and compliance tasks involved with fuel cell technologies and systems that focus on electrical aspects.

RESPONSIBILITIES The ISO, the International Organization for Standardization, is home to all issues relating to hydrogen technologies that focus on the safety during system operation and of the system components, particularly gas processing technology. The latter includes general content for wherever hydrogen is used or produced in an energy system, but also specific applications of H_2 technologies with their specific requirements, such as the H_2 quality or adherence to tank filling protocols or the specified use of filler necks on vehicles.

Initiatives to establish norms often evolve from national product development strategies. The aim of normalization work is nevertheless to shape these nationally derived wishes and requirements, with as international consensus as possible, into something harmonizably appliable. These norms are then carried over to and applied at the nation level in accordance with the respective national regulations.

Each country has a so-called mirror committee (Spiegelkomitee) that serves as a link to the foreign structure. In Europe, there is a cross-border body that bundles the national efforts and tries to establish a consensus of the national industries at the international level, as an added value to the greater community. However, there are also a large number of national bodies that are mirror committees and also directly constitute the technical committees (TCs) of the IEC and ISO.

For fuel cell technologies, the committee IEC TC 105 is internationally responsible and is represented by the national mirror committee in Germany, K 384 of the DKE (Deutsche Kommission Elektrotechnik Elektronik Informationstechnik) [1]. For hydrogen technologies, technical committee TC 197 of the ISO is responsible, which is represented at the nation level by the German association for gas and water standards (Deutscher Verein des Gas- und Wasserfaches, DVGW) within the German standards committee (DIN NA) for gas technology, NA 032 (NAGas) [2] (see Fig. 1).

The scope always shows which topics the committees deal with. The norms themselves also outline the product classes as well as their specific allowed use and use purposes. They always give the first clue as to whether, for example, the product or metric under consideration can be tested or ascertained in accordance with this norm, and whether the use under consideration is in accordance with regulations.

The increasing importance of guidelines for hydrogen and fuel cell applications is reflected in the growing number of industrial companies participating in these norm committees. These companies have also recognized its significance for adding value to products throughout their operations and contribute their experience from product development and application of existing standards to the committee work. In this way, they contribute significantly to the further development and, above all, to the harmonization of norms, so that they continue to reflect the current state of the art in the future and are validated and further developed with regard to their usability.

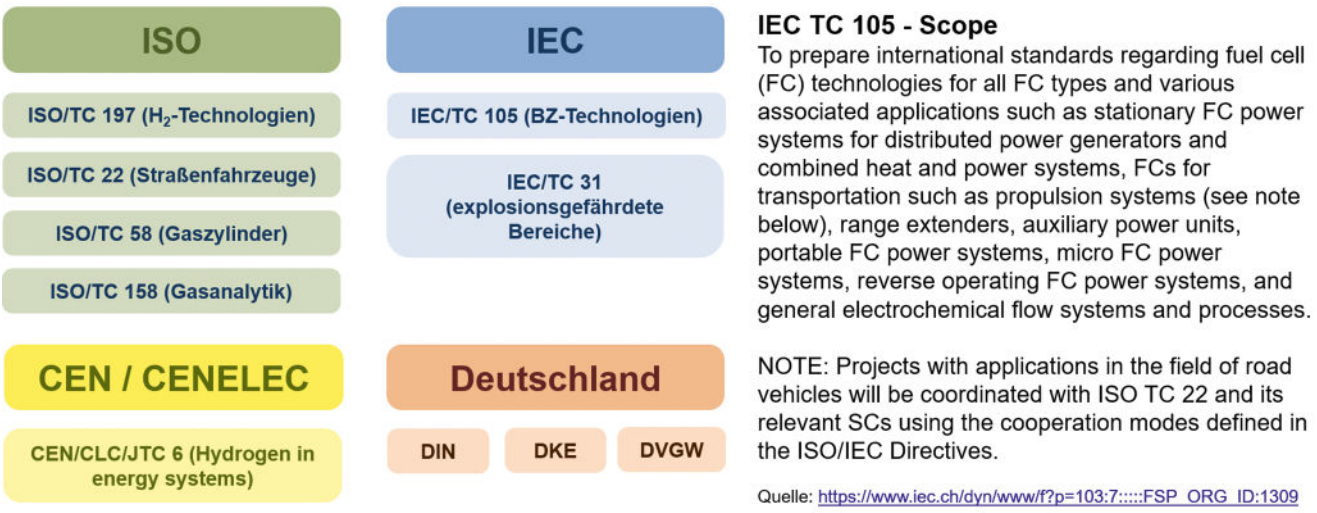

Fig. 1: Relation of standards committees in the field of hydrogen and fuel cell technologies as well as the defined scope of the international technical committee for fuel cell technologies, IEC TC 105, as an example [Source: DLR]

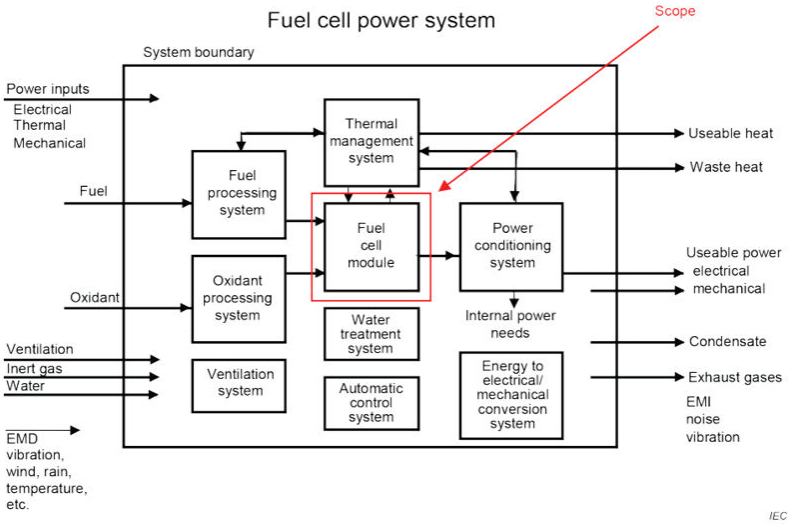

Fig. 2: Definition of the fuel cell module as part of a fuel cell energy system, as generally defined in norm IEC 62282-2-100, or VDE 0130-2-100:2021-04 Brennstoffzellentechnologien [IEC 62282-2-100:2020] [Source: IEC 62282-2-100:2020]

HISTORY OF FC NORM WRITING It started twenty years ago with the development of a norm family for fuel cells [3]. In addition to the definition of terms, the first generation also had a norm for fuel cell safety (see Fig. 2). Considered were one or more fuel cell stacks as well as possible additional components for system integration. Furthermore, this norm, designated DIN IEC 62282-2 in the first generation, is not limited to a specific fuel cell type or power range. Therefore, the defined test procedures can be applied over a wide spectrum and by a large circle of users.

In addition to the abovementioned norm for fuel cell modules and the definition of terms, stationary fuel cells have also been specified as energy generation equipment in the norm family DIN IEC 62282 since 2002. In the first version of DIN IEC 62282-3-2, test procedures for the determination of performance characteristics were defined.

Since then, many other norms have been added to the family for fuel cell technologies. A corresponding overview of topics can be found in Figure 3. From this, it is apparent that certain technology and application fields have undergone further development and classification over the last twenty years.

Thus, for each type of associated product group, there is a description of the safety aspects that must be fulfilled by the product or product group falling within the scope of the norm. This is supplemented by standardized installation instructions. In addition, specific performance tests are outlined for each product (group) and written in internationally recognized norms.

From Figure 2, it is also apparent that the originally pursued detailing will not be further pursued. Also evident was the carrying over of fuel cell terminology from norm 62282-1 into the international electrotechnical vocabulary. The terms can now all be found under the designation IEC 60050-485. Thus, in 2020, a further step was taken towards an even greater normative acceptance of this topic of terminology.

HOW STANDARDS CHANGE THE WORLD It is of great advantage to be able to fall back on a common terminology, in order to avoid misunderstandings in the assignments that may be rampant. The structure of norm IEC TC 105 was adjusted in 2021, and a clustering of application fields was established. The previous structure of the documents remains unchanged until the revision.

Even such a "trivial thing" as the fuel quality of hydrogen for FC application is defined upfront and cost-effective testing for such described. Only this way can system designs and product costs as well as the price for fuel supply be cleanly agreed upon by the market, for example at refueling stations.

In addition to the abovementioned activities in the field of fuel cell technologies, there are a large number of committed experts, especially in Germany, who are pushing forward the issue of norm establishment in the field of hydrogen and fuel cells. In particular, in the area of hydrogen technology, this is NOW GmbH employee Elena Hof, who is currently chair of the national mirror committee ISO TC 197.

RECOMMENDATIONS FOR ACTIVE PARTICIPATION With this article, the two authors wish to raise further awareness of the codification of the current state of the art in the field of hydrogen and fuel cell technologies. However, it is also noticeable from these writings that there are still gaps among the norm families, which – if there is an economic and technological interest in doing so – will probably be filled in the near future. With this should be included general topics like ways to standardize components that are suitable for operation with hydrogen. Only so will it be further possible to establish self-developed products on the market in a norm-compliant and norm-approved fashion based on internationally recognized standards.

Further recommended reading on this subject is the hydrogen standards setting (RCS) roadmap of NOW [4] and the new VDE study "Brennstoffzellensysteme in der Elektromobilität" (fuel cell systems in e-mobility) [5]. This year, NOW launched a searchable website, https://rcs.now-gmbh.de, dedicated to the topic of regulations, codes and standards, in order to raise awareness of the issue and encourage active cooperation. ||

The author of this article is on the national mirror committee at the DKE and international standards committee TC 105. Dr. Alexander Dyck, as long-standing chairman of K 384, often also represents German fuel cell interests, as their elected spokesman, at the annual meeting of IEC TC 105 and is the contact person for some system types in the portfolio of the norm family. Thomas Jungmann works with the working groups for fuel cell modules and for (PEM) single cell characterizations and is also active in K 384. Therefore, this article focuses on fuel cell technologies.

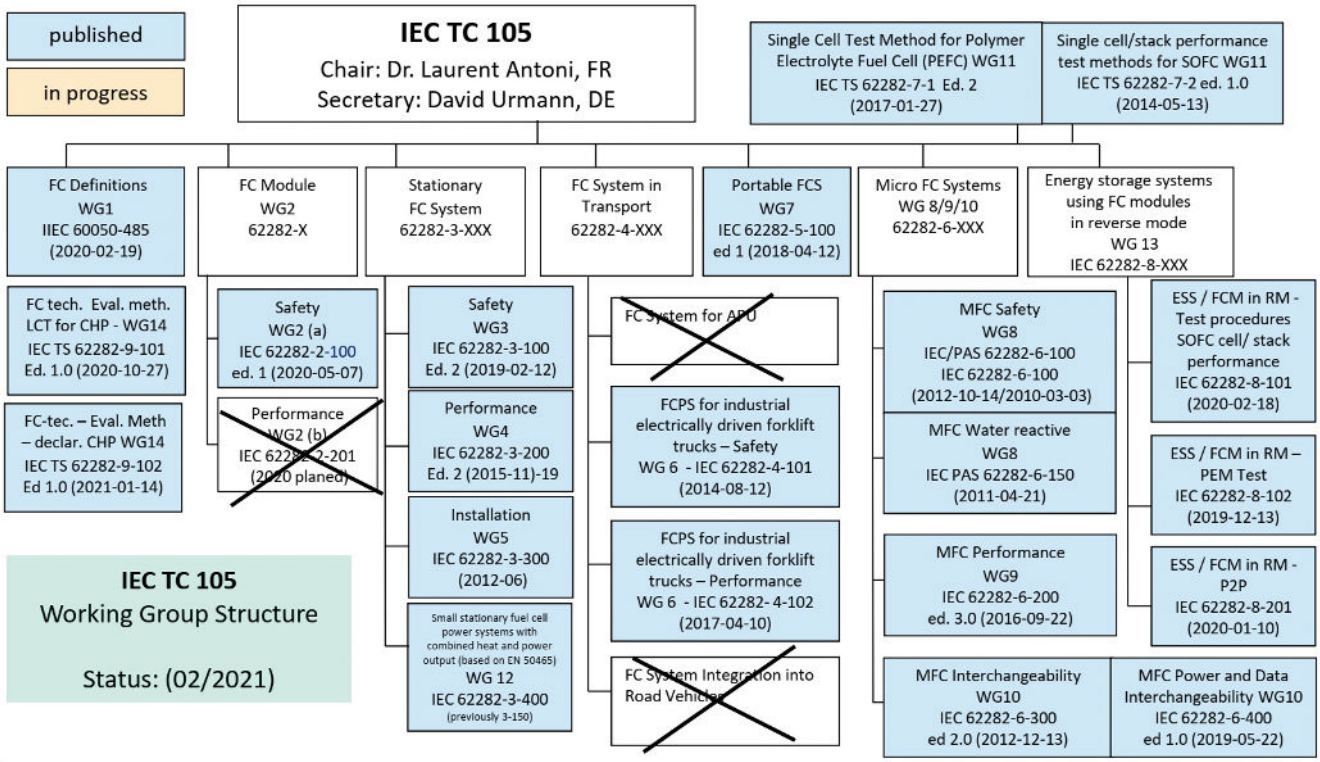

Fig. 3: Overview of norms in the area of fuel cell technologies until 2020 in the old topic-oriented structure [Source: Alexander Dyck]

