THE HYDROGEN MAGAZINE

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Digital twin: Optimizing electrolyzer operation

Hydrogen goes offshore

How fossil fuel infrastructure can be reused in a green future

Check, please.

Every period of time has its sentences that kind of become a mantra. The ones you instinctively reach for when you want to explain something fundamental. “The technology is ready” is one of them these days.

We could have opened practically every article in this issue with that line. We didn’t, because we figure you already know. Instead, we get concrete. The hydrogen sector is producing more and more products and systems, and they are growing increasingly sophisticated. From digital plant models to materials to machines for cell manufacturing, it’s all there. Thousands of engineers have done their homework, and an industrial ecosystem is emerging.

Now all these fine products need to find their market, and that’s the hard part. In most applications, hydrogen technologies are still far from selling themselves. The call for lead markets is getting louder. And the sector rightly highlights the advantages of hydrogen: its storage capability, the option of transporting it affordably through gas pipelines, its flexible range of uses, and its contribution to resilience. Certain numbers keep making the rounds, too, like the estimated nearly 9 terawatt-hours of curtailed renewable electricity in Germany in 2025.

All of this is true. But these are individual talking points. What’s missing is the full picture.

Having covered energy transition topics for more than 20 years, I can say: among the “electricity crowd,” this topic gets way more attention. One scenario analysis follows the next. Some focus on spatial distribution, others on temporal resolution, others on macroeconomics. You can support any of them, poke holes in them, or both, but together they move toward a systemic understanding.

Now comes the part that will probably not make me popular: in the hydrogen sector, I see very little of that. Take the demand to harness those nearly 9 terawatt-hours of curtailed renewable electricity. These surpluses occur in peaks, scattered across a handful of specific locations. Where exactly are those locations? How much of that electricity could realistically feed electrolyzers at decent full-load hours? What kind of support scheme would be needed, and would it actually save money compared to the compensation payments made today? And finally: how long will this surplus electricity even be around? At some point, the long-planned transmission lines to Bavaria will get built, just as Berlin Brandenburg Airport and the Elbphilharmonie concert hall in Hamburg eventually did.

The technology is ready, but that’s not enough. When it comes to making the case, the hydrogen sector could learn a thing or two from the “electricity crowd.”

Eva Augsten
Editor-in-chief
augsten@hzwei.info

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What's up, Hyfindr?

CENTRAL OR LOCAL?

Hyfindr Managing Director Dr. Björn Lüssow shares insights and encounters from the international hydrogen community.

Germany's hydrogen industry lacks systemic thinking, or so the claim goes. Many are calling for a hydrogen strategy embedded in a broader decarbonization strategy for the economy. A centralized approach, in other words – much like China's.

That kind of approach demands fundamental decisions on technology and funding. Should electrolyzers continue to be exempt from grid fees? Does the power grid really need such massive expansion just to enable an "all-electric" scenario? Why do we regulate the color of hydrogen so strictly while imposing no such rules on electricity?

In times of tight budgets, these big-picture questions cannot all be tackled at once with the rigor they deserve.

But let's not kid ourselves: a centralized approach carries its own risks. Weighing multiple trade-offs slows decision-making. Implementation follows years later. And local, potentially disruptive solutions are easily overlooked – or stifled by top-down mandates.

A case in point is Hy2B Wasserstoff. The company operates a 5 MW alkaline electrolyzer with a filling station in Bavaria, supplying two refueling stations for buses and trucks with green hydrogen. Smart power management ensures electricity is purchased when it is cheapest.

The result: green hydrogen below diesel parity. So it can be done.

Central versus local is therefore not the real question, in my view. We need both – a systemic framework that incentivizes local solutions. Local approaches create value and jobs on the ground while reducing energy dependence on foreign suppliers.

Ideas develop a special force when their time has come. When local approaches scale, they gain systemic relevance. "Build local" could be just such an idea. ○

How research is driving the energy transition

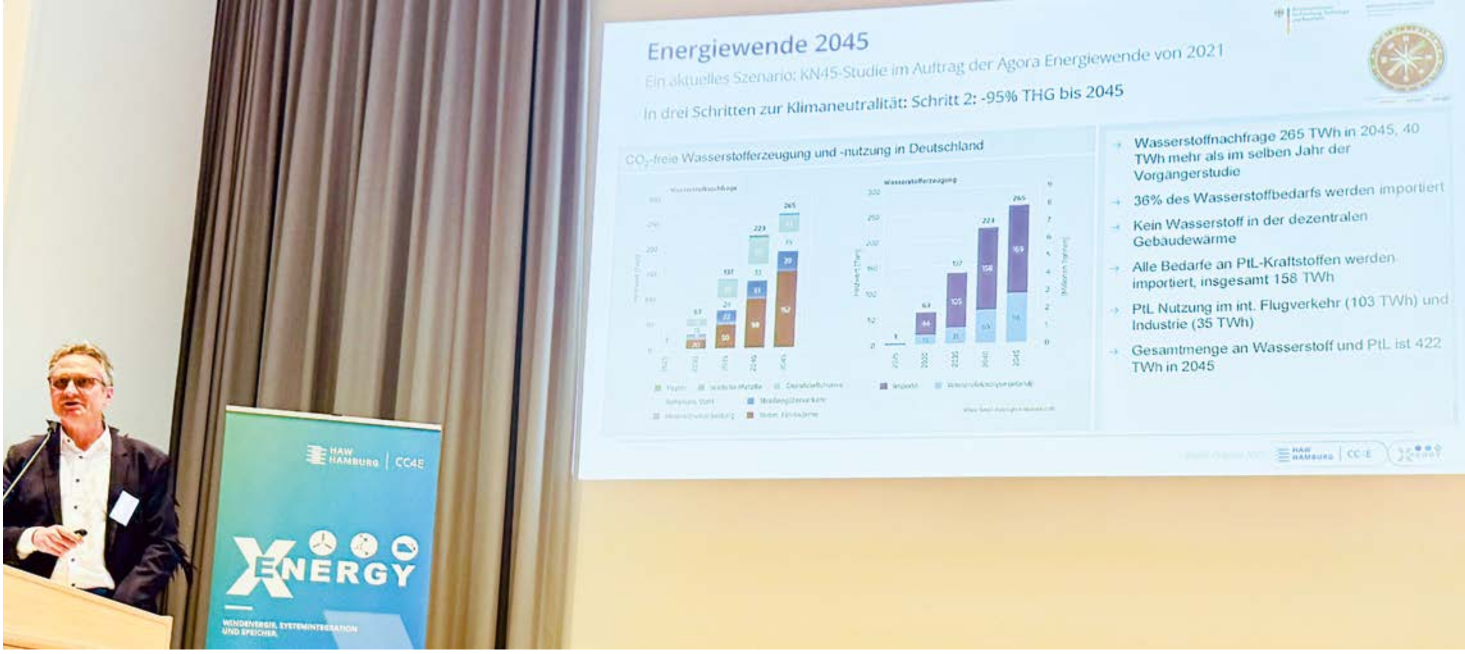
Hamburg University of Applied Sciences (HAW Hamburg) has completed the X-Energy research project after nine years. Together with over 20 partners, scientists from the Competence Center for Renewable Energy and Energy Efficiency (CC4E) developed solutions for sector coupling, power-to-gas, biological methanation, CO2 capture from the air, and carbon cycles, among other topics. The Federal Ministry of Education and Research funded the project with €10.9 million. At a closing conference in mid-February 2026 in Hamburg, the CC4E presented the most important results.

In biological methanation, hydrogen produced by electrolysis is converted with atmospheric CO2 by microorganisms into methane, which can be fed into the natural gas grid. Since green hydrogen alone does not enable sufficient value creation, X-Energy also addressed CO2 capture, which is required for the production of e-fuels and synthetic methane. The combination of H2 and CO2 obtained via direct air capture (DAC) is considered a key building block of the energy transition – for synthetic fuels and storable energy carriers as well as for the chemical industry. Moreover, DAC can contribute to decarbonization, as it enables climate-neutral production processes and potentially even negative emissions.

In the Hymspiel project, the CC4E developed an integrated system for local energy generation, storage, and supply. The goals are more efficient use of renewable energies, relief of the grids, and higher supply security. The core is a 100 kW PEM electrolysis plant that produces around 2.2 kg of hydrogen per hour. "The hydrogen is temporarily stored in a modular storage system with a low-pressure and a high-pressure stage (up to 300 bar)," explains Petrit Vuthi, a research associate on the project. "Reconversion to electricity occurs in the pilot plant through a hydrogen CHP unit and later a fuel cell." Part of the concept also includes using the resulting waste heat to heat the buildings on site.

"Through flexible storage and demand-responsive reconversion to electricity, local energy supply is to be optimized in order to utilize the potential of hydrogen as an energy storage medium in the district," explains Mike Blicker, co-project leader of Hymspiel and coordinator of X-Energy at CC4E. "Grid-supportive use of local flexibilities enables overall better integration of renewable energies into the electricity system." This would also reduce the need for grid expansion. Additionally, the project investigates how buildings can benefit from one another through so-called prosumer models.

System integration was also addressed in X-Energy with the question of how to use wind power peaks for electrolysis or how to plan electricity, gas, and heat networks in an integrated manner. Other researchers optimized two-blade rotors and multirotor systems for wind turbines and, together with the University of Strathclyde, established an international annual conference for multirotor research. Furthermore, one of Germany's first systems for demand-based night marking of wind turbines was put into operation. The innovations and efficiency improvements developed in the project increase the potential for renewable electricity – and thus also for green hydrogen.



Professor Hans Schäfers explains how Germany can become climate-neutral by 2045 with the help of hydrogen. © Monika Rößiger

With more than 20 partners from industry and trade who cooperated closely with the X-Energy engineers, the project went far beyond basic research – to applications already close to market in practice. Two spin-offs demonstrate that technology transfer has worked: one for intelligent control of heat and electricity generators and another in the area of maintenance strategies for wind turbines. "Cooperation between science and business is indispensable for the energy transition in our city," emphasized Hamburg's Second Mayor and Environment Senator Katharina Fegebank at the closing conference. The collaboration "accelerates innovation processes and contributes to the important transfer of knowledge and technology."

An outlook on how research will continue was provided by Hans Schäfers, Professor of Intelligent Energy Systems and Energy Efficiency and head of CC4E. The infrastructure created by X-Energy is already feeding into follow-up projects such as the North German Real-World Laboratory (NRL). Because Hamburg, as Germany's second-largest city and with a significant industrial area in the port – metals, chemicals – wants to become climate-neutral by 2040, urgency is required. Using green surplus electricity to produce hydrogen is obvious, but still difficult for regulatory reasons.

However, the potential is impressive, as a sub-project of the NRL shows. "According to initial findings, with an electrolysis capacity of approximately 2.3 gigawatts distributed across 52 sites at critical grid nodes in Schleswig-Holstein and Hamburg, around 80 percent of the surplus electricity from renewable energies that would normally be curtailed could be reduced," Hans Schäfers tells H2Int. "The concept of decentralized plants can support the hydrogen strategy of the Free and Hanseatic City of Hamburg, which so far primarily includes central projects and facilities such as the Hamburg Green Hydrogen Hub (HGHH) at the site of the former Moorburg coal-fired power plant."

He urgently calls for creating the political and legal framework now to build capacity to meet the projected demand for green hydrogen through both imports and domestic production.

Since X-Energy has intensively engaged with technologies that will likely only be deployed on a large scale in ten to fifteen years, it provides impetus for future storage strategies and the production of climate-neutral molecules. This should be of particular interest to investors, project developers, and municipalities. And it is also the timeframe in which the hydrogen economy will likely enter broad industrial application. ○ **Monika Rößiger**

Spain: 300 MW electrolyzer for Huelva

Thyssenkrupp nucera has signed a contract with Moeve for Southern Europe's largest green hydrogen project. The Dortmund-based electrolysis specialist will install 300 MW of alkaline water electrolysis technology in Huelva, Andalusia. This will produce approximately 45,000 tons of green hydrogen per year and reduce CO2 emissions by around 250,000 tons annually.

Moeve is advancing the "Andalusian Green Hydrogen Valley" project in the La Rábida Energy Park in the port city of Huelva. Under the contract, Thyssenkrupp nucera will deliver 15 standardized 20 MW electrolyzers for the first phase of the project, known as Onuba.

"Together with its partners, Moeve is establishing a strategic hub for clean energy in southern Spain to strengthen Europe's energy and industrial resilience," said Maarten Wetselaar, CEO of Moeve. And Werner Ponikwar, CEO of Thyssenkrupp nucera, emphasizes: "Onuba demonstrates that large green hydrogen projects can progress and reach final investment decision even in volatile markets when the framework conditions are right."

According to the company, the project is the first phase of Moeve's "Andalusian Green Hydrogen Valley." The goal is to build a scalable hydrogen value chain in southern Spain. The region's solar and wind resources, as well as strategic port infrastructure and existing transport corridors, are intended to connect production with industrial demand in Northern Europe. ○

The H2Hub team is delighted to receive this recognition. © h2hub

H2UB ranks among Europe's best start-up centers

H2UB has been included in the Financial Times ranking of the best startup hubs in Europe, published annually by the Financial Times, which compares and evaluates the performance and success of startup hubs in Europe. H2UB, based in the German city of Essen, has established itself as a platform for hydrogen innovation in Europe. Founded in 2021, the company connects startups with industrial partners, research institutions, and investors along the entire hydrogen value chain – from generation through transport and storage to industrial application.

Currently, H2UB counts 168 startups in its ecosystem. 78 teams from eleven European countries have completed the "H2UB Sprint" accelerator program so far. The hub supports founding teams with coaching, expertise, and targeted networking to bring technologies to market maturity faster. According to the company, the participating startups have raised more than €230 million in capital. Their cumulative valuation exceeds €516 million.

Shareholders of H2UB are the RAG Foundation, Open Grid Europe (OGE), TÜV Süd, and the German Aerospace Center (DLR). The Ministry of Economic Affairs of North Rhine-Westphalia supports the hub. Corporate partners include RWE Generation, Dräger, Yokogawa, and 3M, among others. In total, the network comprises more than 40 partners.

In addition to the accelerator program, H2UB offers market analyses and hosts the annual Hydroverse Convention. According to its own information, the event is the largest European event for hydrogen innovation and startups.

Rotterdam: Air Products to Build Europe's Largest LH2 Plant

The industrial gas company Air Products reports construction progress of more than 65 percent on its new hydrogen liquefaction plant in the Port of Rotterdam. The plant is scheduled to go into operation in 2027 and will supply customers in the Benelux region, France, Germany, and the United Kingdom. According to the company, customers include industries such as electronics manufacturing, aerospace, industrial processes, and energy technologies.