APPROVAL – CERTIFICATION – STANDARDS

In addition to the work at the abovementioned standards bodies, the authors of this report have also been contributing to the discussion of the issue at the nation level for over ten years. A series of workshops for this was organized together with ZBT in Duisburg. Interested participants from the industry will be present, and current topics regarding approval, certification and standards discussed. There will be a special focus on reports from the industry based on their observations. This constitutes a foundation for the continuous development of existing norms. After two years in an online format, the 12th ZZN Workshop in this series will take place in person on February 14 and 15, 2023 at the DLR Institut für Vernetzte Energiesysteme in Oldenburg, Germany.

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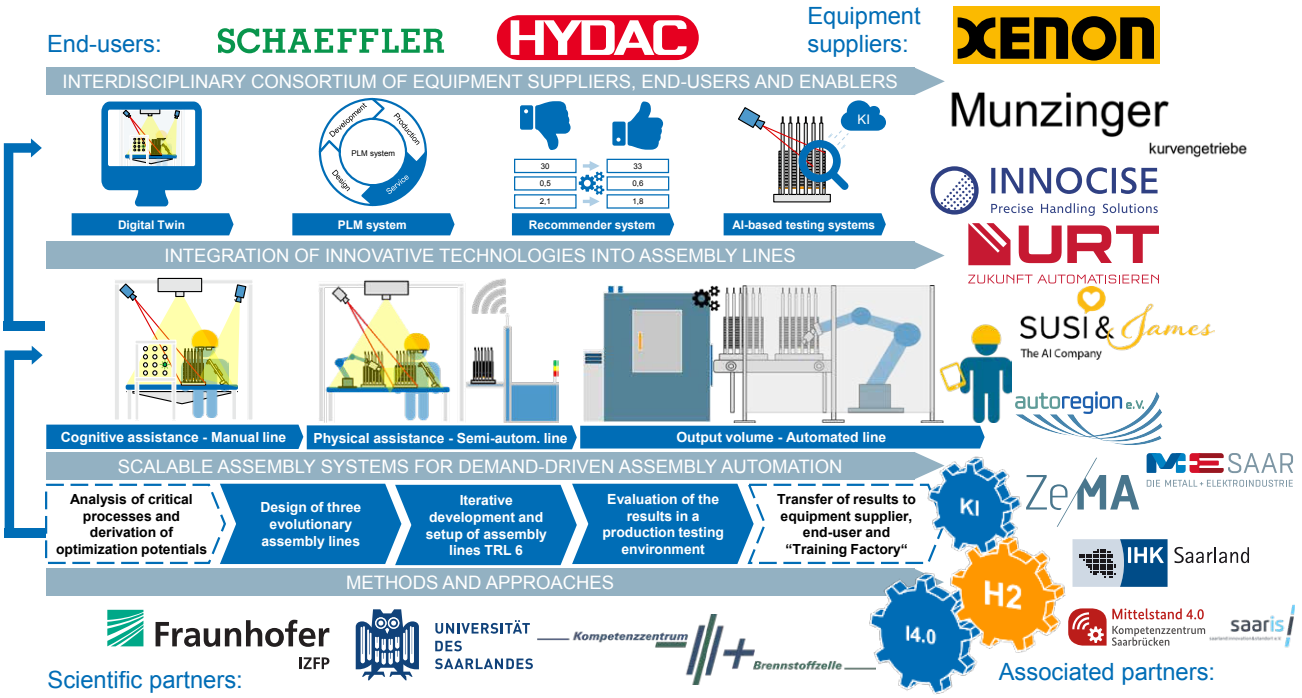
Category: Development | **Authors:** Rainer Müller, Lennard Margies, Fabian Klaus

SCALABLE PRODUCTION OF FUEL CELL STACKS

H_2SkaProMo – developing assembly systems for fuel cells



Increasing demand for hydrogen technologies is prompting the need for automakers and equipment suppliers to align and adapt production capacities to meet new requirements. To enable this to happen, it is essential to establish expertise and develop processes and technologies, particularly when it comes to key technology areas like hydrogen production and consumption systems, since gaining a global competitive advantage in the longer term is dependent on the ability to manufacture these systems economically [1]. That's why the H2SkaProMo joint project is seeking to develop assembly systems for manual, semiautomatic and fully automated production of fuel cell stacks that are readily scalable in terms of their level of automation.

If hydrogen technologies are to be used as a means to achieve the climate targets set by the German government, significant effort needs to be put into developing the fields of hydrogen production, transportation and consumption [2]. At present, the production and use of green hydrogen cannot yet be supported commercially. A great deal of potential for lowering costs lies in the fully automated manufacturing of fuel cells in high numbers and the exploitation of scaling effects [3].

However, as the demand for fuel cells is currently low, this leads to a low utilization of fully automated production systems which in turn results in the payback periods for these pieces of equipment being unviable [4]. Because the demand for fuel cells, and by extension also fuel cell stacks, is expected to fluctuate in the short term and increase sharply in the medium term, assembly systems need to be developed that are easily scalable with regard to output quantity and payback time.

Running alongside this problem is the issue that future refinements to the product are also likely. It is anticipated that such changes will not only affect the geometry of the individual components and the overall system but will influence the type of materials used and the system architecture as a whole. This makes it difficult to perform a simple reconfiguration and thereby hinders the use of the assembly systems for subsequent product generations. Consequently, it is vital to develop assembly systems that both offer the necessary scalability and address the issues of adaptability and reconfigurability.

If we turn our attention to the human factor, it is worthwhile noting that the individual processes involved in fuel cell assembly are often performed by highly qualified technicians who are put under significant strain due to the high degree of product variability, the complex process steps [5] and the high quality expectations for the product. Therefore the assembly systems need be designed with people at their center while also allowing for a certain degree of automation. This includes the consideration and integration of both cognitive and physical assistance systems. Such an approach makes it possible to relieve the mental and physical burden while also involving staff at a shifting level of expertise.

The people factor is highly relevant, here, especially in view of demographic changes and the transfer of employees with decades of experience from the conventional actuator industry. Despite differing operator skill levels, it's important at the same time to take account of the high quality standard required for the product. This is possible via the targeted use of a digital twin for predictive quality tests.

PROJECT OBJECTIVES The overriding aim of H_2SkaProMo is to show how fuel cell stacks can be manufactured economically and competitively using scalable, adaptable assembly stations that can have varying degrees of automation. To this end, three extension levels for an adaptable cyber-physical

assembly line is being developed that cover the processes of isolation, stacking, compression, pressing, finalizing and reworking. These technology demonstrators will be displayed at the ZeMA research center in Saarbrücken and the processes of sealing and load testing will be shown at the Environmental Campus Birkenfeld.

The focus of the project is on easy scalability which is being made possible through a modular design of the assembly system and standardized interfaces. To address the assembly of widely varying products, a manual extension stage is being developed. This enables a high degree of flexibility – an attribute which is needed to meet the requirements of pre-series production. Additionally, this extension stage will use systems to relieve the cognitive load of employees, such as optical operator guidance and motion tracking systems which will take the pressure off staff working on the assembly of widely varying products. The component quality and current assembly status will be continuously monitored by AI-supported inspection algorithms, meaning that faulty components can be reported promptly.

The increasing yet volatile demand for fuel cells will be met through semiautomated assembly processes that give the flexibility to produce small runs while still maintaining profitability. Isolating, stacking and dismounting are examples of critical processes that are well suited to human/robot collaboration. In this case, monitoring systems in combination with an intelligent control system are expected to be able to identify potential contact points between human and robot at an early stage and trigger a change in the pathway or an adjustment of speed to protect the employee. Bionic handling technologies take the use of gripping aids to another level and reduce the deployment of compressed air which is seen as an energy-intensive medium.

Automated assembly processes will facilitate mass production while fulfilling stringent quality criteria and minimizing cycle times. The goal is to realize a stacking frequency for membrane electrode assembly and bipolar plates that is greater than 1 hertz. This is not achievable using robots for handling tasks, given the future stacking speeds required, due to the physical limitations for acceleration and deceleration processes and consequently an approach will be chosen that uses continuous actuator motion in fully automated stacking procedures.

In order to address the differing requirements of individual automation stages, current research topics such as digital twinning, cognitive and physical assistance systems as well as comprehensive and predictive quality monitoring will be taken into consideration. This ensures the development of future-proof concepts.

The design of the prototype demonstrators leads to the consideration of further themes, among them the technical cleanliness of individual processes and the implementation of proactive quality assurance using a digital twin to support production. Production lines will be conceived and developed on the basis of existing processes. The project will adopt a holistic approach that takes account of the changing relationship between product, process and equipment while also addressing the design of the product and the ease with which it can be assembled and disassembled.

MOVING FORWARD To help achieve the project's objectives, users (Schaeffler, HYDAC), researchers (Fraunhofer IZFP, ZeMA, Trier University's Fuel Cell Centre, Saarland University) and equipment suppliers (XENON, URT Utz, Munzinger Maschinenbau, INNOCISE, SUSI&James) are working together to investigate and develop suitable key technologies. These will then be transposed onto test setups in an environment which is close to actual production conditions and translated into an industrial operating environment.

At the start of the project, requirements for the digital twin's data model and for the production systems will be defined. These requirements will be derived from the product and current industrial processes, including the equipment deployed. This foundation will be used to develop manual, standardized base models that will be combined with the necessary process modules and assistance systems. In parallel to this, concepts will be devised for the continuous actuator technology for the purposes of full automation. Following the development of the demonstrators, the project will enter a transfer phase which will take place at both a regional and national level and be supported by the project's associates and their extensive network.

Besides the companies involved making use of the project results, it expected that the initiative will create an R&D corridor that will help bring hydrogen technologies to fruition and enable assembly systems to transfer as smoothly as possible into industry. Therefore, once the project has concluded, the demonstrators will be integrated into an open lab factory where it will be at the disposal of equipment suppliers, users and research facilities for testing and educational purposes. It is already anticipated that the demonstrators will be incorporated into the courses at Saarland University.

The H2SkaProMo project kicked off in December 2021 and will run for 36 months. ||

→ www.h2skapromo.de

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Category: Development | **Authors:** Tabea Arndt, Michael J. Wolf, Mira Wehr

THE HIGHLY EFFICIENT HYBRID ENERGY PIPELINE

Transport of LH_2 and electrical power via high-temp superconductors

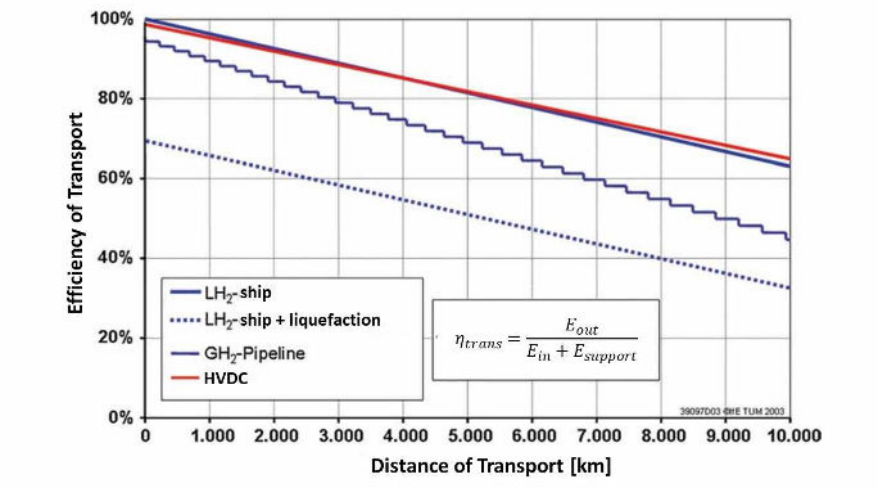

Fig. 1: Transport efficiency of different options over long distances [Source: [1]]

Commonly known is the ever-increasing need to transport energy from north to south within Germany. The rapidly expanding renewable energy generation capacities from wind in the North Sea and the onshoring of liquefied natural gas (LNG) or hydrogen at German seaports – whether as an international import or generated offshore – are further increasing this need.

The intercontinental, large-scale transport of hydrogen –similarly to natural gas – will occur with the liquid form (LH_2). The first shipping routes for this between Japan and Australia have already been established. Since no tanker class for it has been established, the Suiso Frontier is registered as an LNG tanker.

The energy needed to liquefy the hydrogen at the production site corresponds to – taking into account the current efficiencies of existing plants – about 20 to 30 percent of the energy content, i.e. calorific value, of LH_2. Similar to with LNG, the warming up of the LH_2 before feed-in to the gas grid, from the boiling point of 21 K to room temperature, takes about 1.24 kWh/kg in heat energy. With the calorific value of H_2 at 33.3 kWh/kg, that corresponds to a relative percentage of 3.72% "on top."

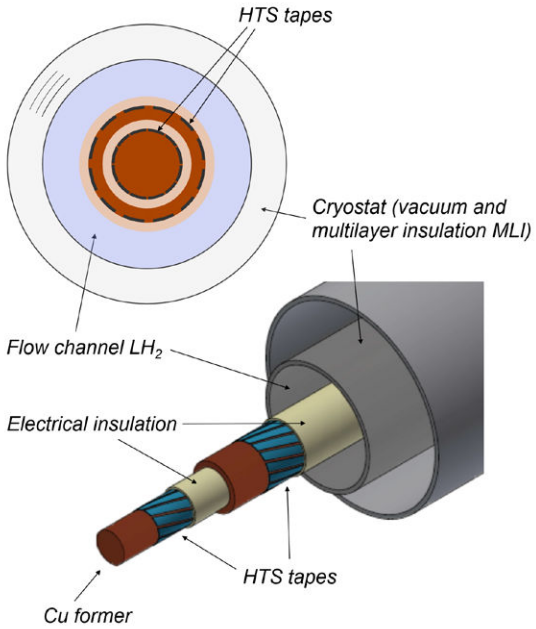

Fig. 2: Schematic structure of a combined pipeline [Source: KIT ITEP]

It would make sense not to spend this energy, as is the case with LNG, on heat exchangers in re-gasification plants near the port of landing, but rather to distribute the accompanying valuable "free cold" further to the consumer. The hydrogen should remain in its liquid form, LH_2, for as long as possible.

It seems sensible to create and utilize a shared pathway for the transport of large amounts of electrical energy along with the large amounts of LH_2, i.e. chemical energy, which could subsequently be routed to divergent regional points for consumption. This could, where possible, accelerate the approval process and raise acceptance within society.

HTS AS AN EFFICIENT LINK Long-distance transport of electrical energy is most efficiently achieved by means of HVDC – so with direct current (see Fig. 1). High-voltage DC lines, with their large voltages, allow for small currents and thus also reduced ohmic losses in the transmission line, even when such losses have already been non-negligibly reduced. The large voltages, in turn, require large insulation distances and set limits to the maximum transmission capability – regardless of whether it is an overhead line or an underground cable.

With a shared track for electrical energy and for LH_2 through the use of high-temperature superconductors (HTS), several aspects advantageously come together:

1. With direct current transport, the HTS conducts the electricity loss-free, if operated under the critical temperature (typically 92 K).
2. The loss-free current transport allows for compact energy transport at the same or lower voltage and at higher currents.
3. At the temperature of LH_2 (21 K), the HTS not only conducts loss-free, but enables, through the large difference from the critical temperature, also a large performance increase (by about a factor of 7 in current carrying capacity) and longer power reserves for high operational reliability.

The combination of LH_2 transport, electrical energy transport and the use of HTS at the temperature level of LH_2 allows for an efficient and compact shared pipeline.

The engineered design of this pipeline can be kept very simple, since the operating temperature of 21 K is rather high compared to that of customary cryogenic setups, which is mainly 4 K. Thus, many complex cryotechnical

measures, e.g. radiation shields or various thermal shields and anchors, can be omitted. Lastly, the low residing heat that penetrates from the environment is easily compensated via the LH_2.

AN INITIAL DESIGN A cross-section of the pipeline (see Fig. 2) shows that the pipes are composed of an outer tubing in which the actual annular, vacuum-insulated, multilayer-insulated pipe for transporting LH_2 is located. In direct thermal contact are the conducting wires (wire bundle), which are responsible for the loss-free electrical transport.

In the first test pipeline, determined by the current framework conditions of the test platform at KIT ITEP, an electrical power of 200 MW is to be transmitted with a current of 10 kA and a voltage of ±10 kV. The transmission capacity for chemical energy in the form of LH_2 results from a combination of internal frictional losses, pressure drop and temperature rise over the length of the line, and the hydraulic diameter.

An outer diameter of about 180 mm and a mass flow of 1.66 kg/s results in a chemical transmission capacity of 200 MW as well (see Fig. 3). Further calculations show that with an overall diameter of less than 0.5 m, both some gigawatts of chemical energy and some gigawatts of electrical energy can be transmitted over long distances.

Advantageous for such pipelines is a segmented design with smooth tubing instead of the corrugated tubing that is customarily used with flexible cables [2]. This hybrid pipeline is almost "invisible" to the external world; it has no thermal or electromagnetic effects on the environment.

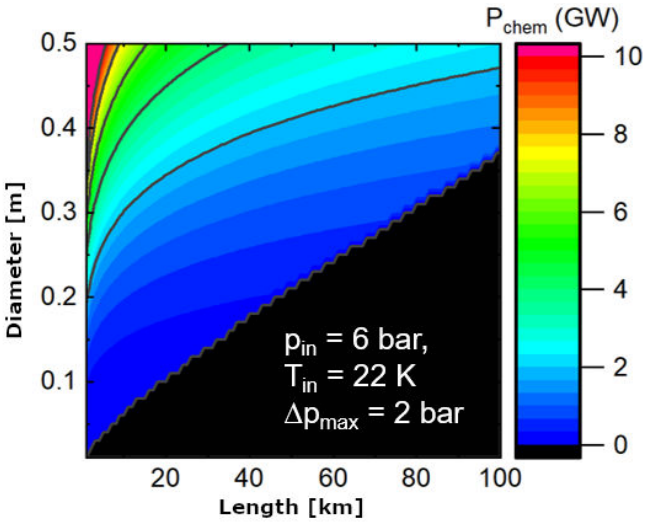

Fig. 3: Example calculation of the chemical transmission capacity P_{chem} as a function of the diameter and length of the line for the given parameters [Source: KIT ITEP]

INCREASED EFFICIENCY FOR END USERS If the liquid hydrogen is not transferred to the gas phase until the end use, e.g. in fuel cells, in large vehicles such as trucks, trains, ships or airplanes, or in industrial applications, then the "free cold" is available to cool the components (see Fig. 4).

With an ideal efficiency of 100 percent, 3.7 kW of cold power would be available for use. For the efficiency of 60 percent for a fuel cell, 6.2 kW of cold power, i.e. 6.2% of the application power, is available. For a conventional drivetrain with an efficiency of, for example, 95%, a dedicated additional cooling system would not be necessary anymore.

If the conventional drive train were to be (partially) realized with HTS components, then the handling of hydrogen

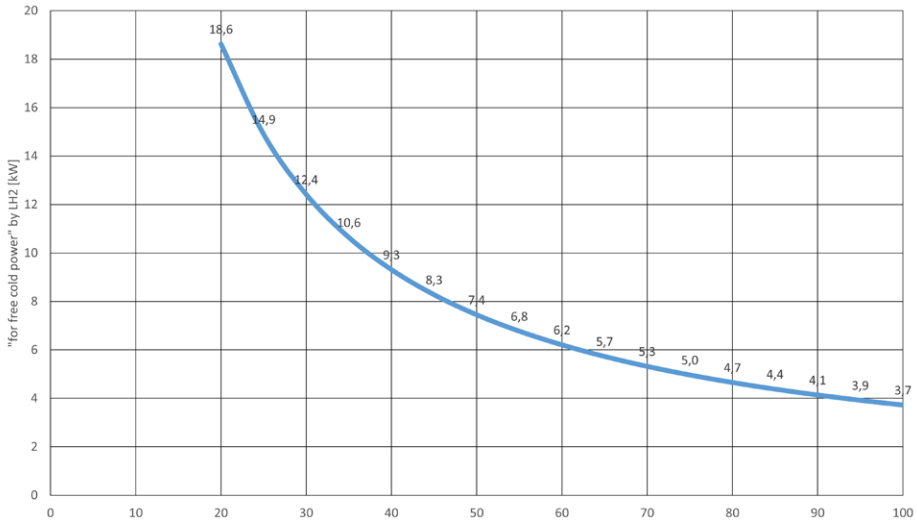

Fig.4: Cold power made available by only converting LH_2 at end use as a function of the efficiency of the end application [Source: KIT ITEP]

as LH_2 until the end use would make completely new, compact, powerful applications possible. For example, for an engine in the 380-kW class, the HTS rotor requires a cooling capacity of 30 W maximum. The total cooling requirement of the machine is 11.6 kW [4] and can easily, e.g. with electrical power supplied by a fuel cell, be covered via the cold from LH_2. Research and development work regarding this on powertrains will be carried out in AppLHy! as well as by air travel companies.

A GAME CHANGER The idea of using combined cryogenic transmission lines is not new [5]. Additionally, some studies on the economic efficiency of H_2 transport within pure LH_2 pipelines have been conducted [6,7]. What these works have in common, however, is a) that the secondary benefit of the cold provided was only taken into account as an expense, not as a benefit; b) that the costs of the LH_2 pipeline unfavorably linearly increase with transport distance; and c) that the space for vacuum insulation has a cost-driving effect. The hybrid energy pipeline presented here neutralizes these premises.

Furthermore, the aspect of vacuum insulation (c) can be solved with further developments, like – similarly for LNG storage and pipelines – thermal insulation by means of perlite or microspheres in combination with larger radial thermal insulation thicknesses, which is possible with smaller electrical insulation thickness.

SUMMARY In the research project AppLHy! of the main project TransHyDE, among other things, a compact, efficient hybrid energy pipeline will be developed. This hybrid pipeline allows the simultaneous large-scale transport of chemical energy in the form of hydrogen and electrical energy via high-temperature superconductors. Since the transport directions of both vectors are identical, this approach enables the realization of considerable advantages with respect to path widths, efficiency, costs and benefits for the end user, not least the high energy density of LH_2 and its cold power. ||

IMPLEMENTATION

As part of the national hydrogen strategy, the German research ministry (BMBF) funds, among other things, TransHyDE [3], the overarching project of research project AppLHy!, which is coordinated by Karlsruhe Institut für Technologie, Institut für Technische Physik (KIT ITEP) and involves 13 partner groups. In AppLHy!, running until April 2025, will not only a liquefaction system for hydrogen be designed and constructed, but also containment strategies and technologies developed, and questions regarding safety, materials aspects, integration with electrotechnology (converters, engines/generators, transformers) answered, and a test track for hybrid energy pipelines constructed. The last will allow the exploration and demonstration of different pipeline configurations on a short track.