"Customers rely on the availability and reliability of hydrogen every day to ensure their operations," says Miquel Lope, Vice President Northern Continent at Air Products. "The continuous progress on our new liquefaction plant in Rotterdam reflects our ongoing investments in security of supply in the region." Boudewijn Siemons, CEO of the Port of Rotterdam Authority, welcomed the construction progress: "Air Products' investment strengthens the infrastructure required for industrial decarbonization and ensures a reliable, locally available supply for companies across the region."

Air Products has been active in the Port of Rotterdam for more than 55 years and claims more than 65 years of experience in hydrogen production, logistics, and infrastructure. The company generated revenue of 12 billion US dollars in around 50 countries in fiscal year 2025.

Local electrolyzers for Germany's south west

The southwest German state of Baden-Württemberg is supporting the development of local electrolysis capacity with the ELY funding program. Funding is provided for the new construction of electrolyzers that produce renewable hydrogen through water electrolysis. The focus is on building hydrogen hubs in the state. The electrolyzers are to be constructed in line with regional expansion of the electricity grid and renewable energy installations.

One background to the program is that the hydrogen core network approved by the Federal Network Agency in October 2024 does not cover all regions in Baden-Württemberg. And implementation of the core network will still take time, according to the state. The additional necessary expansion of the hydrogen network must occur through the Gas and Hydrogen Network Development Plan. Until the long-distance pipelines are built and previously unconnected areas are linked, local generation capacities and value chains are to be established on site.

After the first funding call in 2025, the program is to continue in 2026 with a second round. According to state information, the goal is to achieve sufficient hydrogen supply in the medium term and secure the competitiveness of Baden-Württemberg companies. ○

New electrolyzers are needed: Baden-Württemberg is funding them again.

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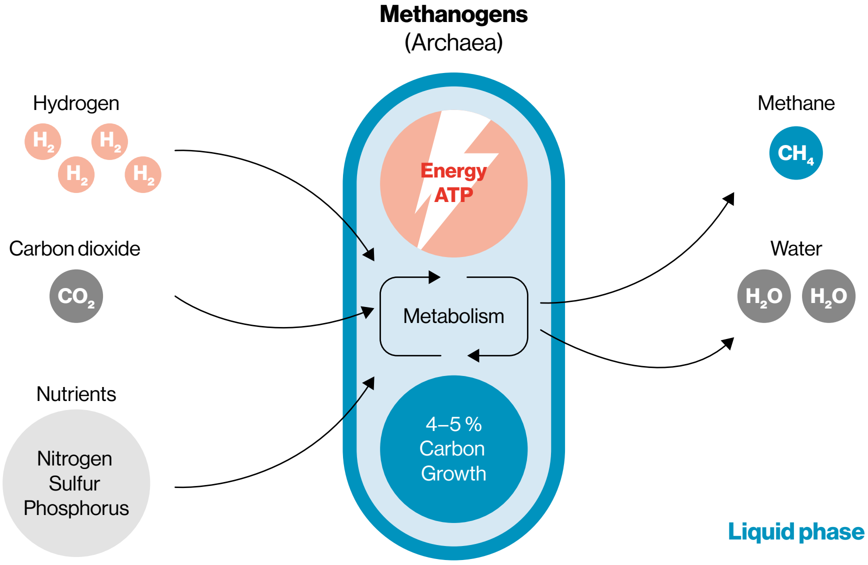
Green hydrogen as an opportunity for the biogas industry



Biological methanation by methane-forming microbes (archaea). © NEONBOLD

The energy transition currently has two major efficiency problems: First, surplus electricity from renewable sources is often curtailed. Second, valuable energy potentials from biowaste often remain unused. This is precisely where a project of the North German Real-World Laboratory (NRL) at the Bützberg biogas and composting plant comes in. It shows how combining both areas can develop a new approach for climate-friendly gas supply.

Marcel Schröder („Stadtreinigung Hamburg", City Cleaning) and M.Sc. She Ming Ng (Hamburg University of Technology) have published a white paper on this. At the center is a power-to-gas approach that has hardly been tested on an industrial scale in this form: biological in-situ methanation in a dry fermentation plant (see H2Int. No. 4-2025).

Hydrogen produced by electrolysis from renewable electricity is introduced directly into the fermentation process. Microorganisms – so-called hydrogenotrophic archaea – convert the CO2 contained in the biogas together with the hydrogen into additional methane.

Technically, the concept is based on a 1 MW PEM electrolyzer that responds flexibly to low electricity prices and thus specifically uses surplus electricity. The hydrogen produced is either fed directly into the fermenters or temporarily stored in a repurposed pipeline section – a comparatively simple and cost-effective solution.

The goal: increase methane yield while improving gas quality. Conventional raw biogas typically consists of only about 60 percent methane, with the remainder predominantly CO2. Through additional methanation, this CO2 content is reduced – a decisive advantage for feeding into the natural gas grid.

While in-situ biomethanation has primarily been investigated in the laboratory so far, the step into practice succeeded in Bützberg. First, laboratory tests at Hamburg University of Technology confirmed the fundamental feasibility under dry, discontinuous conditions – a previously little-researched field.

In subsequent preliminary tests on an industrial scale, hydrogen was initially fed from compressed gas cylinders. The measurement results clearly show: During hydrogen addition, the CO2 concentration in the biogas decreased while the methane content increased – direct evidence of biological methanation in ongoing operation.

In parallel, the plant could be technically upgraded to handle hydrogen. So-called "H2 readiness" includes not only new piping infrastructure but also adapted measurement technology and safety concepts.

The greatest challenge lay not so much in the hardware, but primarily in process control and sensor technology, which must meet particularly high requirements in research operations.

The results are promising: The project shows that existing biogas plants can be expanded relatively easily technically and thus become flexible energy storage systems. Given around 10,000 biogas plants in Germany, this opens up considerable scaling potential.

At the same time, the economic outlook currently remains limited. High electricity costs for electrolysis and comparatively low revenues for biomethane currently prevent profitable operation. According to project information, electricity prices would have to be significantly below today's level to achieve economic viability.

Regulatory framework conditions also slow development. Instruments such as the EnWG (German Energy Industry Act) model "Use Instead of Curtail" could help, but are not yet applied comprehensively. Despite these challenges, the project provides important evidence: Coupling the electricity, gas, and waste sectors can work – even in existing infrastructure.

In addition to improved use of renewable energies, the concept helps to utilize CO2 streams meaningfully and integrate gas networks as energy storage. For the biogas industry, this represents a new perspective. Instead of pure electricity production, plants could increasingly act as flexible methane producers in the future – especially when political framework conditions and market mechanisms are adjusted accordingly.

The North German Real-World Laboratory sees itself as a blueprint. The upcoming project phases, in which H2supply is extended to multiple fermenters and automated, should show whether the results can be stably reproduced. One thing is already clear: Green hydrogen as a booster for biomethane is more than a theoretical concept. In Bützberg, it is becoming industrial reality – with the potential to become an important pillar of the future hydrogen economy. ○ **Monika Rößiger**

The fossil fuel risk

For the second time within just a few years, a war is jeopardizing the supply of fossil energy and sending prices soaring. It is time to strengthen alternatives.

At the time of writing, the Strait of Hormuz remains barely passable, disrupting around 20 percent of global oil trade. The effects are immediately felt at fuel pumps, in heating costs, and across energy-intensive industries.

Since Europe has only about two percent of the world's oil and gas reserves, we are extremely vulnerable to crises. This is nothing new – following the 2022 energy crisis triggered by Russia's war of aggression, the next shock has arrived within just a few years.

This illustrates the risks of waiting for a "smooth transition": For energy-intensive companies, such a crisis means volatile commodity prices, rising transport costs and the threat of renewed inflation spikes. This also significantly influences investment decisions.

This is where an advantage opens up for hydrogen technologies: The more volatile and expensive fossil fuels become, the more attractive long-term supply contracts for renewable energy and hydrogen become, even if the entry price is higher. Companies are not only calculating the pure energy costs per megawatt hour but also the risks associated with fossil options. Green hydrogen scores with more stable costs, a greater number of potential supplier countries and even significant production within the EU.

Hydrogen becomes security-relevant Planning the hydrogen network is therefore not only important for climate policy but also for security policy. In this regard, we are taking an important step these days: With the binding capacity reservation for the future German hydrogen core network (Wasserstoffkernnetz), planning is now becoming concrete; pipeline rights can be booked.

The development of hydrogen storage facilities, import infrastructure and decentralized production plants is now also becoming strategically relevant. NATO is examining scenarios for decentralized energy supply, for example at background meetings with H2 grid operators. Hydrogen and its derivatives are thus also gaining importance in hedging the risks of geopolitical supply disruptions.

The expansion of the hydrogen economy will not succeed on its own. The current crisis can serve as a catalyst. Equally, once prices fall again, we may revert to old patterns – as happened after the oil crises of the 1970s. Two aspects will be decisive:

- Whether industry uses the current willingness to change to secure capacities and long-term hydrogen supply contracts, rather than passively waiting for the next crisis.
- Whether policymakers can maintain the pace of current fast-track procedures and also commit to appropriate funding instruments.

The real lesson from current events: A secure and affordable fossil energy supply is likely a thing of the past. This offers the opportunity for a proactive transformation instead of merely reacting to crises time and again. Green hydrogen is no panacea, but it can effectively link the challenges of energy security, climate protection and industrial competitiveness. ○

STEFAN KAUFMANN

Dr Stefan Kaufmann is a lawyer who advises companies and investors in the hydrogen economy nationally and internationally. He served in the Bundestag, the Federal Parliament of Germany, from 2009 to 2021 and from 2024 to 2025. From 2020 to 2022, he was the Federal Government's Innovation Commissioner for Green Hydrogen at the Federal Ministry of Education and Research. For H2int., he regularly reports on current developments in the energy carrier of the future.

Northern Finland makes its pitch

Text: Eva Augsten

Few places in Europe offer better conditions for hydrogen production than Finland's North. Now the region is making its case to investors.

© Harri Tarvainen

Plenty of space, cheap electricity, a well-educated workforce, solid infrastructure and ports: northeastern Finland has a lot to offer for building a hydrogen economy. In 2023, the Finnish government adopted a plan to contribute up to 10 percent of Europe's hydrogen demand. While this is "only" a government resolution and not a law, the municipalities in the northeast are determined to attract companies along the hydrogen value chain. At the Nordic Hydrogen Week in February, the regions jointly promoted their locations. Around 2,000 guests had traveled in for the event, according to the organizers.

In Sea Lapland, the five municipalities of Tornio, Keminmaa, Kemi, Simo and Tervola along the Gulf of Bothnia have joined forces to promote their region as a hydrogen location. Janne Rautio of Kemi Digipolis wants to "bring the right people to the right place" and has organized a site visit for interested parties and potential investors. Through a winter wonderland of deeply snow-covered conifers, the tour first heads to a pulp mill, then to a seminar hall.

Markku Kivistö of Business Finland backs up Rautio's thesis with figures: Finland uses 96 percent CO2-free electricity, including nuclear energy, at electricity prices of around 50 euros per megawatt hour. The Finnish domestic market is very small, which is why the country sees all of Europe as a kind of home market. "Finland is the most open economy in the world," says Kivistö. And Sea Lapland, he is convinced, is the best location in Europe for hydrogen production.

Biogenic CO2 for e-fuels The site visit in Sea Lapland begins with a tour of a pulp mill, the Metsä Bioproduct Mill in Kemi. The owner of the facility, which is only two years old and cost 2 billion euros, is the Metsäliitto Cooperative, in which around 90,000 Finnish forest owners are organized. On the premises, fully automated cranes receive the incoming logs from northern Finland and Sweden. They learn and improve on their own; no people are to be seen here. The logs are turned into wood chips, which are then cooked with chemicals to extract cellulose. The residues are burned to generate the energy that powers the pulp mill, creating a nearly closed loop. According to the operator, the facility, with 4 million tonnes of biogenic CO2 per year, is the largest single source of biogenic CO2 in Europe.

In the seminar room, Minna Mentzer of the Metsä Group explains the corporation's climate strategy. At 12 million tonnes per year, the corporation accounts for around 6 percent of biogenic CO2 emissions across Europe, Mentzer says. Metsä intends to capture this resource and use it for e-fuels. However, CO2 capture is not being tested in Kemi but at the Rauma site. There, a pilot plant housed in shipping containers ran for six months, developed jointly with technology partner Andritz. The capacity: one tonne of CO2 per day. The result was encouraging, Mentzer says. The captured concentrations were higher than expected, and energy consumption was within an acceptable range. However, it also became clear that waste heat falls far short of what is needed. The energy costs for capturing and, where applicable, liquefying would be the most significant cost factor of the capture process. The use of heat pumps is being evaluated, but details are still pending.

Metsä is planning a phased scale-up: the next step is to be an industrial demonstration plant with 30 to 100 kilotonnes per year; at full build-out, 300 to 1,000 kilotonnes per year would be possible, still well below the theoretical total capacity of the Kemi site.

A decision on the next steps is now pending. Time is pressing, because in order to claim the currently available funding for the demonstration plant, Metsä must have it operational by 2030. At the same time, the market for biogenic CO2 is barely developed. And long-term climate policy also seems uncertain. "It is currently being questioned," says Mentzer.

As an application example, Mentzer shows concrete made with biogenic CO2 by Finnish start-up Carbonaide. But she qualifies: "The market is still undeveloped." Building new, complex value chains requires collaboration among many partners, from capture through transport and storage to utilization. There is a hard deadline: for the currently available funding, at least the demonstration plant must be operational by 2030. "Regulation carries risks," Mentzer warns. "It could be changed. It is currently being questioned."

E-fuels from carbon monoxide Juha Erkkilä of Outokumpu's EvoCarbon project presents an approach where, at first glance, one might suspect a typo. The steelmaker Outokumpu does not want to capture CO2 but CO, which is generated in steelmaking. Because it has a higher energy level than CO2, it can be used to produce e-fuels with less energy input than CO2. The main drivers for decarbonization for Outokumpu are the European Emissions Trading System (ETS) and the Carbon Border Adjustment Mechanism.

Outokumpu has signed a letter of intent with Norsk e-Fuel, and a feasibility ▻

study is set to begin in 2026. At the Tornio site in neighboring Koivuluoto, a plant is to produce 80,000 to 100,000 tonnes of e-SAF per year. For Outokumpu, this would mean a direct CO2 reduction of around 200,000 tonnes per year, roughly 20 percent of the corporation's global direct emissions. If the feasibility study yields a positive result, Norsk e-Fuel expects an investment decision around 2028 and the start of production in 2032.