Because of the already obtained experience in superconducting cables and transmission paths for electrical distribution networks and for power supply to magnets (among other things, for fusion), rapid progress can be expected, so that the above-mentioned research project can be followed, if appropriate, by an implementation phase. Talks have already been held with the first interested parties. KIT itself also intends to further expand its research activities in the field of LH_2 and electrical power engineering and might have an open spot for interested players.

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Category: Market | **Author:** Sven Jösting

KEEP A COOL HEAD AND IT'LL COME WITH TIME

Sven Jösting's stock analysis

Regardless of the many good news and developments around hydrogen, there must of course also be a critical consideration of the aspects that may, for example, hinder or delay rapid build-up of production capacity. In addition to adverse influences due in part to misunderstood or counterproductive regulatory measures (EU/Germany) are aspects such as the shortage of skilled workers, supply chain problems and financing.

The issue of financing is pertinent to, for example, the Australian billionaire Andrew Forrest's company Fortescue Metals Group, whose hydrogen ambitions could very well require an investment of over 150 billion USD. This sum could overwhelm even him. Moreover, hydrogen will no longer be easily producible in the planned quantities if the electrolysis capacities (PEM, SOFC and alkaline) will not be created in time . On top of that, the transport of the H_2 needs to be guaranteed and complete pipelines as well as new ship types in great number need to be built. Everything won't happen overnight.

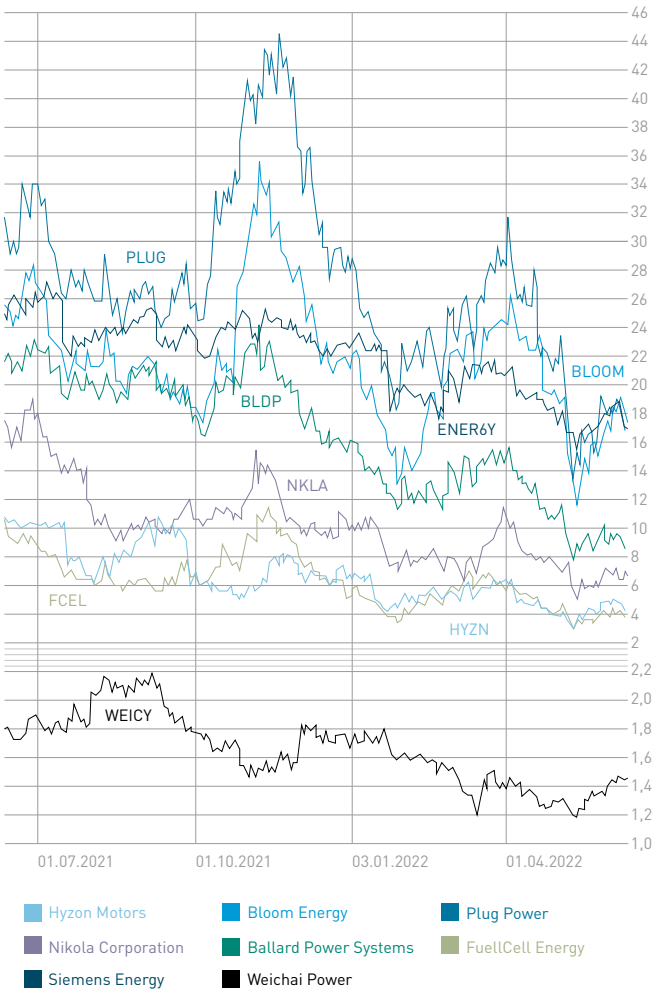

Fig. 1: Share price performance of the companies discussed [Source: www.wallstreet-online.de] Shares on June 3, 2022

The stock market evaluates the future, essentially constitutes an anticipation mechanism, but most shareholders aren't looking too far ahead. Short sellers, in other words, investors who are betting on prices falling, are pursuing their own interests, e.g. to create uncertainty – if only temporarily, unfortunately still often vigorously and effectively, as can be seen from the currently very weak stock market prices of the companies in the sector discussed here.

At the stock exchange are also, at least temporary, players who are trying to torpedo the hydrogen and fuel cell sector by putting in their say to get fast money out. These may be hedge funds or short sellers close to them whose aims are to put pressure on shares of this theme to realize trading profits via falling prices. This will strengthen their usable capital too – even if temporarily – and devalue prices or entire industries. But in the end, it's the hard facts and the prospects that count, and they couldn't be better.

Example: If the value of a company during a trading session drops by 500 million USD with a daily turnover of just 20 to 30 million USD, you can't really talk of selling pressure. As an investor, you then have to pull through, even if it hurts that the shares of this so important future topic are put under so much pressure, with more or less crude arguments based only on quarterly results and trading strategies. But this will pass, as I think over time companies will deliver what they announce and have themselves forecast. Therefore, it is advisable to follow Warren Buffett in his thinking and invest strategically and for the long term.

Just ask yourself: Is hydrogen (in its various colors) the new future trend in energy and sustainability? Is decarbonization fully possible without hydrogen? Could fuel cells and hydrogen compete with batteries in many areas? How are the companies positioned (balance sheet ratios, orders on hand, etc.)? Which company in the industry has the right product and business model for the future H_2 market, and sustainably earns more and more money with it?

DO COMPUTERS DECIDE THE PRICE DEVELOPMENT? For some time now, there has also been robot (algorithmic) and momentum trading. Computer programs and artificial intelligence (AI) make decisions that influence price developments within milliseconds. In this, framework conditions are evaluated if, despite little trade volume and few buyers, some negative news comes in, and then computers decide how to act to depress a stock price (or make it rise) with less or more available equity (leverage). In my opinion, we are dealing with such a phenomenon in the FC shares – just my feeling. It's not healthy, but it's a reality at the stock market. It is clear to me that hydrogen and fuel cells in all their fields of application are creating a new future trend on the stock market, and this will be reflected in rising prices of the shares concerned. The time of 2018/19 will repeat itself, when there was a sideways movement that resulted in sharply rising quotations in the following years. Year 2023/24 and the following years will – I feel – bring the breakthrough, so collect, make cheaper and leave alone.

Fig. 2: 250-kW station at American broadcast company NB [Source: Bloom]

52 BLOOM ENERGY – VERY SATISFYING INVESTOR DAY

The future prospects of Bloom are fully intact and unchanged (over 30% growth p. a.) and allow for a very positive outlook: for 2022, over 1.1 billion USD turnover, cash flow positive, gross profit margin of 24% and on the way to the profit zone with strongly increasing backlog of orders and new complementary fields of activity (e.g. electrolysis). The first quarter, with a turnover of 201 million USD and a stated loss of 78.4 million USD (contains 26.3 million USD stock-based compensation), or minus 0.44 USD per share (GAAP), was disappointing at first glance. Large material deliveries to key customer SK ecoplant in South Korea was one reason for it.

The company itself has said time and again that the real growth will only come in the second half of the year, but now at the percentage of 30 to 70 instead of the 40 to 60. This means that 30 percent of sales are likely to be generated in the first half of the year and 70 percent in the second. Remember 2021, when the very high growth in the fourth quarter resulted in a good year overall? This is because Bloom must first go through the approval procedures for the many FC projects and get those "acceptances" before the actual implementation and accounting can take place. A lot of things may be shifted from one quarter to the next, but the amount of acceptances itself already provides a certainty of implementation. Here, Bloom is on the right track and is also following it as predicted.

Added to this is the massive expansion of capacity, which can be expressed in the annual energy amount that is newly installed. Step by step, this will exceed one gigawatt per year by 2023, and will increase in 2022, through a 150 million USD investment, from 280 to 580 MW. The payback period for the investment is expected to be less than a year. The profit margin could increase as the energy volume increases over the course of the year

INFLUENCES ON THE SHARE PRICE The finance minister of India recently made a visit to Bloom headquarters. CEO K. R. Sridhar stressed that Bloom sources many vendor parts from India and is active there with projects. I could very well imagine that an Indian conglomerate like Adani or Reliance, both of which want to invest massively in the area of hydrogen (over 70 billion USD each), might embark on a project with Bloom and/or contract Bloom for FC power stations. A speculation of mine, but thoroughly realistic. What's more is that Bloom, with its shareholders, is not only building up its major client base, but also gaining more security from being taken over and perfectly expanding the geographic mixing of its activities (globalization).

GENERAL TAKES FROM THE CONFERENCE Investors and public officials will increasingly pay attention to how a company faces climate change. This involves the type of energy, the sourcing, the production and the availability as well as the overall concept of decarbonization. But it's also about security, keyword "cybersecurity." Here, Bloom can naturally come out strong, because the fuel cell power stations, as microgrids, are independent of the public grids and are secure. A power failure can have catastrophic consequences. Cost can also be an issue. Bloom has the right technological answers.

Additionally, it's about the transition from coal to natural gas and all the way to hydrogen – ideally ultimately to green hydrogen. And here, too, technologies are required that can produce clean hydrogen from, for example, biogas, waste or wastewater. Bloom also offers technology that converts the methane that escapes from gas and oil production into useful energy in an environmentally friendly way and thus renders hazardous emissions harmless. If this were to be used worldwide and 75 percent of the methane emissions from fossil fuel extraction were converted in this way, then 60 percent of all coal-fired power plants could be shut down, according to a statement from Bloom Energy.

INVESTOR DAY FULLY MEETS EXPECTATIONS On May 25, 2022, the managing board was able to explicitly clarify the cause of the strong quarterly fluctuations and why the growth in the course of the year and also the profit margins will ultimately ensure a good year overall. And the prospects are bright. Much more considerable, however, is the story that the company presented at the event:

Bloom works with FC technologies that were originally intended to be used for Mars exploration. Its SOFC Energy Servers, conceived for decarbonization, can be used to produce cleaner, reliably available energy – 24/7 zero-carbon power. The architecture of the Servers is modular, so it can be scaled into any form and adjusted to the customer's needs. It can be compared to the clustering of computer servers, where the energy is produced like in a cloud. Bloom is also about using green hydrogen and producing it. Until it is available, all the energy sources from LNG to biogas to natural gas can be used for the stacks. From chemical energy comes electrical and vice versa. This provides the highest flexibility when booting up the systems.

Each stack within the Server – similar to a microchip – can be monitored and controlled in real time, which enables the highest efficiency – better, cheaper, faster. This will then allow electricity to be produced at favorable prices – and with certain calculation. In this way, the next generation of Energy Servers (production facility under construction), designated 7.5, can already achieve over 50 percent higher performance compared to the predecessor model, 5.0 – over the same area or with equal space requirements.

In 2022, 580 MW of energy capacity will be built, which is to be 1 GW per year already by 2023. The payback period is less than a year. The service life of the stacks will be extended from the current 5.6 years to six years, and in the next step will reach seven years before replacement becomes necessary.

One advantage of this technology is that no rare earths or platinum are needed for the SOFC fuel cells. Bloom's FC power plants would also have a much higher efficiency than gas-fired power plants, it is said. It is therefore not surprising that three quarters of all new orders are coming from existing customers. It is how Bloom, with its stationary fuel cell systems, achieved a market share of 80 percent in the USA – and South Korea.

Intellectual property theft is not a concern of Bloom's, expressed CEO Sridhar in answer to an analyst's question. There are currently around 352 patents. Many others are in the process of approval. There is an expert on board who had already been responsible for IP security at INTEL. Re-engineering of the company's technologies is not possible for a number of reasons, which is a particular strength of the company.

In the area of electrolysis, Bloom is in a leading position, considering the efficiency compared to alkaline and PEM electrolysis as well as the fact that Bloom's SOFC technology can be used in 75 percent of markets (steel, cement, etc.). Through a high operating temperature, much more hydrogen could be produced with less electricity in comparison. This ratio is significant because 75 percent of the cost for H_2 production goes to electricity.

Bloom presented a very exciting glimpse into the maritime sector. There is an MSC cruise ship that is equipped with an SOFC system from Bloom and is scheduled to be put into service at the end of the year. Initially, it will be powered by LNG, but later also by green hydrogen. There, Bloom also sees making good progress with Samsung Heavy on cargo ships of all types that instead of heavy fuel oil use (green) LNG, hydrogen, methanol or ammonia. Testing is well underway. What is clear is that emissions from the use of heavy fuel oil are becoming increasingly regulated. Many ports have already adopted strict regulations. LNG vessels and tankers are also getting FC systems. Larger orders in this regard are expected as early as the beginning of 2023.