1,500 km hydrogen network planned The Finnish gas grid operator Gasgrid has been tasked by the state with connecting a large share of the country's industrial customers to a hydrogen network in the early 2030s. The first step is now an environmental impact assessment (EIA). A total of 1,500 kilometers of transmission pipeline is planned, covering 70 municipalities and 14,000 landowners in the study area. This makes the hydrogen network historically the largest EIA process in the country. The assessment began in spring 2025, and the final route planning is to be finalized by early 2027.

Similar to the German core hydrogen network (Kernnetz), Gasgrid in Finland is also collecting letters of intent from parties interested in hydrogen in order to factor them into the planning. So far, 2 million tonnes have been mentioned, according to Gasgrid. Unlike in Germany, the Finnish hydrogen network is to be built entirely from scratch, without repurposing natural gas pipelines. And although Gasgrid is a transmission system operator and will only operate transmission networks, the company is initially also taking on the planning at the subordinate distribution network level.

A stage for hydrogen in Oulu At the Northern Power Forum in Oulu the following day, around 700 guests had attended, according to the organizers. The focus was on hydrogen production and large-scale applications: steelmaking, e-fuels for aviation and fuels for shipping.

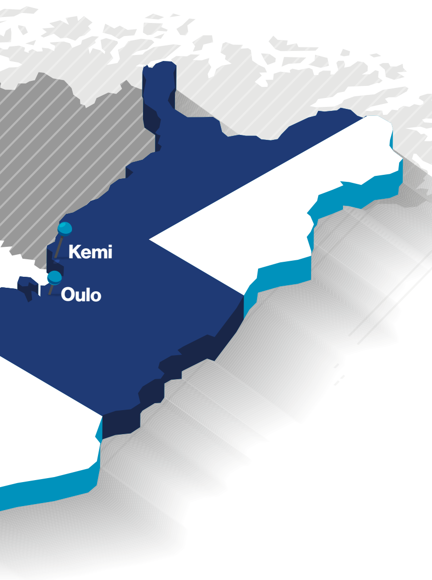
Racing driver and moderator Emma Kimiläinen co-hosted the program together with Herkko Plit, founder and CEO of P2X Solutions. Mayor Ari Alatossava enthusiastically promotes his city: Oulu is young (average age 40), well-educated (one third of the population holds a university degree) and international (with residents from 140 countries). In addition, the city, with just under 220,000 inhabitants, is a European Capital of Culture this year.

The Finns are not short on ambition and vision when it comes to hydrogen. Mikael Lindvall, Chief Technology Officer of Blastr Green Steel, for example, aims to produce 2.5 million tonnes of green flat steel per year. The company intends to build a complete value chain for this purpose. According to the current plan, the production of direct reduced iron (DRI) pellets is to take place in the United Kingdom, while the actual steel production would then be in Inkoo, in southern Finland. The company is currently assembling all the building blocks that precede the actual investment decision. The trader and processor Vogten Staal has declared its intent to purchase from Blastr Green Steel. The city of Inkoo has included the steel mill in its zoning plan. And CTO Lindvall is convinced: "End consumers will prefer low-emission steel. But it also has to be competitive on cost." And so, as with many projects, the final investment decision is still pending. The year 2027 was floated at the conference.

The market for marine fuels is tough. Will consumers actually buy the product? That is the question also preoccupying the aspiring producers of green marine fuels. "When we press the start button for production, we need to see that the demand is really there," says Hege Økland of Hy2Gen. So far, there are no long-term offtake commitments. The company, headquartered in Wiesbaden, Germany, intends to produce green hydrogen at a number of locations across Europe. However, the company's flagship ammonia production project in Norway evaporated between the conference and the editorial deadline for this issue: the grid operator withdrew the connection commitment for 270 MW. Unless they opt for drop-in fuels, shipping companies would also need to invest in new vessels. Ilkka Rytkölä of the

The pulp mill operated by Metsä is one of the largest sources of biogenic CO2 in Europe. © Eva Augsten

The start-up Zun-H produces hydrogen from sunlight using a compact module.



Finnish shipyard Meyer Turku describes the customer reaction: "The demand seemed to be there. But when they heard the price, the demand was suddenly gone."

Like Lindvall of Blastr Green Steel, Økland also sees end customers as important allies. Environmentally friendly logistics is a good marketing tool. And she also sees the cruise industry as an important customer segment, especially when it comes to access to sensitive areas such as the Norwegian fjords. The public sector can also be a good partner for initial demonstration projects, for example with the hydrogen ferry that is scheduled to enter regular service to the Lofoten Islands from 2026. According to Økland, politics plays a major role not only as a source of support but, more recently, also as an active brake. When the International Maritime Organization (IMO) sought to establish a climate target last spring, several countries initially blocked it under pressure from the United States. "It was very good work by the IMO Secretariat that an agreement was still reached," she says.

Aviation under cost pressure Cost pressure hits the aviation sector hard and head-on. Hardly anyone books a flight without having consulted at least one price comparison engine. Accordingly, margins in the industry are tight. According to Antti-Mikael Kaljunen, who is responsible for sustainability topics at the industry association IATA, the sector expects an average profit margin of 3.9 percent for 2026. There is therefore little financial room to make aviation carbon-neutral on a net basis by 2050. Technologically, the lion's share is to come from Sustainable Aviation Fuels (SAF), contributing 65 percent. The remainder is to be saved primarily through CO2 capture and offsetting (19 percent) as well as new technologies such as hydrogen and electric aircraft, but that is likely to take a while yet. The order books of the major aircraft manufacturers are full for the next decade. It could take about 30 years before aircraft with entirely new propulsion concepts take to the skies, it is said.

SAF production figures to date are modest; the association expects 2.4 million tonnes for 2026 (2025: 1.9 million tonnes). These are produced almost entirely from biomass, often used cooking oils, but also alcohol from corn and sugar beets. Their share amounts to less than one percent of aviation fuels in total. The crux with bio-SAF is the limited feedstock. Projections therefore assume that around 176 million tonnes of e-SAF will need to be produced by 2050. If air traffic grows as expected, e-SAF and bio-SAF combined will still not be enough to cover demand. Moreover, the cost of e-SAF is twelve times that of fossil jet fuel, and this will need to change drastically with scaling. Unlike steel in the case of automobiles, fuel prices are not a side issue for airlines. According to Zita Baranova of Air Baltic, they account for around 30 percent of costs.

Jeremiah Dutton of EIT InnoEnergy emphasizes the importance of reliable regulatory frameworks, including for financing. "The certainty of return is important." One option would be contracts for difference. A small mandatory SAF blending quota would also help with offtake. Without reliable frameworks and calculable returns, there will be no financing. And Kaljunen suggests saving the necessary subsidies from fossil fuel subsidies. "Use that money more wisely," he says.

Hydrogen from compact panels One could have left the conference after these discussions with an uneasy feeling. But at the end, there was something tangible to see: a module that produces hydrogen directly from sunlight, developed by a young start-up from Oulu. The module, which the team wheels onto the stage, is similar in size to a solar panel. Inside, sunlight splits the water it contains photocatalytically, entirely without an external power supply. On stage, small gas bubbles can be seen rising inside the module.

Field testing on the Canary Islands is still ahead, as is the establishment of a production line or even a viable commercial use case. But at least Zun H, pronounced "Sun Age," brings the spirit of optimism back to the stage.

Yes to local content, no to lead market

Text: Eva Augsten

The European Commission presented its long-awaited proposal for the Industrial Accelerator Act (IAA) in early March. The law is intended to strengthen demand for low-carbon technologies and products manufactured in Europe. Hydrogen benefits less from this than some had hoped.

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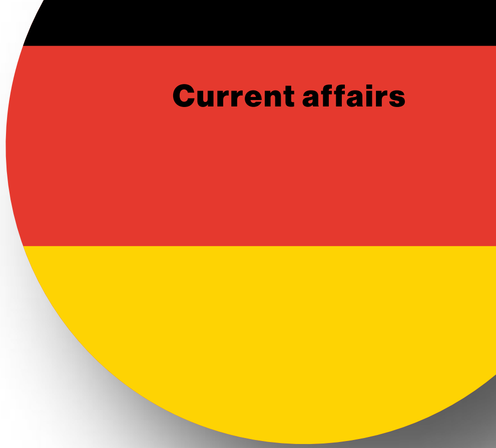
The European Commission presented its long-awaited proposal for the Industrial Accelerator Act (IAA) in early March. The law is intended to strengthen demand for low-carbon technologies and products manufactured in Europe. Hydrogen benefits less from this than some had hoped.

The draft of the Industrial Accelerator Act (IAA) is finally on the table. The law is intended to strengthen European manufacturing and create jobs. The EU is introducing two types of requirements for public procurement, auctions and funding programs: "Made in EU" and CO2 requirements. These apply to strategic sectors such as steel, cement, aluminum, automotive and so-called net-zero technologies, including batteries, solar, wind, heat pumps and nuclear technology. According to the Commission, the framework can be extended to further energy-intensive sectors such as the chemical industry.



The proposal follows the recommendations of the "Draghi Report" by the former ECB President on EU competitiveness and is part of the Commission's Clean Industrial Deal. It now enters negotiations between the European Parliament and the Council.

The state should buy low-carbon One aim of the law is to strengthen demand for clean technologies. When public institutions commission buildings, infrastructure or vehicles, they will in the future be required under the IAA to give preference to steel with a low carbon footprint. However, there are no requirements for steel to be manufactured in Europe.

The precise definition of what qualifies as "low-carbon" will be established through delegated acts under the Ecodesign for Sustainable Products Regulation (ESPR) and the Construction Products Regulation (CPR). The Commission says it wants to give investors planning certainty. Hydrogen derivatives, fertilizers and e-fuels are not yet covered by specific demand-side measures in the regulation text. However, the IAA draft includes an empowerment provision that would allow the Commission to introduce such measures later via delegated act.

Funding only with local content Hydrogen is explicitly mentioned in several places in the IAA draft, though not always on an equal footing with other net-zero technologies.

As with many pieces of legislation, the process is nested. Some key changes are, strictly speaking, amendments to the already existing Net Zero Industry Act (NZIA), which likewise aims to support both climate protection and European industry. New requirements are being inserted into the annex of the NZIA through the IAA.

For auctions allocating funding, the NZIA is set to include, through the IAA, concrete "Made in EU" requirements for electrolyzers. From one year after the regulation enters into force, electrolyzers must originate from the EU, with the stacks and at least one additional main component being of European origin. From three years after entry into force, the requirement increases to stacks plus two additional main components. The same requirements apply when member states use public funds to support the build-up of electrolyzer manufacturing capacity.

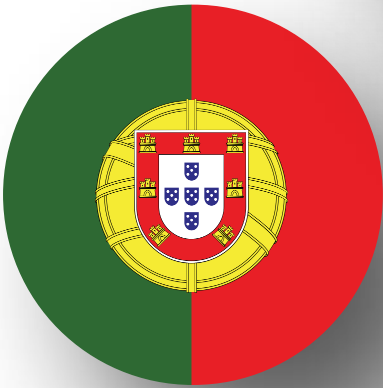
With the requirement to also manufacture electrolyzers in the EU, the Commission goes beyond earlier plans in order to "anticipate and mitigate potential future supply and market risks," as stated in the regulation's explanatory memorandum.

For funding programs targeting end consumers and businesses (so-called "other forms of public intervention"), however, no Made-in-EU requirements are formulated for electrolyzers.

The IAA stipulates that products from certain partner countries are treated as equivalent to the "Made in EU" requirements, meaning they are considered on a par with European origin. Which countries qualify, however, depends on the instrument. In public procurement, products from countries that have acceded to the WTO Government Procurement Agreement (GPA) are also recognized, including the USA, Canada, Japan, South Korea and the United Kingdom. For auctions and funding programs, by contrast, a narrower circle of so-called trusted partners applies, namely countries with a free trade agreement or customs union with the EU. In addition to the EFTA states, these include, for example, the key hydrogen markets of India, Japan, Turkey and the United Kingdom.

Faster permits and industrial clusters The IAA provides for a simplification of permitting procedures. Member states are to establish digital one-stop shops with fixed deadlines. For decarbonization projects in energy-intensive industries, the principle of tacit approval for intermediate steps is to apply. Furthermore, the law introduces so-called Industrial Acceleration Areas. These are intended to promote industrial symbioses and facilitate the development of clusters for clean manufacturing. With the IAA, the Commission pursues the goal of increasing the share of manufacturing in EU gross domestic product from the current 14.3 percent to 20 percent by 2035. ▹

Hydrogen Europe: More to be done The European industry association Hydrogen Europe broadly welcomes the IAA's focus on "Made in Europe" for hydrogen technologies such as electrolyzers and fuel cell vehicles. However, the association criticizes that the scope has been significantly narrowed compared to earlier drafts, especially for hydrogen derivatives, fertilizers and e-fuels, which practically benefit only from simplified permitting. Stronger demand-side measures are needed for genuine lead markets. Hydrogen Europe CEO Jorgo Chatzimarkakis believes the EU must close the gaps in terms of ambition, scope and clarity. "Europe must ensure that its industry can grow, be competitive and play a leading role globally in strategic clean technologies such as hydrogen."



The proposed quota of 25 percent for low-carbon steel in public procurement is too low, the association argues. The fact that the definition of requirements has been deferred to the Ecodesign Regulation also sends the wrong signal to industry and investors. Hydrogen Europe further criticizes the differing definitions of partner countries for public procurement and auctions. This creates additional complexity and legal uncertainty, particularly for auctions, which are the most important funding instrument for the hydrogen sector.

"Made in Europe" divides opinion For the hydrogen sector, "made in Europe" represents an opportunity, since there is currently still a technological lead that China, with ample state support, could soon close. However, the German Mechanical Engineering Industry Association (VDMA) is quite skeptical. VDMA Managing Director Thilo Brodtmann criticizes that the focus on local content distracts from problems such as high administrative burden, a weakened single market and Europe's lack of technological leadership. "A 'Buy European' approach is justified when the EU's security interests are concretely at risk and there is no other way to reduce or preemptively avoid dependence on strategically relevant technologies and critical raw materials," he says. He welcomes the fact that the green steel requirement is limited to relatively few applications.

The added autonomy through "made in Europe" comes at a cost. The wind and solar industries already have experience with this problem. The topic is controversial within the value chain: European equipment manufacturers welcome the competitive advantage from local content requirements. Project developers protest against them. For them, local content means higher procurement prices, which ultimately translates into higher generation costs for solar and wind power.

By comparison, the hydrogen sector is at an earlier stage of industrial development. It still has a technological lead that could be secured in this way, experts emphasize. Local content could thus provide the impetus to achieve scaling and thereby better competitiveness. The hope is that this could keep a future technology in Europe and build long-term resilience.

Requirements no earlier than 2028 The European Commission's draft now enters negotiations between the European Parliament and the Council. Experience shows that such a legislative process takes at least one to two years. If it becomes a regulation, as the Commission recommends, the IAA would apply directly in all member states after its adoption. Transposition into national law would not be necessary, but of course there are deadlines for the requirements.

The plan is for the "Made in EU" requirements for electrolyzers in auctions and for funding of electrolyzer manufacturing to take effect in a first stage one year after entry into force, with stricter requirements after three years. The digital permitting procedures are also set to start one year after entry into force. Adding up the timelines and deadlines, the first rules could take effect in 2028, if for once everything goes smoothly. ○

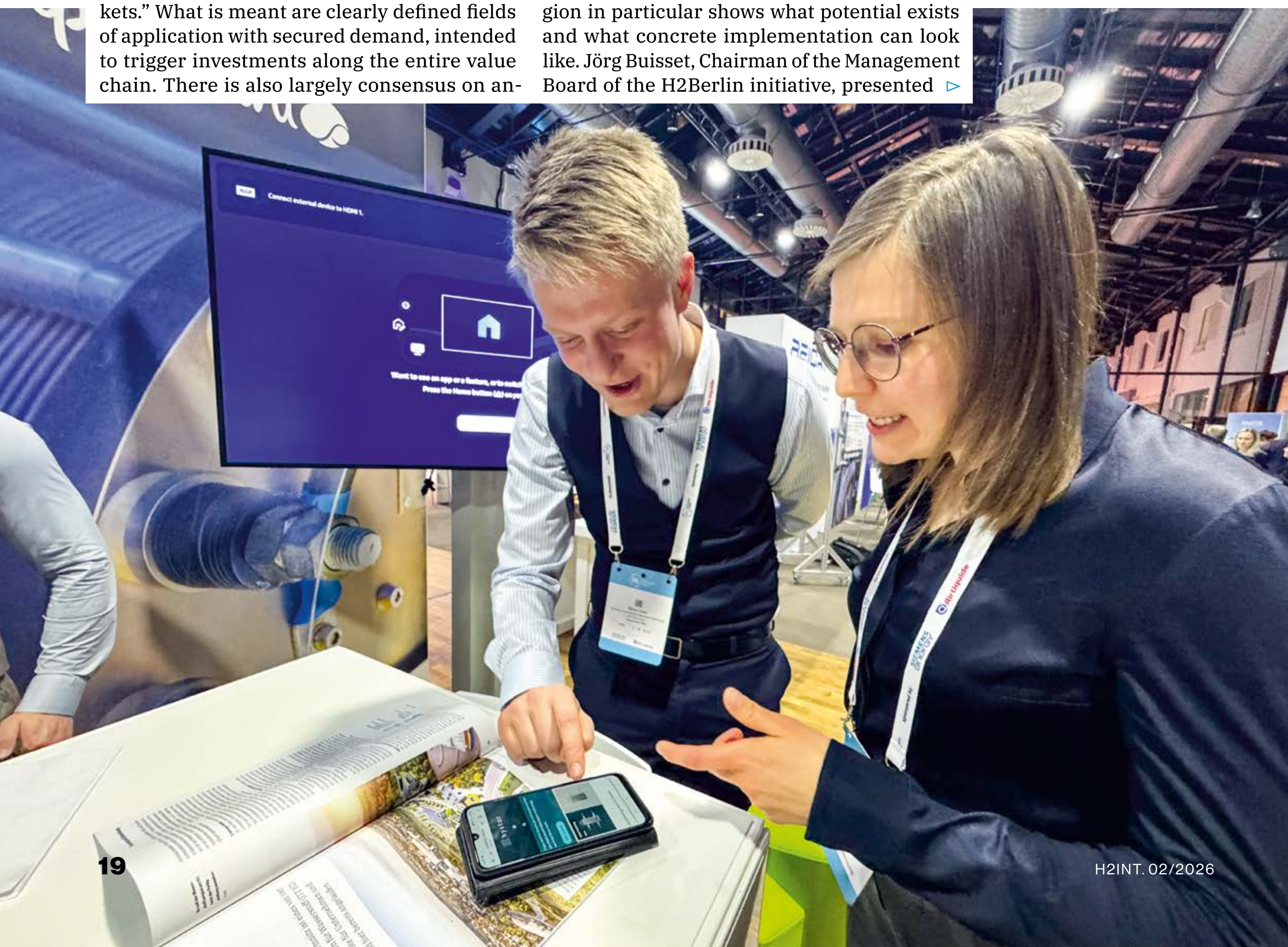
“Offtake” over “chicken and egg”

Text: Monika Rößiger

Some 450 participants, 55 speakers, and 50 exhibitors came together in Berlin in early March to discuss projects, regulation, and technology. The forum billed itself as deliberately compact – “small but excellent” – creating room for in-depth discussion and new partnerships.

The H2 Forum Berlin 2026 shows an industry in transition, away from visions and toward implementation. In terms of content, it quickly became clear that the classic “chicken-and-egg” problem of the hydrogen market is no longer the main focus. Instead, the emphasis is now primarily on “offtakers” and “lead markets.” What is meant are clearly defined fields of application with secured demand, intended to trigger investments along the entire value chain. There is also largely consensus on another aspect: the technology is available, the industry is ready, but the political framework conditions are holding things back. “Hydrogen does not take place in PowerPoint presentations, but in pipelines,” as one participant put it.

Capital on an H2 trip The Berlin-Brandenburg region in particular shows what potential exists and what concrete implementation can look like. Jörg Buisset, Chairman of the Management Board of the H2Berlin initiative, presented ▻



Enthusiastic about technology: Rico Löser, Fraunhofer IWU, and Kristina Baitalow from Capgemini.

© Monika Rößiger

its projects at the H2 Forum. Around 30 companies in the capital region are working along the hydrogen value chain to build three H2 hubs, one of them at BER Airport. Its operation is to be completely decarbonized with the help of hydrogen. This affects not only the energy supply of the buildings, but also the drives of baggage tractors and passenger buses on the apron, as well as the ground power that aircraft require before takeoff. This is to be converted from diesel to hydrogen in the future. In addition, there is enough space on the BER site to produce climate-neutral kerosene via PtL in the future.

The H2Berlin projects also include the Ruhleben energy triangle in western Berlin, where a fossil cluster is being converted into an H2 hub. The existing combined cycle gas and steam plants are to be retrofitted so that they can in future be operated entirely or partially with hydrogen. Ruhleben is also a possible feed-in or utilization point for the planned German and European H2 core network. In the energy triangle, hydrogen is to serve primarily as a seasonal energy storage and backup when renewable energies are insufficient, for example during a period of low wind and solar generation. It also links the sectors of electricity (electrolysis), heat (district heating supply), industry (high-temperature processes such as automotive painting at cooperation partner BMW), and mobility (company fleets).

Next to the energy triangle is the Ruhleben wastewater treatment plant, which will use the oxygen produced by the planned 10 MW electrolyzer for the fourth purification stage. It is scheduled to be ready in summer 2027. The waste heat from electrolysis will also be used and fed into the connected district heating network.

Berlin City Cleaning Authority („Berliner Stadtreinigung“) is also participating in the initiative. It already has more than a dozen H2-powered refuse collection vehicles in operation and will further expand its fuel cell fleet. On the outskirts of Berlin, surplus wind power from Brandenburg is to be increasingly used in the future to produce hydrogen and later serve as the basis for e-fuels.

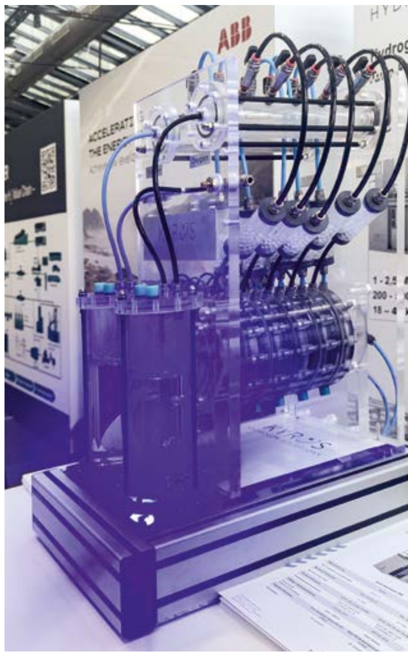
Curtailment as the Achilles’ heel of the energy transition A recurring theme throughout the conference is that renewable electricity continues to go unused on a large scale due to grid bottlenecks. In 2025 alone, interventions together with voluntary curtailment amounted to an estimated around 8.5 terawatt-hours; exact figures were not yet available at the time of editorial deadline. This green electricity should finally be used for hydrogen production.

“The fact that we are still curtailing renewable energy today is simply absurd,” criticizes Jorgo Chatzimarkakis, CEO of Hydrogen Europe. For him, as for many other industry representatives, this is a symptom of political failure, not to say mismanagement. Unlike China, which interprets the rules in its own way, “we in the EU are far too nice,” he says. And he deliberately asks provocatively: why not disregard excessive rules for once, enter into conflict, and, if necessary, risk legal proceedings? After all, “what can be wrong with producing CO2-free molecules?” A stimulus for thought that led to lively discussions not only during the following lunch break, but also echoed on the panel on the second day of the forum.

Industry is also voicing clear criticism. Stefan Engelshove, Managing Director at Siemens Energy, points out that neither the technology nor scaling are obstacles, his company already produces electrolyzer stacks in Berlin with a capacity of one gigawatt. “The technology is there. But we need clear regulations in order to be able to invest.” Hybrid connection nodes are also necessary.

“We have no choice but to rely on the use of green molecules such as hydrogen,” says Georg Friedrichs, CEO of the energy supplier GASAG, particularly to store renewable energy from summer for winter. Hydrogen is the most important storage and import medium for green energy. He therefore views the development of the H2 core network positively, especially since his company is involved via its subsidiary NBB with 60 kilometers. The emerging infrastructure does allow initial investments, but without clear demand perspectives the risk remains high. Contracts for Difference (CfDs) could be one way to remedy this.

How fragile business models currently are is illustrated by an example from EWE Hydrogen: subsidized green hydrogen can currently be offered for about five to six euros per kilogram, says Managing Director Geert Tjarks. After the subsidies expire and with additional grid charges, however, prices of nine to ten euros threaten, hardly competitive for industrial off-takers.



TOP: On the panel, among others, Ivana Jemelkova and Jorgo Chatzimarkakis as representatives of the European H2 industry.

© Monika Rößiger

BOTTOM: Model of an electrolyzer at the stand of Kyros Hydrogen Solutions.

© Monika Rößiger

Geopolitics increases pressure to act At the same time, the pressure to accelerate the transformation is growing. The geopolitical situation – the blockade of the Strait of Hormuz began on the day before the H2 Forum – has once again highlighted dependence on fossil imports. “H2 made in Europe is a value in itself,” emphasizes Christian Feuerherd, CEO of Berliner Energie und Wärme (BEW). Hydrogen is not only an instrument for decarbonization, but also a strategic building block for security of supply and resilience.

Against this background, the price per kilogram of H2 is almost secondary, says the head of Western Europe’s largest heating network, thus speaking from the offtaker perspective. Industry representatives competing internationally are likely to see this differently, because for them the price is decisive. How Berlin’s more than 2,000-kilometer district heating network can become climate-neutral by 2045 is another question.

The perspective of security of supply runs through many discussions at the forum. Alongside climate protection and sustainability, industrial resilience is increasingly coming into focus. International actors such as Ivana Jemelkova, CEO of the Hydrogen Council, warn that Europe risks falling behind in global competition, while countries such as China, India, and Korea are moving ahead decisively. Like Chatzimarkakis, she — no less temperamental — also denounces the “policy problem” from which the entire industry suffers.

Or, as Jasmin Kaboni-Voit, Head of Hydrogen Regulatory & Funding at RWE, puts it: “All solutions are on the table. Nothing needs to be invented anymore.” Politicians should also understand this and support companies in implementation, at least by reducing “over-complexity.”

Criticism of regulation A recurring topic is therefore the simplification of rules. In particular, the implementation of European requirements such as RED III or the definition of RFNBO criteria are considered by many to be too complex and impractical. “There are already so many rules at EU level, for example for green, blue, turquoise, and pink hydrogen. But there is not enough hydrogen,” says Heike Denecke-Arnold, Chairwoman of the Executive Board of Salzgitter Flachstahl.

In addition to supply, demand also remains a sticking point. Without binding offtake guarantees or quotas for green products, for example steel, many projects lack an economic basis. Accordingly, support at the H2 Forum is strong for instruments such as Contracts for Difference or EU-wide offtake guarantees.

In addition to politics and the market, technical progress is also showcased at the Berlin H2 conference. Start-ups and established companies present solutions ranging from modular electrolysis systems to underground storage and AI-supported efficiency improvements. The tenor is that major innovation leaps are increasingly occurring in system integration, no longer in basic development. The potential for cost reductions also lies in the areas of integration, operation, and digitalization.

“We produce hydrogen from sh.....,” says Andy Gradel bluntly at the beginning of his short presentation. “And very successfully.” Of course, the young engineer means green H2 from slurry and manure or biogas via steam reforming, and describes this as a “decentralized boost for the expansion of the hydrogen economy.”

Gradel, who is also founder and managing director of BtX energy, lists the advantages of the innovative process: “We do not have a chicken-and-egg problem. We do not have to wait for sun and wind. We use methane that would otherwise be harmful to the climate and even achieve negative emissions with H2 production.” It is also “pretty cool” to refuel one’s own hydrogen car just 20 meters away from the cows that provide the feedstock for the fuel.

Despite all the challenges, cautious optimism prevails in Berlin. The ramp-up of the hydrogen economy is progressing more slowly than expected just a few years ago, but it is happening, step by step. Projects and industrial applications are going into operation, infrastructures are under construction and becoming visible.

The decisive factor will now be whether it succeeds in developing scalable markets from individual projects. Lead markets could play a key role here, provided that policymakers and regulation set the course accordingly. Or, as one participant put it: hydrogen is not decided in strategy papers, but in real projects. Berlin has shown that such projects already exist. Now they must be scaled and rolled out broadly. ○

A Chance for the hydrogen ramp-up

Text: Kora Töpfer

A future hydrogen economy doesn't just depend on building new electrolysers. Equally decisive is how flexibly the power system can absorb surplus electricity. This is exactly where local flexibility markets could play a key role, argues regulation expert Kora Töpfer of EPEX SPOT.