SouthernCaliforniaGas (20 million customers) is closely working with Bloom and already has various FC power plants in use. They plan to build up 20 GW of energy capacity via hydrogen. The Angeles Link project is the largest of this kind in the USA. The energy provider is also working with Bloom on research projects for the transport of hydrogen in the gas networks (blending). SoCalGas plans to invest 20 billion USD, and pretty soon Bloom will receive some large orders – is my expectation.

With a power purchasing agreement (PPA), Bloom does not sell Energy Servers (hardware) to certain customers, but the clean, CO_2-free electricity produced with it (software) over a period of time. And then the company sells this energy output to investors via PPAs to generate liquidity. Now, they're certainly planning to – I presume – buy back the PPAs. A hefty reason: With the new Servers (7.5), electricity can be produced much more cheaply, so PPAs back in the hands of Bloom promises a higher return.

In addition to the expansion of activities to various other US states, Bloom is active, above all, in Asia (see SK ecoplant), but is also to expand its activities in Europe. Tim Schweikert, former head of maritime solutions at GE, spoke of a great many activities also in Germany.

10-MW PROJECT WITH LSB INDUSTRIES Together with LSB Industries, Bloom is planning an electrolyzer project with a volume of 10 MW for the production of green ammonia. So we're talking about 13,000 metric tons per year. The SOFC electrolysis of Bloom is said to have tipped the scales here, with the goal of producing hydrogen very cost-effectively. ThyssenKrupp is a technology partner in this. The project in Pryor, Oklahoma, will most likely receive funding from the US state. With this is an initial project to showcase the technology, in particular that green ammonia is to be considered an important medium for the transport of hydrogen – in addition to its use as fertilizer.

Bloom is also cooperating with Westinghouse. In over 50 percent of the world's nuclear power plants, Westinghouse Electric Company is present and can look back on over 130 years of experience. Through the SOFC electrolysis of Bloom, the heat from the generation of steam via nuclear energy is to be used for the production of red/pink hydrogen. This is also a very large market for CO_2-free hydrogen, even if one may be critical of nuclear energy.

SUMMARY The words of CEO Sridhar can aptly be reformulated like so: We know where we'll be in a few years. Which company can already claim this? With currently over 8.5 billion USD in orders on hand, though, such certainty is comprehensible. However, the second quarter is still likely to provide an "expected" disappointment, as already described. Short sellers (currently another 18 million shares sold short) will possibly know how to exploit the publication of these figures in July to sharply push the share price back down. One possible strategy: Whoever wants to buy again anyway, place buy limit orders for lower share prices for the month of July in the market, in case the publication of the figures for the second quarter leads to major price swings to the downside. This could happen, but good news is not guaranteed. Otherwise, Bloom shares should be understood as key investments in the subject hydrogen and fuel cells and be left in the portfolio medium- to long-term. My goal is 100 USD in three years.

BALLARD POWER – OVER 50 PERCENT OF STOCK MARKET VALUATION IN CASH

It is unfortunately so: There are many traders and short sellers, but also some analysts, who do not focus on the prospects of a company, but take quarterly results as the basis for classification – a very short-term placement, but of course with a (short-term) impact on the share price performance. We're also seeing this with Ballard, for which I often hear that the turnover is disproportionate to the stock market valuation and that the company is still making losses.

What is forgotten here: Ballard positions itself in many markets (rail, ship, truck, bus, also stationary energy supply) via fuel cells. There are many prototypes, small series and pilot projects. What they all have in common is that they are developing into huge markets and Ballard sees itself as a technological frontrunner. An order for ten bus stacks then quickly turns into 100, or even 1,000, with corresponding scaling and profit margin. That, first, an investment in the production capacity is needed, huge amounts of money poured into optimization and proper positioning, for example through successful completion of pilot projects, before it can go into large series production, is obvious. But this takes time and must be seen in terms of years rather than individual quarters. This calls for patience on the part of the investor and also a certain optimism, coupled with staying power in the face of falling prices.

The reward is then visible at the end of the day in a stock market valuation that takes account of the prospects. High order growth and, of course, a sustained strong increase in company profits are enticing. Ballard is steadfastly implementing its plans – which, with over 1.1 billion USD in the bank (more than 50 percent of the stock market valuation), it can finance through its own means. The first quarter in figures: A minus per share of 0.14 USD, 21 million USD turnover, order backlog on an annual basis of approx. 100 million USD, new orders in the quarter of over 27.8 million USD.

SIEMENS' H_2 TRAIN MIREO PLUS H I venture to predict that in some markets, such as buses, things are now getting off the ground and will continue until the point that there's even a boom and buses worldwide are equipped with fuel cells and hydrogen. Following buses will be trucks and heavy-duty vehicles like mining trucks, rail vehicles, ships, and, in addition to backup power systems for data centers, above all, stationary FC power systems. Ballard is at the forefront of all of it, as also directly graspable from a large number of news reports:

After three and a half years of its development together with Siemens Mobility, the first hydrogen-powered train, Mireo Plus H, was presented to the public (see Fig. 3). Now, field tests will follow until it goes into large-scale production. The German rail plans to use it first in Bayern. The refueling process does not take longer than with diesel, and the hydrogen is to be produced decentrally from renewable sources. A gigantic future market for Ballard. Siemens already has seven trains on the order log – it could become several hundred. The range of this train is 800 km (500 mi) at a speed of 160 km/h (99 mi/h).

In addition, Canadian Pacific plans to retrofit two more of its locomotives with fuel cells – Ballard inside. Three different locomotive variants are to be converted and tested. Such a pilot will then turn into large orders, with the goal that in the future all of the locomotives will run on hydrogen instead of diesel.

NUMEROUS ACTIVITIES Anglo American, the South African/British raw materials giant, recently put into service a 290-tonne mega-truck that runs on hydrogen – Ballard inside. Thus, 3,000 liters of diesel per day have now been replaced by hydrogen. In the future, 40 of these beasts are to be converted to hydrogen. To the great advantage of other companies in the industry as well.

With partner Linamar, Ballard presented a Hydrogen Class 2 chassis for a RAM 2500 truck at the commercial vehicles trade show ACT Expo in California. With this, the truck market for fuel cells is addressed. In the meantime, Wrightbus in England reported 1 million kilometers traveled with the fuel cells from Ballard in its buses. Ballard is involved in FC projects in 17 EU countries and is active in 6 US states. A recently designated subsidy program by the US government in the amount 1.1 billion USD is banking above all on the use of fuel cells by buses.

Ballard is now collaborating with the South Korean Doosan Group, Doosan Fuel Cell, for the use of its BZ stacks

Fig. 3: The new hydrogen train from Siemens [Source: Siemens]

in various applications – starting with buses. Doosan sees advantages in the PEM FC technology of Ballard over the SOFC FC, which could be used in other applications. After extensive market analyses, Ballard was chosen as a partner. An accolade and proof of the quality that Ballard delivers.

DNV has certified the first fuel cell system in a ship – Ballard inside: FCwave. With this, DNV attests the safety of the FC systems, runtime, performance, and so on – all this as a basis for large-scale deployment in the decarbonization of maritime transport. FCwave will also be used more and more in the field of stationary energy systems. I rate this market as one of the largest FC markets for Ballard.

More proof of the quality and standing of Ballard as a leading PEM fuel cell manufacturer is not needed. Now, however, large orders must be placed in order to start series production. But that will come and, by my calculation, before the end of this calendar year – although it won't be implemented until 2023 and the years following.

Of course, there are also negative effects from what's happening in the supply chain area on Ballard. Before the ramp-up, there is still a need for some streamlining of the regulatory framework and further subsidy programs. But the positive path is clearly discernible, even if the breakthrough (inflection point) is still a little while coming. That the ramp-up will come is beyond question for me. The currently very strongly depressed share prices are therefore well suited for new as well as additional purchases, if you give it about a year or two.

A good piece of news to end with: The public transit company for Cologne, Regionalverkehr Köln GmbH (RVK), has ordered a hundred hydrogen-powered buses (40 fixed and 60 flexible). The buses will be supplied by the Ballard customers Wrightbus and Solaris, so the FC stacks will ultimately all come from Ballard.

NIKOLA MOTORS – FOUNDER STILL WREAKING HAVOC

The expansion of the company is proceeding according to plan. Prototypes will be delivered so that customers can familiarize themselves with the vehicles (battery-electric and hydrogen-powered). The first successes can be reported: ten MCTs (Mobile Charging Trailers) have already been delivered (1.9 million USD in sales), which can fully charge battery-electric trucks in a hundred minutes.

Ten Tre BEV units have already been delivered, and 40 in total produced. All for testing by customers and sales partner companies. TTSI (Total Transportation Services Inc.) has already covered over 11,000 miles with the trucks in daily use. Ten Tre units were confirmed for the subsidy program in California – at least 150,000 USD per truck subsidized. Since the end of March, 134 of the trucks have been requested through this alone. So 510 Tre BEVs are now in the order books – full utilization of the current capacity until the end of the year, if all are delivered.

With the hydrogen-powered Tre FCEV (FCEV = fuel cell electric vehicle), major customer Anheuser-Busch is already carrying out test runs and has already put 12,000 miles on it in daily operation. And 19 test vehicles are to be on the road. Series production will then begin in the second half of 2023. Through letters of intent, Nikola already has 1,010 trucks in the books.

In addition, Nikola is building the first H_2 stations (refueling time under 20 minutes) and has set itself on self-production of hydrogen, since the company not only wants to sell trucks, but also earn money from the energy source. TC Energy supplies 60 tonnes of hydrogen per day. The next goal is 150 tonnes per day, with Nikola itself also investing in the production (waste-to-hydrogen).

Nikola is now represented in 27 US states at 127 locations (sales partners). The building up of capacity is going according to plan: 2,500 units can now be supplied per year from Coolidge – first, battery-electric and then, from 2023, hydro-

Fig. 4: The battery-electric Nikola Tre BEV [Source: Nikola]

gen-powered as well. By 2023, the capacity should already be increasable to 20,000 units.

The figures for the second quarter: The quarterly loss amounted to 152.9 million USD. However, in this was included stock-based compensation in the amount of 44.8 million USD, so it is not the operating loss. And legal fees in the amount of 14.1 million USD from the legal dispute with former CEO Milton. Here is still a chance that Nikola recovers the amount from the settlement with the SEC (US Securities and Exchange Commission).

A good 385 million USD in cash was in the bank by the end of the first quarter. Another 409 million USD is considered callable capital via share issue (3i/Tumim), making 794 million USD available. A recently issued financing via convertible bond in the amount of 200 million USD is coming on top. In all likelihood, there will be further capital raisings via share issues to achieve all targets (production capacities) for 2023, which shouldn't be a problem if the shareholders agree.

The cooperation with Iveco is not only going well, but seems to suggest that they will be working more closely in the future. Nikola will let the trucks built within this joint venture in Ulm be sold with its branding by Iveco. There are plans to work more closely together on the research side, according to a press release. A hint that Iveco will enter into a stronger engagement with Nikola?

In light of the depressed stock price for Nikola, if I were in Iveco's place, I would massively raise the interest in Nikola of 6.7% (latest status) via capital raising. This would have several consequences: the equity base of Nikola would be – if successful – even better, and the stock market would express this with higher prices as a sign of confidence. Nikola could then issue fewer shares to trade at higher prices.

The annual general meeting of shareholders was postponed until the end of June. At fault is Trevor Milton, who torpedoed the necessary voting majority (AGM majority of voting rights). The topic at issue was authorization of capital, expressed in terms of potentially 200 million new shares to be issued (increase from 600 to 800 million). Currently, 420 million are issued. Now, company founder Milton has objected to – he himself still holds – directly and indirectly through the family – around 90 million shares. He sees this measure as a potential dilution of his stake should Nikola issue further shares, which it would naturally do, as Nikola would be better off financing its growth via its own capital (shares) than through credit. For me, a sideshow that will not influence the development of Nikola.

BASIS FOR A SHORT SQUEEZE? Nikola Motors is going the distance by, first, building up production capacity for battery-electric trucks and, later (2023), also for hydrogen-powered trucks. Expressed in the expectations of analysts, there should be in this first year of production 110 million USD turnover, but already 630 million USD in 2023 – with similar hikes in the following years. The group of short sellers do not share this expectation. The level of short interest reached an astonishing 92 million shares in June – after the 70 million shares sold short in May. Could these investors betting on falling prices be miscalculating? What if Nikola can get some large orders that encompass – a vision of mine – 1,000 or even 10,000 trucks?

In many countries, it is not only the specification of emission values for commercial vehicles that is causing great pressure on companies and logistics companies to convert their vehicle fleets to climate-friendlier ones. A contract awarded today can, at any rate, only be implemented in subsequent years. For me, Amazon is such a candidate, as they just placed an order for 100,000 battery-powered vans and will certainly follow suit with long-haul trucks. Of course, then a company like Nikola will not alone be awarded such a contract, but so far there are only a few suppliers on the market who are ready to go (H_2-ready). Additionally, Nikola is determined to itself offer the energy supply – electricity for battery-electric and hydrogen for fuel cell commercial vehicles – which is expressed in a specially developed mobile charging device, but also in its own hydrogen production, together with partners such as TC Energy. Walmart is also now planning to use the Nikola Tre BEV in test trials in California. Is there more to come?

In addition, state subsidies in amounts of 150,000 USD per vehicle are waving in US states like California and New York. Nikola was recently approved for subsidization of its battery-electric truck in NY(185,000 USD), where many more will be added, and such support is also conceivable in the EU. Regarding the short sellers, this can – if successful – mean that they will (have to) buy back the shares sold short on the stock market when prices rise, to either realize existing book profits or prevent losses.

A short squeeze would then be seen as a price explosion, where the stock market drives the share price up sharply on good news and can put the short sellers under a lot of pressure. So it could actually be the short sellers to thank for good prices, especially as there are also institutional investors (hedge funds) who like to put short sellers under pressure.

I'm betting on such a scenario, as Nikola is moving exactly in this direction, so good news (orders, cooperations) that will drive share prices back up is tentatively expected. Then, such a share could also quickly rise from 7 USD to 15 USD – within very few days. The current low prices are at any rate good for repeat and new investments, for those who want to place a wager on the commercial vehicle sector and give it time.

Summary: Everything's on the right track, but the share price is "still" at its lowest level. A basic condition for this speculative investment, as it is on a startup, is time. One to three years is needed.

FUELCELL ENERGY – WHERE ARE WE GOING?

FuelCell Energy should actually have generated a quarterly turnover of over 30 million USD in the second quarter, ending April 30th (fiscal year), but it was by then only about 16 million USD with a stated loss in the amount of about 31 million USD, or minus 0.08 USD per share. The management board nevertheless believes that they are on track to achieve a turnover of 300 million USD by 2025, and 1 billion USD by 2030. The order backlog was almost unchanged at about 1.3 billion USD. In the bank lies a formidable 490 million USD, for which a multitude of share placements (64 million new shares) is responsible – in proportion to the stock exchange value of 1.4 billion USD, a healthy basis, even if the question arises as to how these share placements were justified.

Regarding the projects, there are many questions surrounding the schedules for plants reaching the customers. The cooperation with ExxonMobil with regard to carbon capture technology is indeed continuing, however there is no prospectus filed stating how they'll earn money with it (margin? potential?).

Summary: For me, companies like Bloom Energy (comparable with regard to FC power plant application, albeit a different technology) are more clearly established in terms of their business model. FuelCell Energy will remain, as expressed in the share, a trading value, since neobrokers and trading platforms are strongly active in driving up prices here, as evidenced by the high daily turnover. Whoever approaches trading here highly speculatively will know to use the at times very high daily fluctuations to their advantage, as there is a high volatility directly driven by news developments. Otherwise, rated sufficiently good.

SIEMENS ENERGY – FINALLY THE FINAL STEP WITH SIEMENS GAMESA

Now it has come to the final step with the loss-making Siemens Gamesa: Siemens Energy will fully integrate the 67.1% subsidiary, as was to be expected. The parent company is buying the remaining shares via a takeover bid for 18.05 EUR per share. As interim financing, a loan in the amount of 4 billion EUR was taken, which will surely be refinanced through the issuance of treasury shares – there's talk of up to 2.5 billion EUR. Now, there can be – as similarly put in some commentaries – a crackdown, as not all figures at the subsidiary were so transparent and some calculations are now being reconsidered.

The leveraging of synergies is now in the foreground. This could certainly strengthen the joint purchasing power for raw materials and parts (cost-cutting potential), which, however, may also bring with it reductions in staffing levels and thus a leaner personnel structure. So 30 percent of management positions will probably be eliminated, which is always done during takeovers and integration processes, to become leaner in the hierarchy and in the cooperation within the company, in particular through shorter decision-making pathways.

Fig. 5: Gamesa plan of energy supply sources in the future [Source: Gamesa]

Cost reductions (synergies) in the amount of 300 million EUR a year should be quite possible. More importantly for me is the expectation that the various business divisions will be able to exploit existing synergies, for example in the area of hydrogen, more effectively. An example: A customer can then buy in addition to the wind turbine, offshore or onshore, the electrolyzer that produces hydrogen via wind energy – with all further possibilities of energy production (electricity, heat). As the H2 factory concept developed by Siemens Energy arranges: one-stop shopping – everything from one source.

Ultimately, good money can then be earned again, which in turn is the basis for the stock exchange to let the share price rise again and become independent of the major shareholder, i.e. Siemens (holds 30% in Siemens Energy, but wants to give up this percentage). The stock market shares my opinion here, as the rise in the share price over the past few days in reaction to the taken measure makes visible.

Summary: Regarding the huge markets for safe, CO_2-free energy, Siemens Energy is on course. The expected acquisition of large orders from all over the world will drive the share price development. In addition, Siemens Energy will pay special attention to the profit margin of the projects and include Gamesa in this process. When it comes to hydrogen, we are only at the beginning of a new megatrend. In addition, large investment management companies such as BlackRock (has already invested in Siemens Energy) are participating more strongly in areas of the stock market that are active in the large field of sustainability. This includes Siemens Energy. A "buy on bad news" strategy can also be used here. ||

WEICHAI POWER – THE SHARE PRICE IS RISING

The shares of Weichai Power could not escape the negative trend in the fuel cell sector. They suffered from the lockdown in China, but now we can see a strong upward trend again.

On the stock market, the company is, in relation to those such as the US-based Cummins Engine, too lowly valuated (15 billion USD valuation versus about 30 billion USD). However, both are market leaders for diesel engines who are now increasingly entering the field of hydrogen and fuel cells. Weichai has a market share of 30.7 percent of the heavy-duty truck segment in China, a very important market for fuel cells in the future. Additionally, the corporation is involved with Ballard Power (51:49 joint FC stack production in China) and strongly active in the area of heavy commercial vehicles (number one in bulldozers, cranes). Bus manufacturers belong as much to the corporation as the forklift manufacturer Kion (10 billion EUR turnover with over 500 million EUR profit). As the ramp-up of the hydrogen economy in China is coming, Weichai should be regarded as a key investment.

CAN PLUG DELIVER ALL THAT WAS ADVERTISED?

Huge news has reached us regarding Plug Power: H2 Energy Europe has contracted Plug for an electrolysis capacity in the amount of 1 GW. A complex is to be built in Denmark and the regenerative electricity generated via wind power. The goal is to produce 100,000 tonnes of green hydrogen per year, which is to be used primarily in hydrogen-powered trucks, specifically to fuel 150,000 of them per day.

The Swiss company H2 Energy has joined forces with the US oil company Phillips66. They are to build 250 H_2 fueling stations across Denmark, Germany and Austria. In addition, FC trucks are to be acquired. Construction of the plant is scheduled to start in 2024; hydrogen production in 2025. In Belgium, 100 MW of electrolysis capacity is to be built in Port of Antwerp. It is unclear so far whether these are orders that can be valued (investment/order volume) or if Plug is a co-operator in this and itself will invest. Other projects planned are in Egypt (100 MW) and, with billionaire Forrest of Fortescue, in Australia (1 GW). A lot about it seems much too "giga" to me.

Fig. 6: Plug subsidiary Hyvia was also represented in Hannover

Regarding the first quarter: The stated loss turned out to be a remarkable 156.5 million USD, making it clear that Plug will have to invest a great deal in order to achieve its ambitious goals. The turnover also rose considerably, to 140.8 million USD (over 90% increase from the same period of the previous year). A minus per share of 0.27 USD (0.11 USD higher than expected – the analysts' consensus). The high increase in price of the natural gas for the production of the hydrogen, which Plug probably still purchases itself, created increased costs. By the end of the year, however, the company's own hydrogen production should reach 70 tonnes per day (one third of the current cost). In the plans are an electrolysis capacity of 1 GW.

Side note: The payment to the management board (including option rights) in 2021 was a considerable 52 million USD, after the 13.6 million USD in 2020 and 3.7 million USD in 2019. For a company with such high losses, this is relatively generous compensation in relation to the turnover and perhaps should be scrutinized.

Summary: Investment banks see the share at 21 USD (27 USD according to Truist Securities) to 45 USD (Evercore ISI). The company has positioned itself very well in terms of PR and IR (IR = investor relations) and has a large following of fans, so the share in the hydrogen domain has reached good visibility. Only the very high investments to be expected will cause the capital base to melt away and result in logical losses before Plug will earn money with hydrogen. That should be taken into account when making an investment. Further share issues for the various projects are very conceivable. Higher share prices are needed for this – if that's the case.

HYZON MOTORS – AWARD WINNER AT WORLD HYDROGEN SUMMIT IN ROTTERDAM

Hyzon Motors was able to close the first quarter with a low stated loss of minus 0.03 USD per share. At the end of the quarter, cash and cash equivalents amounted to about 407 million USD. This should be evaluated in relation to the stock market valuation of about 1 billion USD. The build-up of capacity is proceeding according to plan. So 10 to 15 trucks for testing will be delivered to customers by the end of the year. A total of around 300 to 400 commercial vehicles are to be delivered in 2022. It is said that a variety of customers is involved, among them in China.

Concerning the own hydrogen production, the company is focusing mainly on waste-to-hydrogen projects with partners, but also other projects with pipeline companies like TC Energy. Plus: In Europe, the share in Hyzon Motors Europe B.V. was increased from 50.5 to 75 percent – surely the right step and ultimately also a basis for a full takeover.

One milestone has been reached in the meantime: In the USA, production of the company's own fuel cell stacks and MEAs (membrane-electrode assemblies) was started. Hyzon will also focus on, in addition to its own production of hy-

Fig. 7: Presenting of the Hydrogen Transport Award to Hyzon at the World Hydrogen Summit [Source: World Hydrogen Summit]

drogen-powered commercial vehicles, the repowering of existing diesel trucks. The chassis of these are readily available, whereas waiting or delivery times of up to 16 months are possible for new chassis. Hyzon will install its fuel cell system in the trucks or replace the old diesel engine system with it. They can be compared to the German company Clean Logistics, which is taking the same path of repowering. The Hyzon Repower program will be implemented together with partner Fontaine Modification.

The perfect complement to Nikola Motors in the area of H_2 commercial vehicles. This market is furiously growing due, among other things, to statutory regulations on environmentally harmful emissions, which is readily seen by also the various collaborations of major truck manufacturers, like Daimler Truck with Cummins Engine in the USA, Toyota and Kenworth, or Cellcentric (Daimler/Volvo joint venture) here in Germany. Hyzon has the advantage of being able to offer a specially developed fuel cell system and hydrogen storage system as well as in-house H_2 production, as a one-stop-shopping partner. It's conceivable that Hyzon will be able to gain strategic partners – similarly to Nikola with Iveco.

The current stock market valuation is completely disproportionate with the prospects of the company and the global market it addresses. At the hydrogen summit in Rotterdam, Hyzon was distinguished for its technology and business model – a good sign and a confirmation of previous assessments.