Electrolysers are predestined for local flexibility markets: as is well known, they can adjust their power consumption at short notice, alleviate grid congestion and at the same time convert surplus wind and solar power into green hydrogen. However, this potential remains largely unused in Germany to date. While other countries have already transferred local flexibility markets into regular operation, Germany continues to rely on cost-based redispatch, thereby also slowing down the ramp-up of the hydrogen economy.

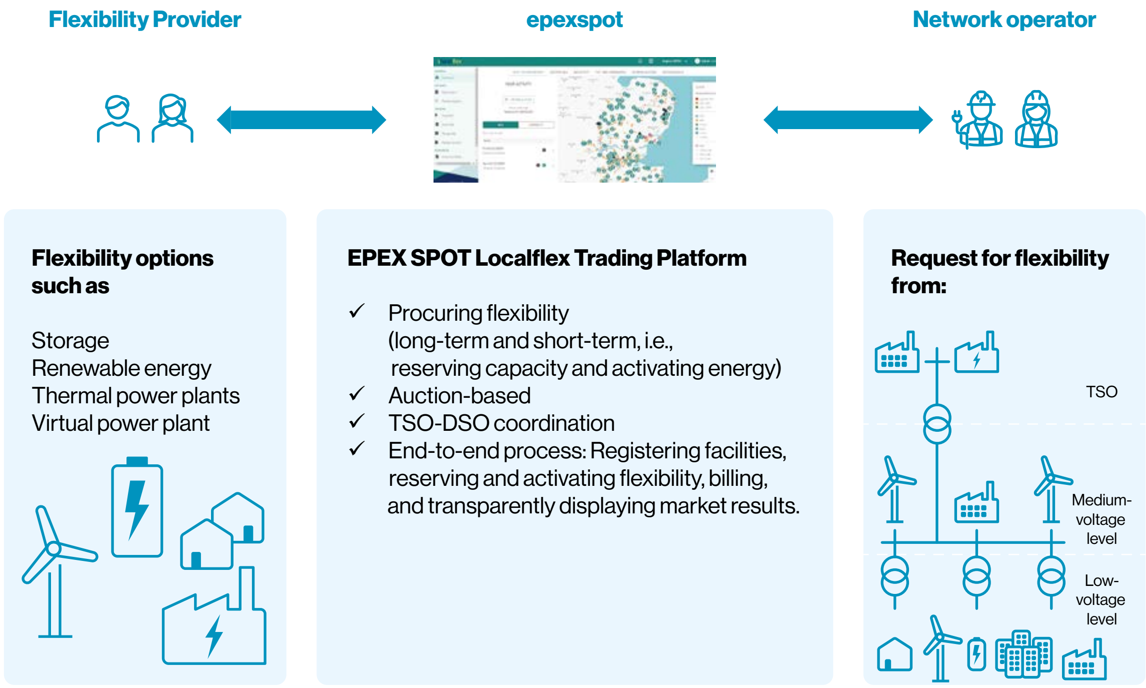
Germany itself co-developed local flexibility markets and technically tested them in pilot projects such as *enera*. Internationally, these approaches attracted considerable attention. Other countries have since gone a step further. In Great Britain or the Netherlands, local flexibility markets are already part of the regular toolkit of grid operators. Germany, by contrast, continues to rely primarily on cost-based redispatch. As a result, large parts of the decentralized flexibility potential remain unused, precisely those resources that would be crucial for a successful energy transition and an economically viable hydrogen ramp-up.

The paradoxical reality Modern grid regulation can create incentives to resolve grid congestion efficiently via the market: Great Britain links investment and operating expenditures in the so-called TOTEX approach, enabling grid operators to use market-based flexibility instead of new lines. There, this is already established practice, for example at UK Power Networks DSO, where since 2024 a flexibility market with hundreds of thousands of flexible assets and dozens of active providers has been operating. Although congestion management and grid expansion face enormous challenges, valuable demand-side flexibilities remain unused in Germany, precisely the resources needed for a successful energy transition. This also applies to offshore electrolysis: while combined electricity-hydrogen connections would be technically possible in the North Sea, German regulations prevent their grid-supportive integration. Energy generated from offshore wind is therefore often curtailed.

Local flexibility markets are intended to resolve grid congestion via a market- based approach. Grid operators procure flexibility in a targeted manner, for example from batteries, power-to-X, industrial plants or electrolysers. Operators can offer their capacity specifically where it can be used in a grid-supportive way.

Via platforms such as EPEX Localflex, flexibility supply and demand are brought together in clearly defined zones, usually via auctions. In this way, grid-supportive behavior is remunerated, congestion is avoided and grid expansion can be reduced. This market-oriented procurement creates a transparent, non-discriminatory mechanism that enables new business models and significantly accelerates the integration of decentralized flexibilities.

The hurdles in Germany's regulatory framework Policymakers have created this status quo, and they can also change it. Article 13a of the German Energy Industry Act (EnWG) effectively cements cost-based redispatch as the stand-



Local flexibility markets for congestion management create the right economic conditions for the development of flexibility.

© epexspot / NEONBOLD

ard. Instead of fully implementing the European Clean Energy Package, Germany has taken a special path here. Article 14c EnWG could enable market-based procurement of flexibility by distribution system operators, but remains unused to date, so that genuine congestion management via the market is effectively absent.

In addition, the Incentive Regulation Ordinance (ARegV) does not recognize the costs of market-based flexibility procurement, a clear disincentive that pushes grid operators toward CAPEX-intensive "fit & forget". Finally, excessive concerns about IncDec gaming are slowing the discussion, although proven countermeasures exist.

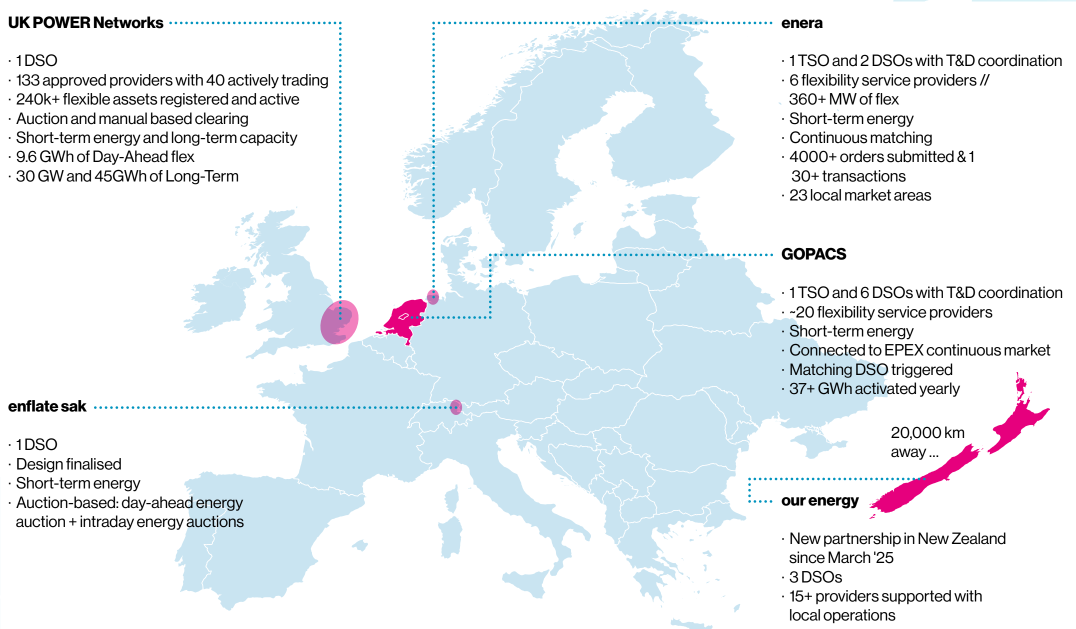
Immense savings possible Local flexibility markets activate resources that hardly appear in Redispatch 2.0 so far: heat pumps, charging infrastructure, industrial loads, smaller generators, and above all electrolysers as electricity consumers for hydrogen production. Instead of curtailing wind farms and paying power plants for redispatch, grid operators could activate flexible consumers in a targeted way. Studies and practical experience show that grid expansion costs would decrease significantly; in Great Britain, targeted savings of hundreds of millions are reported.

The magnitude of possible savings would also be considerable in Germany: a study by Frontier Economics commissioned by AquaVentus shows that integrating offshore electrolysers and hydrogen pipelines can reduce system costs in the German energy system by up to 1.7 billion euros annually (see H2international 5-2025). These estimates refer only to one type of flexible generator, namely offshore hydrogen. The overall potential increases sharply with the diversity of technologies, as power-to-X plants, heat pumps, EV fleets, battery storage, etc. are also included in the market design.

It is also crucial that flexibility markets complement the wholesale market; they are not a parallel universe. They enable close coordination between transmission system operators and distribution system operators and create transparency, competition and reliable price signals for investments in flexibility, a lever that is particularly important for business models in the hydrogen sector. And: they are EU-compatible. The upcoming European "Network Code on Demand Response" anchors local flexibility markets as a standard instrument for congestion management in Europe, a new opportunity for Germany to catch up internationally.

What this means for the H2 ramp-up Electrolysers will play an important and fundamental role here; especially those producing hydrogen at sea. Unlike onshore plants, offshore electrolysers do not compete with grid connections but complement them. When the wind blows strongly and grid congestion looms, offshore electrolysers convert electricity into hydrogen, which is transported via dedicated pipelines. This relieves expensive subsea cables and avoids curtailment.

In addition, this approach allows sectors to be linked, from electricity to heat to ▷



EPEX SPOT's Localflex offer is designed to ease grid congestion and drive the transition to a smarter, decentralised power system.

mobility. The revenues generated in the process improve economic viability. Where grid congestion currently delays H2 projects, flexibility markets can facilitate location decisions: they provide a price signal indicating where and when flexibility is particularly valuable and help integrate electrolysis clusters in a system-supportive manner. For operators, this creates a dual benefit: participation in the wholesale market and additional regional flexibility remuneration, both within clear, rule-based processes.

Further development instead of system disruption
No one is calling for the abolition of cost-based redispatch overnight. What is needed is a hybrid model: the existing redispatch remains in place for large generation plants, complemented by market-based procurement for demand-side flexibility and smaller assets. In parallel, three regulatory building blocks are crucial:

1) **Reform Article 14c EnWG** and explicitly extend the term "flexibility services" to congestion management; missing specifications for distribution system operators are to be developed jointly.

2) **Recognize flexibility costs**: classify flexibility procurement as permanently non-controllable costs in incentive regulation, only then will a fair investment and operating incentive emerge.

3) **Standardize processes**: uniform prequalification, market-neutral baselines, transparent clearing rules and coordinated interfaces between TSOs and DSOs.

This creates a scalable model that transfers pilot knowledge into regular operation, compatible with European regulation, connectable for the energy industry and attractive for new flexibility investments.

IncDec gaming? Manageable and overestimated Concern about strategic bidding behavior, so-called gaming, must be taken seriously, but must not block progress. Practice, including in German pilots, shows: gate-closure rules, robust baseline methods, price caps and market monitoring are effective. In addition, small, shiftable loads such as heat pumps or many charging processes are only partially suitable for gaming; the technical effort is disproportionate to the potential return, especially as the risk of detection is high. The measurable benefits of local flexibility markets, less grid congestion, lower expansion costs, faster hydrogen ramp-up, clearly outweigh the theoretical risk. The right answer is therefore good market design, not abandoning markets.

A German comeback, now Germany co-developed an innovative concept and tested it in its own energy system. Other countries have transferred it into regular operation; we can do the same. Anyone who blocks local flexibility markets blocks cost efficiency in grid expansion and the flexibilization of our power system, and thus the H2 ramp-up. Policymakers must set the right course: if regulation and market design are considered together, Germany will unlock its flexibility potential, reduce system costs, scale innovation and accelerate the energy transition. Local flexibility markets could provide exactly this lever. Without them, a large part of flexibility in the energy system remains unused, and with it part of the hydrogen potential. ○

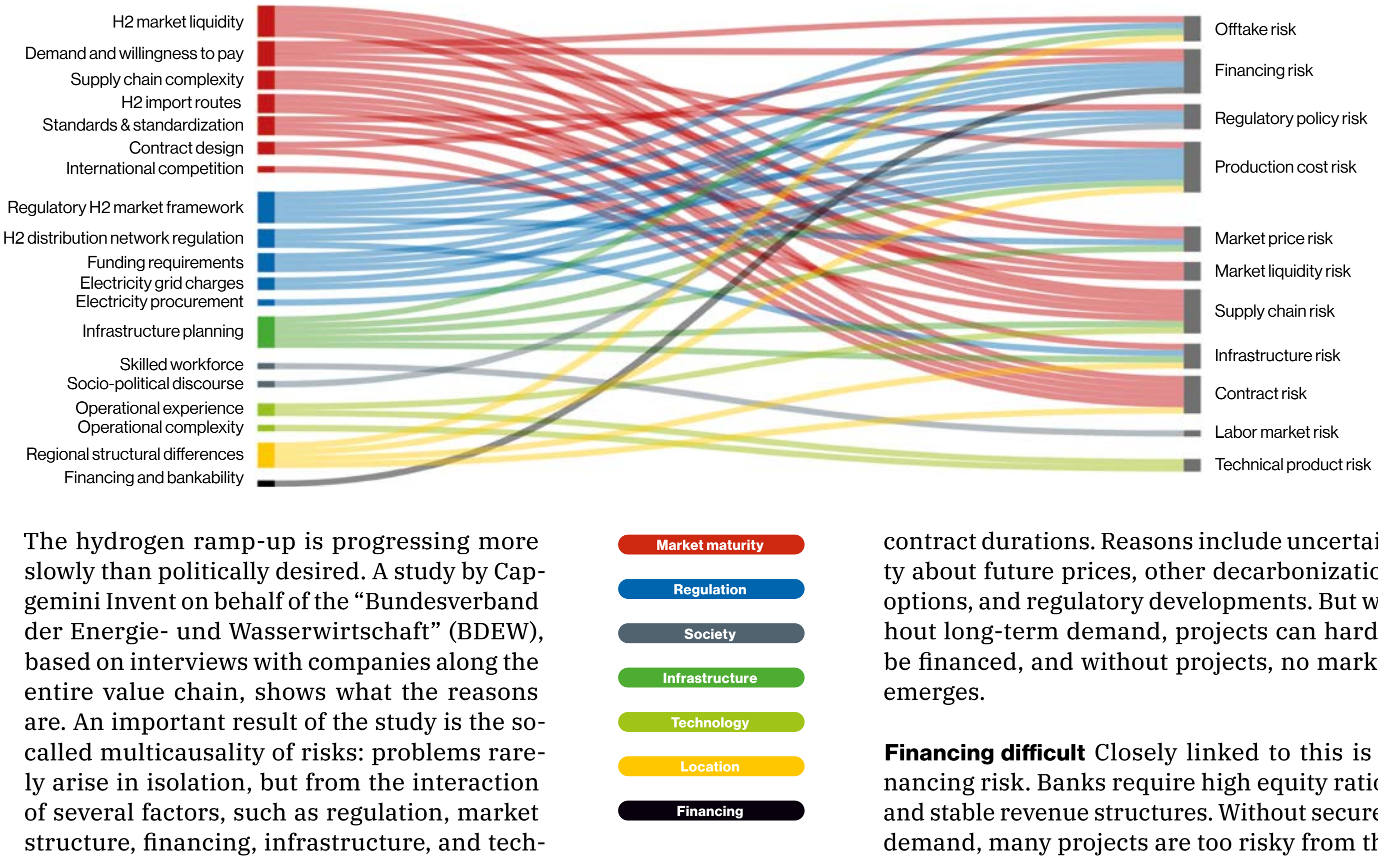
Local flexibility markets operated by EPEX SPOT are already in use in various parts of the world. The pilot project *enera* has now been completed.