BURCKHARDT COMPRESSION – FIGURES INDICATE A CONTINUATION IN POSITIVE DEVELOPMENT

It's been over a year now since Burckhardt Compression has been discussed here. In the meantime, the share price rose from 300 CHF to over 500 CHF, with a reaction (profit-taking?) occurring only recently. Shares will continue to move in accordance with the figures and prospects: Order volume rose sharply by 44.3 percent from the previous year to 1 billion CHF. Turnover in 2021 amounted to 650.7 million CHF and is to reach (planned) 720 to 760 million CHF this year, far outpacing the 700 million CHF originally targeted. Shareholders can rejoice, as they will see a planned 15.4% dividend increase to 7.50 CHF, if the proposal of the board is accepted. Basis is an increase in earnings per share to 14.82 CHF from 13 CHF, which corresponds to an impressive payout ratio of nearly 50 percent. Especially from markets related to hydrogen, great growth opportunities are expected. With 242.9 million CHF in equity and thus a ratio of 29 percent, the company is well positioned.

Summary: In view of the enormous growth prospects of the markets that Burckhardt Compression addresses technologically (hydrogen-driven), this stock is still interesting to add to the portfolio, as a steady, healthy growth can be assumed. However, it is a stock with a narrow market (Swiss stock exchange) that can be classified as a long-term investment in hydrogen. ||

WARNING
Each investor must always be aware of their own risk when investing in shares and should consider a sensible risk diversification. The FC companies and shares mentioned here are small and mid cap, i.e. they are not standard stocks and their volatility is also much higher. This report is not meant to be viewed as purchase recommendations, and the author holds no liability for your actions. All information is based on publicly available sources and, as far as assessment is concerned, represents exclusively the personal opinion of the author, who focuses on medium- and long-term valuation and not on short-term profit. The author may be in possession of the shares presented here.

Category: International | **Author:** Stefan Liebing

CAN AFRICA SOLVE THE ENERGY PROBLEMS?

Why our neighboring continent is still underrated

Fig. 1: The port of Barra do Dande in Angola could be the site for a future hydrogen project [Source: Lars Schneider]

While German economy minister Robert Habeck is busy visiting Qatar and Norway in a bid to ease Germany's dependence on Russian energy supplies, representatives from the Italian government are heading for Algeria, Angola and the Republic of Congo. The German administration, it would seem, still continues to undervalue Africa, both as a potential supplier of natural gas and a partner for new hydrogen projects.

Industry experts are unanimous: Germany will need to rely on energy imports for the long haul. Currently we import over 60 percent of our energy, with the rest of our needs met by home production. Oil, coal and natural gas top the list of energy imports. Renewable energy expansion in Germany – in itself – will not be sufficient to replace these vast volumes. It is therefore critical that we are in a position to buy in additional green energy supplies from abroad in the future.

The growing awareness of hydrogen has succeeded in accelerating the debate on energy imports. The immediate solution might be to transport green electricity over long distances. But then what could be done to shore up the energy supply in the post-fossil fuel era?

For starters, many lessons can be learned from the international natural gas industry. While Minister Habeck has been touring the world looking to purchase liquefied natural gas, he's generally been informed that usually 80 percent to 90 percent of gas volumes have to be sold in the form of long-term off-take agreements even before building work begins. That's in order to make the construction of new LNG liquefaction plants possible in the first place. These agreements are required by the banks that would be prefinancing such projects, often to the tune of tens of billions of euros. This is because they need a cast-iron guarantee that the LNG output will be bought, and won't be affected by the global economy at the time.

The upshot is that there is only a small percentage of free capacity that can be traded on the short-term spot market. And this is now the main problem facing Germany's LNG supply: Anyone intending to acquire large volumes on a regular basis, and who doesn't want to rely on short-term stock market trends, must make long-term purchasing commitments. However, entering these kinds of deals is something that Germany has, so far, neglected to do for LNG, preferring instead to concentrate on contractual arrangements with Russia, Norway and the Netherlands.

NEW PARTNERSHIPS NEEDED FOR HYDROGEN SOURCING A similar problem also arises in relation to the steady, long-term sourcing of green energy for the simple reason that new hydrogen projects are only built if energy buyers sign the appropriate agreements. The import terminals for green methanol and ammonia that are currently under discussion will remain empty if there is not a joined-up procurement strategy. In many potential partner countries it's political decision-makers who are the ones responsible for making commercial decisions, meaning that the political agenda also has a hand in the process. Germany's efforts will only be successful if its government pursues a serious, independent "hydrogen foreign policy" that does more than simply tag onto commercial projects during state visits or offer advice on foreign business dealings through the chambers of commerce, as has often been the case in the past.

Choosing suitable countries to partner with has a particularly significant role to play here. Naturally, it's of paramount importance that the underlying technical conditions are right. The production of hydrogen from renewable plants is, even in the current climate of high oil and gas prices, only financially viable if green power can be generated for less than EUR 0.02 to EUR 0.03 per kilowatt-hour. This whittles down the selection to countries that have copious amounts of wind and sun. In principle, both wind and solar resources are needed since an electrolyzer plant can only operate profitably and competitively if it can run nonstop, in other words if wind power can kick in when the sun disappears below the horizon. Battery storage systems are much too pricey. That's why we should focus our efforts on countries that have the potential for both wind and solar plants. Other essential factors are the availability of sufficient water for electrolysis as well as access to export infrastructure, i.e., a coastal position and the presence of the necessary loading terminals.

WILL AFRICA PROVIDE US WITH GREEN ENERGY? A study by the German education ministry comes to the conclusion that western Africa alone could harbor sufficient potential to cover the world's hydrogen needs [1]. However, these findings need to be viewed with caution. Adequate levels of solar radiation can be found predominantly in the northern area of western Africa while good locations with plenty of wind are situated only in southern regions close to the coast. Combining both forms of power generation currently requires large sums of money to be invested in power grids and pipelines.

Nevertheless, there are a number of countries that already meet all the technical stipulations: adequate sun and wind levels, access to water and availability of export infrastructure. Those most commonly cited are Egypt, Algeria, Morocco, Mauritania, Namibia and South Africa.

Alongside technical and commercial matters, issues of investment security and project financeability have a part

Fig. 2: Stefan Liebing in conversation with Ethiopian ambassador Mulu Solomon [Source: German-African Business Association / Fabian Hammerl]

to play. And this is where Africa's poor reputation prevails. That's not to say that this impression necessarily reflects the reality down on the ground, rather it is often attributable to an outmoded cliche that has become ingrained in many company headquarters.

However, one thing the business community has now realized is that, despite short-term setbacks caused by COVID-19, Africa is home to some of the fastest-growing economies in the world. Not only that, there are many safe and stable African nations that are tackling corruption and are making valiant efforts to improve their infrastructure.

In spite of reservations about doing business in Africa, German companies have made more headway than previously thought: In Namibia, a consortium including the German corporation Enertrag has recently received a grant of up to USD 9 billion to invest in the production of green ammonia. Meanwhile in Angola, companies Gauff (Nuremberg) and Conjuncta (Hamburg) have become exclusive partners of the state oil group Sonangol as part of an initial hydrogen collaboration. Plus, other German developers and plant construction companies are pursuing interests in Egypt, Morocco and South Africa.

While German companies are currently spearheading developments in Africa, it is remarkable that this primary position can be credited to just a few medium-sized enterprises. There would certainly be ample scope for dozens more hydrogen investors from Germany to do business on the continent.

ENERGY PROJECTS GET POLITICAL Yet it is true to say that many of the companies that could consider making such a move would have to make some adjustments. One unusual aspect of working in Africa is that commercial projects are much more political than in more developed nations such as those in Europe or North America, where German mid-tier companies have traditionally preferred to do business. Organizations looking to make successful investments in Africa need to understand that, in many cases, the decision to award the contract for a particular project is made based on political considerations – and that rival bidders are often state-run concerns from other countries that enjoy a high degree of support from their governments. This means that project developers need to take greater account of political matters and circumstances, not to mention the fact that things won't go anywhere without strong backing from the German government.

Hence the German administration has struck hydrogen partnership deals with Angola, Morocco, Namibia, Nigeria, South Africa and Tunisia. Consequently, six of the 21 partnering countries are African nations [2]. The unfortunate reality is that the content of these collaborative agreements frequently skirts around the most important issues. By and large, German corporations are fully aware of the technical and economic prerequisites that need to be met before making an investment, and therefore they seldom need assistance in this regard.

By contrast, companies do need support in obtaining political assurances, in creating a level playing field when competing against other foreign governments and, particularly, in accessing finance. The idea of the H2Global Foundation, which will sign off-take agreements backed by the German government, is a step in the right direction in terms of providing greater assurances to banks. However, it remains difficult for banks in Europe to finance projects in what are seen as "exotic" African nations. One of the reasons for this is tighter regulation on banks.

Therefore, instead of offering seminars and hydrogen welcome receptions in Africa, the German government should concentrate on supporting specific projects by throwing its full political weight behind them and, above all, providing financing guarantees that will enable private banks to fund hydrogen schemes.

AFRICA HAS A MAJOR ROLE TO PLAY If the political establishment and commercial enterprises were to work together more closely on hydrogen projects to supply green energy to Germany, then Africa would have the chance to make a much more significant contribution to German energy supplies, due to its favorable technical conditions and geographical proximity to Germany. We are starting to see a group of African nations emerge that could become the new energy export champions of the world, thanks to their copious sun and wind resources, and thereby take the place of many traditional OPEC countries.

German politicians and business leaders still appear to underappreciate the importance of Africa. While Italy has already secured quantities of unsold LNG, the German economy minister has yet to make any travel plans to the region. Africa is capable of assisting with LNG supplies – not only in the short term but also particularly in the medium term as a partner for bilateral supply agreements on green energy.

The question, nevertheless, is whether Germany is agile enough to seize this opportunity. Not only could it secure green energy for its citizens, but also explore an attractive growth sector for the German economy. However, it's also entirely possible that we squander the chance to become international market leaders in an innovative sector by being too sluggish in our foreign economic policy. Adopting a completely new approach that supports an interest-led foreign policy for green hydrogen – now that would be a real turning point. ||

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GERMAN H_2 TECHNOLOGY IN THE FAR NORTH

Finland still hesitant with its hydrogen strategy

Fig. 1: Planned P2X Solutions site in Finland [Source: P2X Solutions]

For this Scandinavian country, the natural foundation for a hydrogen economy, compared to many others in Central Europe, is rather good. Finland has sufficient renewable energy resources, an enormous amount of water sources at its disposal and competitive electricity prices. Of the electricity generated from renewables in 2021, the highest share in Finland was nuclear at 35.6%, but hydro with 22.5% constituted nearly one quarter. Wind with 12.5% was the third most significant renewable electricity source. Biomass closely followed with 10.3%. All this accompanied by an intensely developed and reliable energy transmission network and the technological and digital expertise to make power generation in Finland extremely efficient and low cost.

The current requests to the national grid operator Fingrid for wind power grid connections amount to nearly 100 GW of additional power. Furthermore, publicly announced projects in various stages of planning so far total 21 GW of additional capacity. In 2020, Finland's total electricity generation capacity, from all energy sources, lay around 16 GW. The growth in forecast is therefore promising, as are the major leaps in development of onshore wind and biomass.

Especially great potential is to be offered by the expansion of offshore wind energy. This is currently not a major area in Finland, but the Finnish wind industry is talking of 31 new offshore farms that may appear along the country's coast in the future. The first tenders for offshore wind energy, according to the Finnish government, will be possible in 2023 and 2024.

"In January 2021, the first approvals for offshore wind energy research in Finland's exclusive economic zone (EEZ) were issued. WPD Finland Oy was allowed the area west of Jakobstad. Shortly before, OX2 Finland Oy had received clearance to perform research in this area. In addition, the latter has been authorized to carry out research to the west of Hailuoto," said the German economic development agency Germany Trade and Invest (GTAI) in January 2022. WPD Finland is also extensively active in the area of onshore wind. The company is investing in wind power plants in the far north of Finland, among other things, and with the wind park Nuolivaara, Lapland, the first construction project beyond the Arctic Circle was realized.