Kora Töpfer
Head of German Regulatory Affairs at EPEX SPOT Paris
publicaffairs@epexspot.com

It's the risk, stupid!

Text: Monika Rößiger

The biggest obstacles to hydrogen are not technical – they are economic and regulatory in nature. That is the finding of a Capgemini study commissioned by BDEW, Germany's energy and water industry association: too many projects are stalling because investment conditions remain too risky.



The hydrogen ramp-up is progressing more slowly than politically desired. A study by Capgemini Invent on behalf of the "Bundesverband der Energie- und Wasserwirtschaft" (BDEW), based on interviews with companies along the entire value chain, shows what the reasons are. An important result of the study is the so-called multicausality of risks: problems rarely arise in isolation, but from the interaction of several factors, such as regulation, market structure, financing, infrastructure, and technology, which reinforce each other. As a result, risk premiums increase, which makes financing ("bankability") more difficult and delays final investment decisions (FID). As a consequence, even projects with high funding commitments are postponed or stopped.

Lack of offtake The authors view offtake risk as particularly critical. For the financing of large electrolysis projects, producers require long-term offtake agreements with terms of fifteen to twenty years. However, many potential industrial offtakers prefer significantly shorter contract durations. Reasons include uncertainty about future prices, other decarbonization options, and regulatory developments. But without long-term demand, projects can hardly be financed, and without projects, no market emerges.

Financing difficult Closely linked to this is financing risk. Banks require high equity ratios and stable revenue structures. Without secured demand, many projects are too risky from the perspective of capital providers. Funding programs can offset part of the investment costs. However, they are not sufficient to significantly reduce capital costs or sustainably improve the financing structure.

Conclusion A market does not emerge on its own. Only when risks along the entire value chain are reduced can large-scale investment take place and a functioning hydrogen market emerge. ○

The figure illustrates the relationship between categorized risk drivers and the risks.

See more at: www.capgemini.com

Hannover Messe

Meet in Hall 11

Text: Eva Augsten

Hannover Messe is a fixture in the hydrogen industry's calendar. As part of Hydrogen + Fuel Cells Europe in Hall 11, many companies are showcasing new products, a selection of which we present here.

© Hannover Messe

For nearly 80 years, Hannover Messe has been a marketplace of international significance. From the very beginning, it has focused on industry and exports. Unlike many other industrial trade fairs, Hannover Messe has never been limited to a single sector. Instead, it features focal themes and special exhibitions that have continually evolved. Hydrogen has been a permanent part of Hannover Messe since the 1990s. This year, Hydrogen + Fuel Cells Europe can be found with 63 exhibitors in Hall 11.

As usual, this year again features the Public Forum Hydrogen + Fuel Cells Europe. From Monday through Thursday noon, presentations, interviews and panel discussions on hydrogen innovations will be held in 20-minute intervals.

With H2international, you can make your trade fair visit easy. We have already compiled some news for you here, but we are constantly receiving further updates. Under the tag "Hannover Messe 2026" at hzwei.info, you will always find the latest information. On April 16, our newsletter will include a summary. Signing up for the newsletter in time is doubly worthwhile for anyone interested in Hannover Messe: in addition to trade fair coverage, everyone who subscribes now will also receive free trade fair tickets. ○

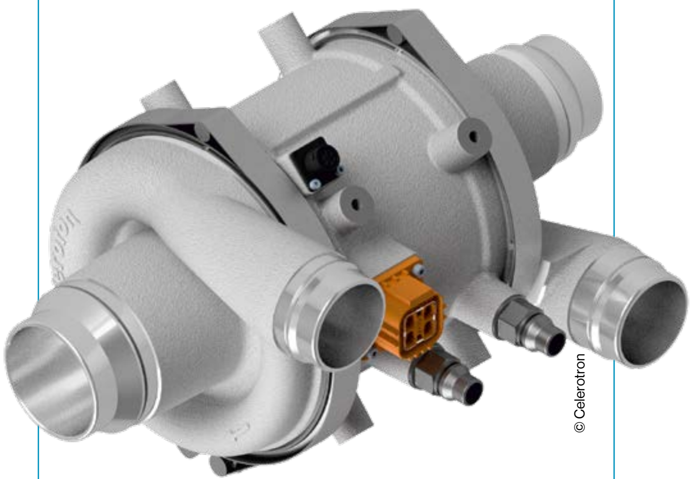
Get trade fair updates and free tickets now: www.h2-international.com/newsletter


© Solydera

Solid oxide fuel cells are the focus at **Solydera**. The company is presenting the PMX platform, an integrated system combining stack, hot-gas peripherals and controls. It is modular in design and rated for outputs from 10 to 100 kW. Solydera has also developed a 45 kW containerized system to supply power to data centers and other critical infrastructure.
Hall 11, Stand D12

On the first day of the fair, **Cellcentric** is celebrating the official launch of its new fuel cell powertrain for long-haul heavy-duty trucks. The module remains as compact as a diesel engine, delivers more drive power than its predecessor while consuming less, and is easier to cool. It will be on display at the stand from the second day of the fair onward.
Hall 11, Stand D22

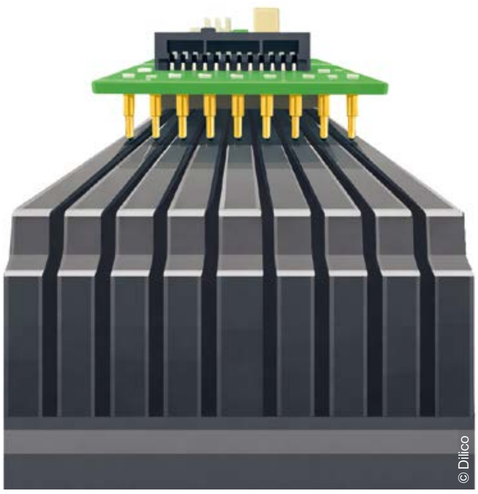

© Cellcentric


© Celeroton

Celeroton Turbocell is presenting a new electrically driven turbo compressor for fuel cells in the 100 to 200 kW range. The STE-400x is paired with the CC-4000 inverter and can optionally be combined with a turbine expander.
Hall 11, Stand E26

There is always something to discover at the large Fraunhofer Institutes stand. **Fraunhofer ISE**, for example, is presenting its production research on membrane electrode assemblies (MEAs) along with a new pilot facility. The facility is designed to help manufacturers of components, machinery and systems quickly translate new concepts into practice.
Hall 11, Stand E11


© Fraunhofer ISE


© Dilico

Dilico is showcasing a new generation of cell voltage monitoring: the Cell Voltage Pickup (CVP). It combines cell contacting and data acquisition in a modular design. The measurement system is intended for both development and continuous industrial operation. It will be demonstrated live at the trade fair stand.
Hall 11, Stand E07/1

A new home in Munich

Interview: Eva Augsten

Hydrogen Dialogue is relocating from Nuremberg to Munich and will, for the first time this year, be part of the energy trade fair The Smarter E. Fabian Pfaffenberger from the Hydrogen Center Bavaria (H2.B) explains what this means for guests interested in hydrogen.

Mr. Pfaffenberger, the Hydrogen Dialogue is well known in the industry but has until now been based in Nuremberg. Are you looking forward to the move to the state capital and the new neighbors?
Pfaffenberger: The new environment offers a great opportunity. We are moving to a global metropolis with a very strong trade fair location and international reach. At the same time, we remain true to our Bavarian roots. In terms of content, it is also a good fit. Hydrogen cannot be viewed in isolation, after all. It is always also about power generation, conversion, energy management, decentralization and digitalization. These are exactly the topics that The Smarter E covers in Munich. There, we can think about sector coupling much more consistently.

Speaking of Bavarian roots: What role does H2.B play in the Hydrogen Dialogue?
H2.B, the Center for Hydrogen Bavaria (Zentrum Wasserstoff. Bayern), is the coordination and networking body of the Free State of Bavaria for the Bavarian hydrogen economy. We bring stakeholders together, inform, advise and connect. For the Hydrogen Dialogue, we serve as the non-commercial sponsor. This means we contribute our expertise and our network and are responsible for leading the conference program. The organizer is now Solar Promotion, and the Bavarian Minister of Economic Affairs serves as patron.

A dedicated exhibition area on the topic of hydrogen was already part of The Smarter E in 2025, when it was called the Green Hydrogen Forum © Solar Promotion

The Smarter E has a reputation for being very international. Does a Bavarian format fit in there?
Absolutely. The Hydrogen Dialogue was never a purely Bavarian event. Since 2019, it has been clear: On the one hand, we want to offer the central platform for the Bavarian hydrogen economy; on the other hand, we want to deliberately involve international players and cover federal policy topics. Through delegation trips and cooperations, a robust network has emerged. We invite this network to Bavaria. In Munich, that is even easier than in Nuremberg.

“The Hydrogen Dialogue was never a purely Bavarian event.”

Dr. Fabian Pfaffenberger is the Managing Director of the Hydrogen Center Bavaria (H2.B). © H2.B

What changes for visitors?
It will be bigger. The trade fair in Munich has a significantly higher visitor frequency. This creates more opportunities for contacts, not only within the hydrogen community, but along the entire value chain: from power generation through hydrogen production to storage, conversion and application.

Also new is the standalone “Hydrogen Dialogue Summit” as a specialist conference in Munich. It focuses on the energy and economic policy perspective at a strategic level.

As in previous formats, we again have a high-caliber program, featuring among others Bavarian Minister of Economic Affairs Hubert Aiwanger, economic policy advisor Veronika Grimm, and Jorgo Chatzimarkakis from Hydrogen Europe. Thematically, it covers system integration, green lead markets, industrial competitiveness, the role of hydrogen in diversifying energy supply, and the geopolitical situation. The technology competition with Asia also plays a role.

In addition, there continues to be the dedicated exhibition area at the trade fair, the Hydrogen Dialogue Forum, which focuses more on deep tech. There are also guided tours for international delegations and, going forward, visits to companies in the region again, though not yet this year.

The hydrogen industry and the renewable energy industry represent quite different energy worlds. What do you expect from this encounter?
Indeed, and that is a good thing. This is already the case within the hydrogen industry itself. On one side, there are established energy suppliers who see hydrogen as a complement and bridge to existing business models. On the other side, players from the renewable energy scene who want a transformation “from the bottom up.” In between lie topics such as CCS/CCU, where on the one hand there are concerns about lock-in effects, but on the other hand there is also the argument that hydrogen would otherwise not be affordable.

These tensions are part of the reality of the industry. That is why we will also discuss CCUS in a panel at the conference. We do not want to exclude this debate.

What is your goal for the coming years?
The brand will continue to integrate at the new location. The growth potential is there, thanks to the higher visitor frequency and the thematic overlaps. With the somewhat broader orientation, we also reach players who have not primarily come from the hydrogen world until now but see the topic as a strategic add-on.

We also want to strengthen the international dimension. The Hydrogen Dialogue should be a platform, a space for debate and a showcase all at once, for Bavaria, for Germany and for the international hydrogen economy. If we succeed in bringing different perspectives together constructively, then we will have achieved a great deal.

One more question for future capital-city dwellers: How do you even find a hotel room in Munich?
Anyone who wants to attend the Hydrogen Dialogue and The Smarter E should act fast. The room situation is indeed more difficult than in Nuremberg. ○

ABOUT THE SMARTER E AND HYDROGEN DIALOGUE

It all started with a small solar trade fair in a gymnasium in the German city of Pforzheim. After 35 years and a series of relocations, it has become Europe’s largest exhibition alliance on the topic of energy. The Smarter E reliably fills exhibition halls in Munich to capacity, and the hotel situation looks similar. Exhibitors and events related to hydrogen can be found at The Smarter E as part of the sub-exhibition ees Europe, which focuses on energy storage. This year, the Hydrogen Dialogue is part of the event for the first time, having previously been hosted at Messe Nürnberg (NürnbergMesse).

WHEN: Trade fair with Hydrogen Dialogue Forum from June 23 to 25, 2026; specialist conference Hydrogen Dialogue Summit on June 24 and 25

WHERE: Messe München (Munich Trade Fair Center) and International Congress Center Messe München (directly on the exhibition grounds)

WHO: The organizers expect 2,800 exhibitors and over 100,000 visitors across the entire trade fair.

TICKETS: For H2international readers, the code eesEU_2026_HZwei provides a free allocation of trade fair tickets here: t1p.de/tz31q

Shifting risks with leasing

Text: Michael Almeida

In many industries, leasing is a proven financing model. In the hydrogen sector in Germany, funding conditions have often prevented its use. That is now changing.

Fuel cells, electrolyzers, storage solutions or hydrogen-based production processes are technically available. But the ramp-up of the hydrogen economy also requires investment. For many companies, especially small and medium-sized enterprises, the question therefore arises: How can the entry be financed in an economically viable way? Leasing is a suitable model for many of these projects.

Leasing or loan? At first glance, leasing and a bank loan appear similar. In both cases, regular installments are paid, the financing partner wants to limit its risk and achieve a return on the capital provided. Leasing is no magic bullet; the equipment does not become cheaper through a leasing contract. What changes is the structure: Who pays what and when, and who bears which risk?