Promising developments can also be seen in the biomass sector. Last year, about 110 biogas plants were in operation in Finland. Twenty new plant construction projects are currently in progress. In this domain, the production of synthetic natural gas is being considered. The synthetic methane would be produced by combining hydrogen and carbon dioxide. Economic feasibility studies on this are currently being carried out.

WITHDRAWAL FROM FOSSIL ENERGY

Despite some important initiatives that have helped in the development of hydrogen business clusters, Finland's position on hydrogen production and use of the fuel is hesitant and cautious. There is plenty of technological resource commitment and good coordination between commercial enterprises and research centers. However, Finnish policymaking with respect to hydrogen has been passive and restrained. The approach seems to be based on the limited commercialization of hydrogen technology.

"The hydrogen strategy presented in the climate and energy strategy does not yet meet the needs of the Finnish economy," criticizes Tuuli Kaskinen, head of the Climate Leadership Coalition.

In 2019, the Finnish government under prime minister Sanna Marin stated the goal of a climate-neutral Finland by year 2035. The retreat from fossil fuels has accelerated since Russia's invasion of Ukraine and the recent halt in gas deliveries from Russia. However, there is little in the Finnish energy and climate strategy on the subject of hydrogen.

However, this technology is important in the industrial context. "The use of emissions-free hydrogen and e-fuels is to be directed primarily towards industry, the transport sector and the energy system in Finland. For hydrogen produced by electrolysis, at least 200 MW for 2025 and at least 1,000 MW for 2030 are the targets," according to the policy paper on the national climate and energy strategy. On closer examination, however, the use of hydrogen here is limited to industry and heavy freight transport.

Regarding the use of hydrogen in transport, the Finnish government appears primarily interested in heavy freight transport: "Pilot projects are to test the use of hydrogen in transport, especially for heavy road and maritime transport."

H_2 PRODUCTION IS STILL IN THE EARLY STAGES

Green hydrogen production aided by wind power and solar plants has only just begun in Finland. The first batches are foreseen for 2024.

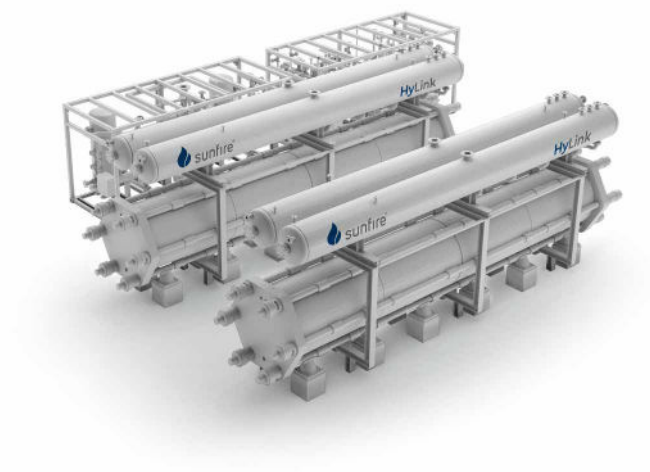

Fig. 2: The alkaline electrolyzer to be put in use [Source: Sunfire]

The first pilot project, with a capacity of 20 MW, is relatively small. The low volume is also reflected in the planned number of employees, which is estimated to be a maximum of 20.

Finland's first electrolysis plant will be built by P2X Solutions Oy together with German company Sunfire GmbH in Harjavalta, not far from Turku (see Figs. 1 and 2). "The project is the first industrial green hydrogen project in Finland. Its progress is thus also a great leap for our Finnish hydrogen economy," Finnish parliament member Eeva Kalli shared in a press release.

Green hydrogen will be generated at this plant, which uses water from the river Kokemäenjoki, with emissions-free wind power. The hydrogen will subsequently be sold to industrial businesses. Here, H_2 gas is to be processed to make methane, which can then be used as fuel for heavy haul vehicles and specialized machines like dump trucks.

"Our investment in Harjavalta opens up the Finnish market for green hydrogen and is a step towards an emissions-free welfare society. The expected supply of green hydrogen and renewable synthetic fuels will create a new demand for them. A functioning hydrogen market will make an emissions-free energy and raw material economy possible for the industrial and transport sectors," Herkko Plit of P2X Solutions told Finnish media.

Experts point out that in addition to the use of hydrogen in industry and transport, more attention should be paid to the Finnish heating sector. Finland is the coldest country in Europe, leading it to have the highest annual heat demand of all European countries. In urban areas, heat is supplied via district heating networks, which in turn is provided through combined heat and power generation. The generation offers an opportunity for the use of clean H_2. That would improve the cost-efficiency of hydrogen production and would contribute to further decarbonization of heating.

FINNISH HYDROGEN INITIATIVE Hydrogen Cluster Finland is the most prominent example of Finnish engagement in hydrogen. It is a network of businesses and industry associations that promotes information exchange, cooperation and the development of an H_2 economy in Finland. Among the members are not only prominent Finnish corporations, such as Fortum and Gasgrid Finland Oy, but also international giants in the hydrogen industry, like Linde, and other businesses that are important for the Finnish economy, for example Metsä and Wärtsilä.

The expectations of the economy for the emerging hydrogen industry are extremely high. The assumption is that 10,000 new high-value jobs along the Finnish hydrogen chain could be created. Commercial enterprises hope that the CO_2 footprint of Finnish exports will become more favorable, so that their shipments can increase, even if Finnish goods are rarely available at particularly low prices. ||

To read about another of Finland's projects, see page 20.

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

Celeroton AG, highly compact turbo compressors for fuel cell air supply, Industriestr. 22, 8604 Volketswil, Switzerland, Phone +41-44-25052-20, *info@celeroton.com, www.celeroton.com*

Haskel International, LLC, 100 E Graham Place, 91502 Burbank, CA, USA, Phone +1-818-84-34000, Fax -14291, *www.haskel.com*

sera ComPress GmbH, sera-Str. 1, 34369 Immenhausen, Germany, Phone +49-5673-999-04, Fax-05, *info-compress@sera-web.com, www.sera-web.com*

GAS DIFFUSION LAYERS (GDL)

MeliCon GmbH, Metallic Lightweight Construction, Porschestr. 6, 41836 Hückelhoven, Germany, Phone +49-(0)2433-44674-0, Fax -22, *www.melicon.de*

SGL Carbon GmbH, Werner-von-Siemens-Str. 18, 86405 Meitingen, Germany, Phone +48-(0)8271-83-3360, Fax -103360, *fuelcellcomponents@sglgroup.com, www.sglgroup.com*

HYDROGEN GENERATION

RIX Industries, 4900 Industrial Way, Benicia, CA 94510, USA, Phone +1-707-747-5900, *learnmore@rixindustries.com, www.rixindustries.com*

Rouge H_2 Engineering GmbH, Reininghausstr. 13, 8020 Graz, Austria, Phone +43-316-375-007 Germany: Rouge H_2 Engineering Deutschland GmbH, Maurener Str. 11/1, 71155 Altdorf, Phone +49-2175-6688-575, *www.rgh2.com*

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

MEASUREMENT AND CONTROL TECHNOLOGY

ADZ NAGANO GmbH, H_2-pressure sensors with EC79 approval, Bergener Ring 43, 01458 Ottendorf-Okrilla, Germany, Phone +49-035205-596930, *sales@adz.de, www.adz.de*

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JUMO GmbH & Co. KG, Measurement, control and automation technology for hydrogen applications, Moritz-Juchheim-Str. 1, 36039 Fulda, Germany, Phone 0661-6003-0, Fax -500, *mail@jumo.net, www.jumo.de, https://en.jumo.de/web/applications/hydrogen*

S++ Simulation Services, Ralf Kraume, Waldstr. 5, 82418 Murnau-Westried, Germany, Phone +49-8841-672147-0, *ralf.kraume@splusplus.com, www.splusplus.com*

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hySOLUTIONS GmbH, Steinstrasse 25, 20095 Hamburg, Germany, Phone +49-(0)40-3288353-2, Fax -8, *www.hysolutions-hamburg.de*

National Organisation Hydrogen and Fuel Cell Technology (NOW GmbH), Fasanenstr. 5, 10623 Berlin, Germany, Phone +49-(0)30-3116116-15, Fax -99, *www.now-gmbh.de*

ORGANIZERS (EVENTS)

ees Europe – International Exhibition for Batteries and Energy Storage Systems / Solar Promotion GmbH, P.O. Box 100 170, 75101 Pforzheim, Germany, Phone +49-7231-58598-0, Fax -28, *www.ees-europe.com*

European Fuel Cell Forum, Obgardihalde 2, 6043 Luzern-Adligenswil, Switzerland, Phone +41-(0)4-45865644, Fax 35080622, *forum@efcf.com, www.efcf.com*

f-cell 2022 | Hydrogen & Fuel Cell Conference and Trade Fair, 4-5 October 2022, Messe Stuttgart, Germany, *www.f-cell.de*

Tobias Renz FAIR, Berlin, Tobias Renz, *tobias@h2fc-fair.com,* Phone +49-30-60984556, *www.h2fc-fair.com*

REFORMERS

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

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DBI Gas- und Umwelttechnik GmbH, Karl-Heine-Str. 109/111, 04229 Leipzig, Germany, Phone +49-341-2457-113, *www.dbi-gut.de*

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

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STORAGE

GKN Powder Metallurgy Holding GmbH, Pennefeldsweg 11-15, 53177 Bonn, Germany, *www.gknhydrogen.com*

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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, *contact@borit.be, www.borit.be*

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*

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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)5139-9855-0, Fax -33, *www.ja-gastechnology.com*

Maximator GmbH, High Pressure Hydrogen Technology, Testing Equipment, Customer Testing Services, Lange Strasse 6, 99734 Nordhausen, Germany, Phone +49-3631-9533-5040, *info@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*

Sonplas GmbH, H_2 test stand, Testing of hydrogen-carrying components with real fuel, Sachsenring 57, 94315 Straubing, Germany, Phone +49-9431-9275-0, *info@sonplas.de, www.sonplas.com*

TesTneT Engineering GmbH, Eschenallee 11, 85445 Oberding 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

DAM Group, 200 Rue Léon Blum, 69100 Villeurbanne, France, Phone +33-478-269583, *www.damgroup.fr*

EVENTS

You can also find upcoming online and live events as well as possible changes to these at www.h2-international.com/events.

SEPTEMBER

Mastering Green Hydrogen
Prepare yourself for The Competitive Future of Hydrogen Energy, September 15, 2022, online
www.keynotive.io/events

3rd Germany-Korea Hydrogen Conference
Conference about hydrogen logistics
September 29, 2022, Berlin
Please contact: sven.ortmann@hs-anhalt.de

OCTOBER

f-cell at Messe Stuttgart
organized by Landesmesse Stuttgart GmbH
October 4 – 5, 2022, Stuttgart, Germany,
www.f-cell.de

eMove360° Hydrogen & Fuel Cell Conference 2022
eMove360° Europe 2022 goes Berlin
October 5 – 7, 2022, Hall 25 & Hub 27, Messe Berlin
www.emove360.com/

Hydrogen Technology Expo Europe
October 19 – 20, 2022,
Messe Bremen, Germany
www.hydrogen-worldexpo.com/

NOVEMBER

HOC – Mission Hydrogen
HYDROGEN ONLINE CONFERENCE
November 8, 2022 – online
www.hydrogen-online-conference.com/

Forum Hydrogen Business for Climate
November 8 – 9, 2022, in Montbéliard, France
www.hydrogenbusinessforclimate.com

DECEMBER

f-cell China at Shanghai Automobile Exhibition Center
organized by Nanjing Stuttgart Joint Exhibition Ltd
December 1 – 3, 2022, Shanghai, China,
www.f-cell.com.cn

Berlin Electrolyser Conference
December 7 – 8, 2022, Berlin, Germany
www.nextgen-electrolysers.com/

EVENTS 2023

JANUARY

20th International Conference on Renewable Mobility Fuel of the Future 2023
January 23 – 24, 2023 – in Berlin at the City Cube
www.kraftstoffe-der-zukunft.com

MARCH

FC Expo
March 15 – 17, 2023, Tokyo Big Sight, Japan
www.fcexpo.jp

LEGAL NOTICE

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Cover image: Enginius hydrogen truck
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