Bank loan: The company takes on debt, purchases the equipment and records it as a fixed asset on the balance sheet. The liability appears on the liabilities side of the balance sheet. This burdens key financial ratios such as the equity ratio and debt-to-equity ratio, and limits the scope for further investments.

Leasing: The equipment remains the property of the lessor. For the lessee, the investment does not appear as a liability on the balance sheet. The lease payments are tax-deductible as operating expenses. The company uses the equipment without having to own it, thereby improving its credit lines and creditworthiness vis-à-vis banks.

Leasing is particularly recommended when liquidity and balance sheet flexibility need to be preserved, when predictable operating costs over a medium-term period are desired, or when the technology is still evolving and a later replacement is foreseeable. A bank loan may be more appropriate when long-term ownership is the goal or when tax depreciation benefits are to be utilized.

Leasing does not work for every investment size. At Würth Leasing, the practical entry point is an investment volume of around 50,000 euros. Below that, the administrative effort of a leasing contract is often not economical.

Typical terms for industrial equipment range from 36 to 72 months. The specific term is determined by three factors: the technical useful life of the equipment, the tax depreciation requirements (which define minimum and maximum terms) and the company's liquidity planning. Short terms mean higher monthly installments but offer earlier flexibility. Longer terms reduce the installment and preserve liquidity. At Würth Leasing, there is a purchase option at the end at a residual value agreed upon at the time of contract signing.

A different risk allocation structure Leasing changes the risk structure. Würth Leasing operates as an asset-based financier and places the primary risk on the asset itself. The assessment therefore focuses on the equipment and its technical quality, the realistic useful life and the recoverable residual value. In other words: Could the equipment be resold or otherwise utilized if needed?

The company's creditworthiness must also be sound, but it is not the primary focus. A company with good assets and a solid project basis can be eligible for leasing even when conventional banking ratios signal no further borrowing capacity.

Depending on the technology, the project and the credit situation, it may be advisable to agree on a down payment. This reduces the monthly lease payment for the lessee and provides the lessor with additional security, as part of the asset value is covered from the outset.

For young technologies such as electrolyzers, the residual value assessment is naturally more cautious than for established industrial technology. This is factored into the calculation. Leasing is therefore not a tool for circumventing risks; rather, it is a different, and often better-suited, structure for risk allocation.

Case study: When the bank says no This could look as follows, for example: A medium-sized metalworking company wants to purchase an electrolyzer for on-site hydrogen supply at a cost of 800,000 euros.

The company is financially healthy but has financed substantial investments in new production lines through bank loans in recent years. The debt-to-equity ratio is correspondingly high, and the company's principal bank sees no further scope for additional liabilities.

Through leasing, this project can be structured differently. The new equipment does not appear as a liability on the balance sheet. The credit line with the principal bank remains untouched. Würth Leasing assesses not only the company's creditworthiness but also evaluates the equipment itself and its technical quality, the useful life and the realistic residual value. On this basis, a leasing contract over 60 months can be structured that fits the liquidity planning. The project thus becomes feasible by allocating the risk differently.

The funding bottleneck Many hydrogen projects originate in existing industrial and SME structures: in mechanical engineering, metalworking, supplier companies or energy-intensive industries. As part of the Würth Group, Würth Leasing has been supporting such companies for many years.

In recent months, companies from these industries have repeatedly expressed interest in Würth Leasing's offerings with specific hydrogen projects. These involved electrolyzers for on-site supply, infrastructure for hydrogen-powered logistics or production facilities with new processes.

Nevertheless, such projects could often not be implemented via leasing until now, because funding programs did not allow it. An explicit exclusion of leasing is rarely found. Rather, many funding programs require the applicant to be the legal owner of the funded equipment. Since ownership remains with the lessor in a leasing arrangement, such investments have been considered ineligible under numerous programs to date.

Affected programs include, among others, various KfW programs for energy efficiency and decarbonization, BAFA funding for process heat systems, as well as several federal state funding programs with a technology focus.

Even if a project is technically and economically worthy of funding, eligibility has until now been able to fail due to the form of financing.

Funding programs are opening up This situation is beginning to change. According to the German Federal Association of Leasing Companies (Bundesverband Deutscher Leasing-Unternehmen), several federal state funding programs are adapting their guidelines and opening up to this form of project implementation as well. Some programs are reviewing their guidelines and creating exceptions or clarifications that can permit leasing. This means: In the future, investments may more frequently be eligible for funding even when they are financed through leasing.

This has a significant impact in practice. Leasing, independent of funding programs, has been an established financing instrument for decades. Companies can use equipment without it appearing on the balance sheet, thus preserving their financial flexibility.

Where funding programs can additionally be utilized, this effect is amplified: public funding and structured lease financing can be combined, which can significantly improve the economic viability of individual projects. Especially in an early market phase, this can facilitate private-sector financing and thus the ramp-up of the hydrogen economy. ○

Michael Almeida
Sales Manager bei Würth Leasing

Emergency power supply

Backup goes green

Text: Niels H. Petersen

Data centers, cell towers, substations: wherever power failure is not an option, fuel cells offer a clean alternative to diesel generators. Not as a replacement for batteries, but as their perfect partner.

In the Dutch city of Groningen, a project with signal effect is launching in mid-June, at least for European data center operators. NorthC is installing a 500-kilowatt fuel cell module in its new data center to replace conventional diesel backup generators. According to the company, it is the first data center in Europe to switch to green hydrogen.

"The transition from diesel-powered backup generators to sustainable alternatives is a significant next step," says Jarno Bloem, Chief Operating Officer at NorthC. Green hydrogen offers the best possibilities for this. The system is expected to save tens of thousands of liters of diesel annually and reduce CO2 emissions by more than 78 tonnes per year. If demand grows, additional H2 modules could be added. While these are more expensive to purchase than diesel generators, the company expects costs to decline as the technology advances.

Why UPS and emergency power are indispensable

The abbreviation UPS stands for uninterruptible power supply. And it is no luxury but a lifeline in many industries. It protects sensitive electrical systems, such as servers, network equipment, hospital medical devices or control systems, from the consequences of power outages and grid disturbances. In the event of a grid failure, the UPS delivers power immediately, stabilizes voltage fluctuations and gives operators time to shut down systems in a controlled manner or switch to a longer-term emergency power supply.

Batteries typically handle this immediate supply for seconds to a few minutes, while diesel generators, known as standby power systems, provide longer-term operation, i.e. emergency power supply. But it is precisely these diesel generators that are coming under increasing pressure: they cause emissions,

Data centers require a lot of power, and always need protection against a power outage, too.

noise and considerable maintenance effort, and must be tested monthly even though they rarely run in an actual emergency. Every test run burns diesel. Stricter environmental regulations, such as the German Energy Efficiency Act (Energieeffizienzgesetz), and the climate targets of major corporations are making the search for alternatives more urgent. Fuel cells are therefore moving more sharply into focus, even though it is still a niche market.

Complementing batteries Fuel cells will therefore not replace lithium-ion batteries in UPS applications. In fact, the two technologies are less in competition with each other than they are complementary. Batteries respond in milliseconds, making them still unmatched for immediate bridging during a grid outage.

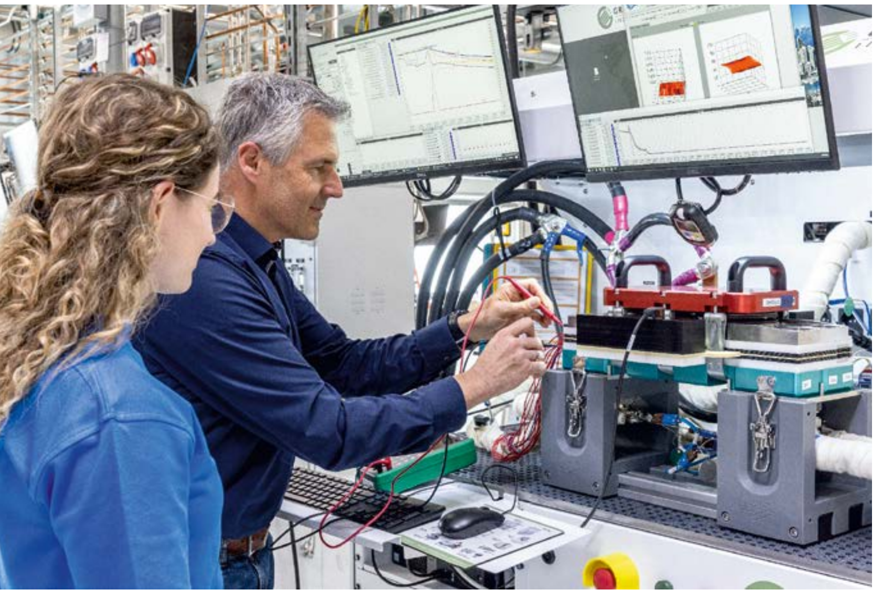
Fuel cells, by contrast, need a few seconds of start-up time. Their strength lies in long-duration supply: as long as hydrogen is available, they deliver power continuously, for hours or even days. Batteries are usually depleted after a few hours and then simply empty, says Alexander Kabza, Head of the Fuel Cell Systems Division at the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW). The key question is how long a UPS must operate independently of the grid. For minutes or a few hours, batteries can usually be dimensioned sufficiently. “If, on the other hand, longer grid-independent operation must be ensured during a dark doldrums period, or if no adequate grid infrastructure is available at all, which is already the case for large data centers today, then fuel cells can also provide large amounts of electrical energy on a sustained basis via hydrogen stored on-site or delivered by pipeline.”

Ulrich Misz, Head of the Fuel Cell Systems Department at the Center for Fuel Cell Technology (ZBT) in Duisburg, Germany, confirms this assessment: “The central advantage of fuel cells lies in extending autonomy time. While battery systems quickly become large and expensive for long bridging periods, the energy capacity of fuel cell systems can be increased relatively easily by using larger hydrogen storage,” says Misz. In addition, the high energy density of hydrogen allows large amounts of energy to be buffered in a compact form.

Longer runtime, easier storage, less maintenance The real competitive battle in the future will be between fuel cells and diesel generators. Compared with diesel, fuel cells score with several advantages: they operate not only emission-free and virtually silent but also require significantly less maintenance. Oil changes, “diesel bug” (microbial contamination of fuel) and regular load testing are eliminated. Hydrogen can also be stored for years without self-discharge, whereas batteries require active charge management.

For a 48-hour emergency power supply, a pure battery system would in many cases simply be too large and too expensive; a hydrogen tank is considerably more compact. “Fuel cell solutions can be expanded very easily to achieve longer backup times,” says Stephan Laistner, Director Sales Europe at SFC Energy, based in Munich, Germany. “Battery systems must be completely replaced after ten to fifteen years.” Laistner, too, is seeing rising demand for UPS solutions combined with a fuel cell.

Bridging 72 hours That the technology works beyond the pilot stage is demonstrated by several ongoing projects. The grid operator Schleswig-Holstein Netz has replaced the previous battery solution with a hydrogen fuel cell from SFC Energy at a substation. The old system ▻



TOP: Researcher Alexander Kabza inspects a fuel cell stack. © ZSW, Martin Duckek
BOTTOM: Fuel cell UPS secures power grid operation. © SFC Energy AG

no longer met new statutory requirements for bridging time. The new system, an Efoy H2-Cabinet, delivers four kilowatts of power over 72 hours using two fuel cell modules.

The hydrogen supply is provided by three cylinder bundles, each with twelve cylinders at 300 bar; an automatic switchover controls the operation. “This energy solution offers the opportunity to ensure emergency power supply with an innovative approach while simultaneously contributing to climate protection,” says Tobias Lützen of Schleswig-Holstein Netz. The entire system is housed in a space-optimized outdoor cabinet on approximately 16 square meters and can be integrated into existing plant structures.

Deutsche Telekom is also field-testing the technology. At the Nibirii Festival in Düren, Germany, a hydrogen fuel cell, also from SFC Energy, powered a mobile cell tower continuously for 14 days for the first time, replacing the diesel generator that would otherwise have consumed 35 to 40 liters per day. The mobile tower, developed by two Telekom employees themselves, supports 5G and LTE and can be set up by a single person within 20 minutes. The test demonstrates that such a solution is suitable not only for short-term events but also for longer-term standby power operation, for example in disaster areas.

Data centers as micro power plants The biggest driver for hydrogen-based emergency power supply is the rapidly growing demand for computing capacity, also driven by artificial intelligence. Data centers are increasingly evolving from passive power consumers into independent micro power plants. So-called microgrids combine battery storage, on-site power generation and grid-forming inverters into a self-sufficient campus grid that can, in an emergency, decouple from the public grid and independently maintain a stable 50-hertz power supply.

Microsoft is already operating a three-megawatt PEM-based fuel cell system in Wyoming, housed in two 40-foot containers. Vertiv, in cooperation with Ballard Power, offers a modular system designed to replace conventional diesel generators. Rolls-Royce supplies H2-ready certified gas engines under the MTU brand that initially run on natural gas and can later be converted to up to 100 percent hydrogen.

Market growing every year According to analysts, the European fuel cell market will grow by approximately eleven percent annually through 2034. The ZSW also sees clear market prospects: “The mere fact that companies are developing products for these applications shows that a market is forming,” emphasizes Alexander Kabza. Nevertheless, further hurdles remain: the acquisition costs for fuel cell systems are still significantly higher than those of conventional generators, the hydrogen infrastructure is still patchy, and lithium-ion batteries are becoming steadily cheaper and more powerful. Yet fuel cells score particularly where diesel generators have dominated so far, with emission-free energy and high flexibility. The political framework conditions and climate targets are playing into the fuel cell’s hands. It is not only in Groningen at NorthC that this signal has been recognized early on. ○

Planning tomorrow's refuelling stations today

Text: Marcus Merkel

The market ramp-up of fuel cell trucks requires refuelling stations and infrastructure, and the German federal government is accelerating its funding policy. For operators and investors, the key question now is: What must an H2 refuelling station deliver today so that it can still hold its own tomorrow, in a dynamically growing fleet?

Hydrogen refuelling stations are a long-term investment – at least that is how it should be, so that it pays off for everyone involved. This is where a current recommendation by the independent expert body Clean Energy Partnership (CEP) comes in. "Technical performance parameters for classifying refuelling station configurations" translates regulatory requirements and lessons learned from initial large-scale projects into practical planning criteria for the heavy-duty sector.

Refuelling large quantities quickly While standards such as AFIR (Alternative Fuels Infrastructure Regulation) set minimum targets for network coverage and capacities, the concrete technical design of hydrogen refuelling stations for heavy-duty transport remains a complex undertaking. The requirements of trucks weighing up to 40 tonnes are fundamentally different from those of typical passenger car installations. ▻

The hydrogen refuelling station in Düsseldorf on Höherweg is suitable for refuelling at 350 and 700 bar. © H2 Mobility

Refuelling volume: While a passenger car takes about 5–7 kg of hydrogen, the energy quantity required per heavy-duty truck is usually between 40 and 60 kg.

Fast refuelling: Short downtimes are an economic necessity – the target is a maximum refuelling time of ten minutes.

Back-to-back refuelling: The standard benchmark is at least three trucks per hour, without the storage being depleted afterwards or the chiller overheating.

All of this calls for high-performance, redundant and modularly designed systems.

Criterion	Target/Recommendation
Refuelling volume per vehicle	40–60 kg (truck)
Refuelling time	≤ 10 minutes
Refuelling rate	90 g/s (prerequisite for the target time)
Back-to-back refuelling	min. 3 trucks/h without fill loss
Available hydrogen per day	1 tonne H2
Modularity	etrofittability for higher throughput
Components	High-pressure storage (min. 350 bar), high-performance pre-cooling, redundant compression and cooling reserve

The most important planning data for future-proof hydrogen refuelling stations at a glance © CEP

At least three trucks per hour In the discussion about hydrogen refuelling stations, reference is often made to the nominal daily capacity of a facility, for example in the form of a "1-tonne station." However, this metric is of limited use. What is actually decisive for practical suitability in truck operations is the ability to refuel quickly and repeatedly, as well as ensuring a throughput that keeps pace with the work cycles of major logistics operators.

This is particularly important in long-haul transport. Often, several vehicles need to be refuelled almost simultaneously in the morning, each with 40 to 60 kg of hydrogen. A high calculated daily capacity is of little help in that case. Rather, storage and cooling must be designed for back-to-back refuelling.

On this point, the CEP recommendation sets a clear focus: The pure hourly or daily quantity must be backed by high-performance storage, compressor and cooling systems, so that multiple trucks in succession – at least three per hour – can be served without significant waiting times, refilling or regeneration phases.

Checklist for performance parameters Together with the Sustainable Transport Forum and on the basis of industrial experience, the CEP partners have defined the most important parameters that enable a refuelling station to meet the actual needs of the logistics sector. The most important ones are summarised in the table. They assist with system design, procurement and operation. According to CEP, they represent the minimum for refuelling stations to remain economically and technically viable in the future.

Two technical components are central: the storage capacity of the high-pressure storage systems and the pre-cooling of the hydrogen. Both must be designed so that individual full-volume refuelling events in regular operation as well as multiple consecutive truck refuelling events can be carried out without capacity loss and with consistent quality. A typical 700-bar station dimensioned for passenger car throughput would reach its limits in a short time.

CEP recommends modularity. From the outset, systems should be designed so that they can be scaled through straightforward retrofits, for example by adding storage bundles, compressor stages or dispensers. As the vehicle fleet grows – as freight carriers particularly expect in metropolitan areas and at logistics hubs – a single-bay solution designed for today's needs will quickly no longer suffice.

Logistics, economic viability and funding compliance Last but not least, a refuelling station must be designed so that it can be seamlessly integrated into existing logistics processes.

Refuelling must be ensured outside conventional opening hours, for example. The station must be quickly accessible and the process straightforward. In addition, all parameters that are relevant for funding eligibility must be met.

The CEP recommendations show that the dimensioning of an H2 refuelling station does not have to be a compromise between cost and future-proofing. Those who observe the minimum standards foreseeable today and rely on modularity are not only laying the foundation for investment and funding eligibility, but also for a smooth adaptation to steeply growing demand. This is how the technical and economic backbone of sustainable logistics for the future is created. ○

Dr. Marcus Merkel
Clean Energy Partnership

The floating hydrogen factory

Text: Jens Cruse, Moustafa Abdel-Maksoud, Andreas Bösmann

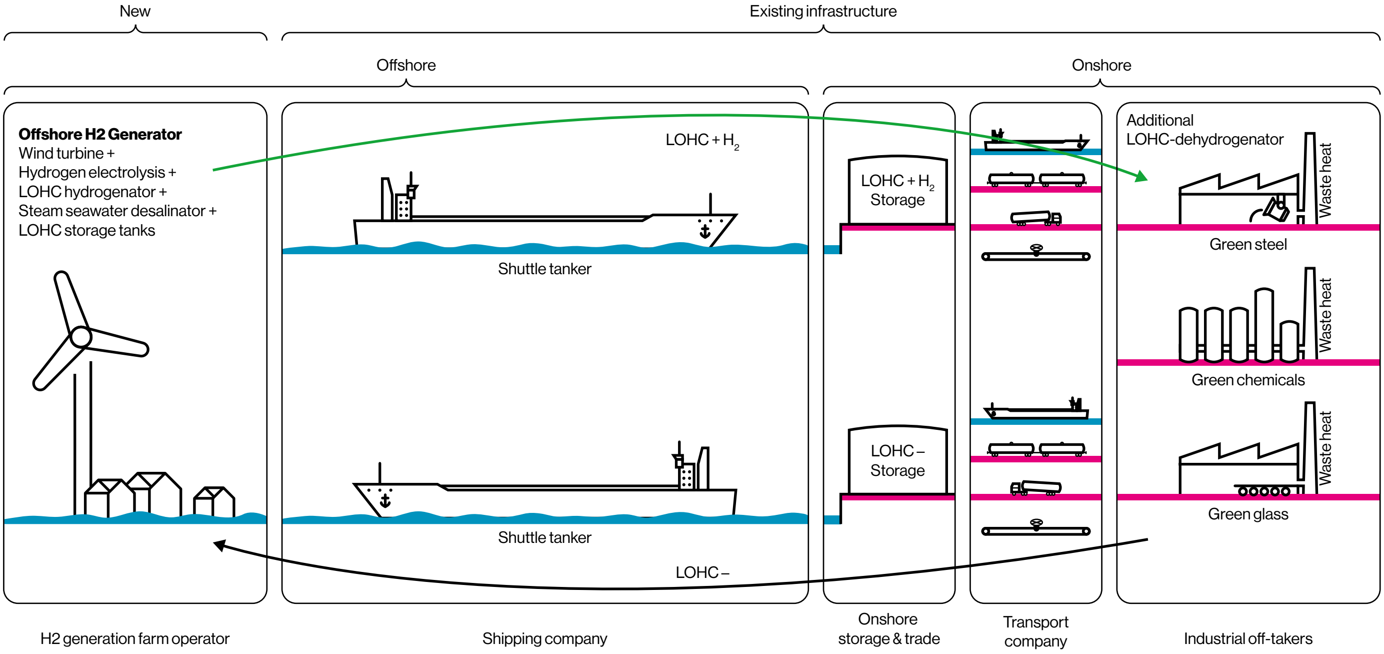
Why bring electricity ashore when you can use it at sea? A floating offshore hydrogen generator converts wind energy into green hydrogen on the spot. Tankers then handle transport and storage – following a standard in the oil industry.

The success of the hydrogen economy depends largely on whether green hydrogen can be provided reliably, cost-effectively, and in large quantities. This is of decisive importance for future energy sovereignty and industrial resilience in Europe. A floating offshore hydrogen generator uses the energy from offshore wind turbines directly on site and converts it into hydrogen via electrolysis, without connection to the onshore power grid.

The principle is similar to the operation of a ship: the generated electrical energy is consumed directly on the platform. The largest share flows into the electrolyzer, which produces hydrogen from desalinated seawater. For storage and transport, a liquid hydrogen carrier is used, a so-called Liquid Organic Hydrogen Carrier (LOHC). This carrier fluid enables hydrogen to be stored and transported safely at ambient pressure and ambient temperature.

For transport, the concept is based on established solutions from the offshore oil industry. Similar to floating production, storage and offloading units (Floating Production Storage and Offloading Units, FPSO), the energy carrier is not transported ashore via pipelines. Instead, shuttle tankers, for example ▻

This is what an offshore hydrogen park could look like. The wind turbine is connected underwater to a desalination plant, an electrolyzer, and an LOHC container. © COG



Value chain including production and consumers. © COG

on a monthly basis, exchange the LOHC loaded with hydrogen for unloaded carrier fluid.

The tankers transport the loaded LOHC to major industrial ports such as Hamburg, Antwerp, Amsterdam, Rotterdam, or Dunkirk. These locations already have a high-performance infrastructure with connections to inland waterways and rail networks. Another advantage is that existing facilities and logistics structures of the oil industry can also continue to be used.

After dehydrogenation, that is, the release of hydrogen, the unloaded LOHC is transported back to the offshore facility via the same route and reloaded. The system thus essentially functions like a liquid battery that continuously circulates between the offshore facility and industry.

A key cost factor of the hydrogen economy lies less in production itself than in transport, storage, and conversion. Therefore, the concept considers the entire value chain, from generation to industrial use.

Large hydrogen consumers such as the steel and chemical industries are included in the system analysis. Many of these plants are located either directly on the coast or on navigable rivers such as the Rhine. For them, a reliable supply of cost-effective hydrogen is crucial in order to remain internationally competitive and to meet political carbon dioxide reduction targets.

Research on the way to a prototype The development of the floating offshore hydrogen generator is being advanced as part of a research project funded by the German Federal Ministry for Economic Affairs and Energy. Participants include the Hamburg University of Technology (TUHH) in the field of offshore technologies and fluid dynamics, as well as Friedrich-Alexander University Erlangen-Nuremberg (FAU) with a focus on LOHC storage technology.

In the project, the platform and overall system are optimized under realistic environmental conditions. This includes extensive simulations, wind tunnel, and wave tank tests. The results to date are promising: the development is approaching prototype maturity. Many of the components used come from established industries and already have a Technology Readiness Level (TRL) of at least 7 in onshore operation.

CRUSE Offshore GmbH has currently reached TRL 4 for the floating body and initially plans the construction of a 5 MW pilot project. This will be followed by series systems with around 15 MW output, which can be used in offshore hydrogen farms on a gigawatt scale.

Modular hydrogen farms on a gigawatt scale The planned offshore hydrogen farms consist of several floating generators, each supplied by its own wind turbine. This modular concept enables almost arbitrary scaling of plant capacity. Operation is particularly economical in regions with consistently high wind speeds. High capacity factors ensure that the capital-intensive electrolyzer can be operated as continuously as possible and that large quantities of green hydrogen are produced. The systems are to be installed preferably within the exclusive economic zones of the respective states in order to ensure planning and legal certainty.

Prof. Dr. Moustafa Abdel-Maksoud
Head of the Institute of Fluid Dynamics and Ship Theory at Hamburg University of Technology (TUHH).
m.abdel-maksoud@tuhh.de

Dr. Andreas Bösmann
Head of the Hydrogen & Energy research group at Friedrich-Alexander University Erlangen-Nuremberg (FAU).
andreas.boesmann@fau.de

Jens Cruse
Naval architect and founder as well as managing director of CRUSE Offshore GmbH (COG), which is responsible for the industrial exploitation of the offshore H_2 generator.
jens.cruse@cruse-offshore.de

The northern North Sea as an ideal location The sea area between the Shetland Islands and Norway is considered particularly suitable. There, high and relatively constant wind speeds prevail, while at the same time enormous sea areas are available.

In addition, this region has decades of experience in the offshore energy industry, an important prerequisite for the transition from fossil fuels to renewable energy carriers such as green hydrogen.

Interest in such concepts is also growing at the European level. The European Commission has launched a program with the "Sustainable Transport Investment Plan" (STIP), which specifically supports investments in sustainable fuels. Hydrogen plays a central role in the production of synthetic aviation fuels (eSAF).

The largest share of costs in the production of such power-to-liquid fuels is attributable to the provision of hydrogen, around 70 percent of total costs. The actual Fischer-Tropsch synthesis and the provision of carbon dioxide, for example via Direct Air Capture (DAC), account for only about 30 percent. Cost-effective offshore hydrogen would therefore make a decisive contribution to the economic viability of such processes.

Hydrodynamics and operating strategy of the platform In the ProHyGen project, the Institute of Fluid Dynamics and Ship Theory at TUHH investigated in particular the performance and reliability of the system from a hydro- and aerodynamic perspective. Based on weather data from the past 30 years, a realistic wind energy output profile was calculated, which served as the basis for the design of the electrical system.

Especially in autonomous offshore operation, calms and temporary shutdowns play an important role for the operating strategy. Therefore, it was examined how standby times and battery capacities can be optimized. At the same time, the analyses allowed a detailed evaluation of potential locations off the Norwegian and Scottish coasts as well as on the open sea.

Stable even in extreme sea states Simulations of the planned 15 MW system also show very high hydrodynamic stability. Even under extreme sea conditions with wave heights of more than 30 meters, as can occur in typhoon regions, the platform remains stable and exhibits only moderate accelerations. For the planned 5 MW prototype, corresponding verification has been provided for North Sea conditions.

Safety analyses also confirm the robustness of the concept. Even in the event of a collision with a ship and the resulting leak in one of the floating bodies, the system remains afloat under moderate sea conditions. The lateral floating bodies are additionally protected against major leakages by double hulls of the LOHC tanks and internal bulkheads.

Making sensible use of waste heat Another research focus lies on the energy integration of the overall system. Among other things, it was investigated how the reaction heat generated during LOHC hydrogenation can be used effectively. During the loading of the LOHC, around nine megawatt hours of heat per tonne of stored hydrogen are released at temperatures between 150 and 200 °C. This amount of energy is sufficient to operate a standardized maritime desalination plant that provides the ultrapure water required for the PEM electrolyzer. For the distillation of the required nine tonnes of water per tonne of hydrogen, about five megawatt hours at around 100 °C are required. In addition, part of the heat can be used to dehumidify the operating rooms.

LOHC as a flexible hydrogen source The later use of the hydrogen stored in the LOHC was also investigated. For the release of hydrogen from the carrier fluid, about nine megawatt hours of heat at temperatures between 250 and 300 °C are required.

Its use is therefore particularly efficient in processes that themselves generate large amounts of high-temperature heat. One example is the production of synthetic fuels such as eSAF. In Fischer-Tropsch synthesis, about six megawatt hours of heat at around 250 °C are generated per tonne of hydrogen, that is about two thirds of the energy required for dehydrogenation. If carbon monoxide is used instead of CO_2, a heat surplus is even generated.

Power generation in high-temperature fuel cells also offers interesting possibilities. Solid oxide fuel cells (SOFC), which operate at temperatures between 600 and 900 °C, provide sufficient heat for hydrogen release or even additional surplus heat depending on the operating state.

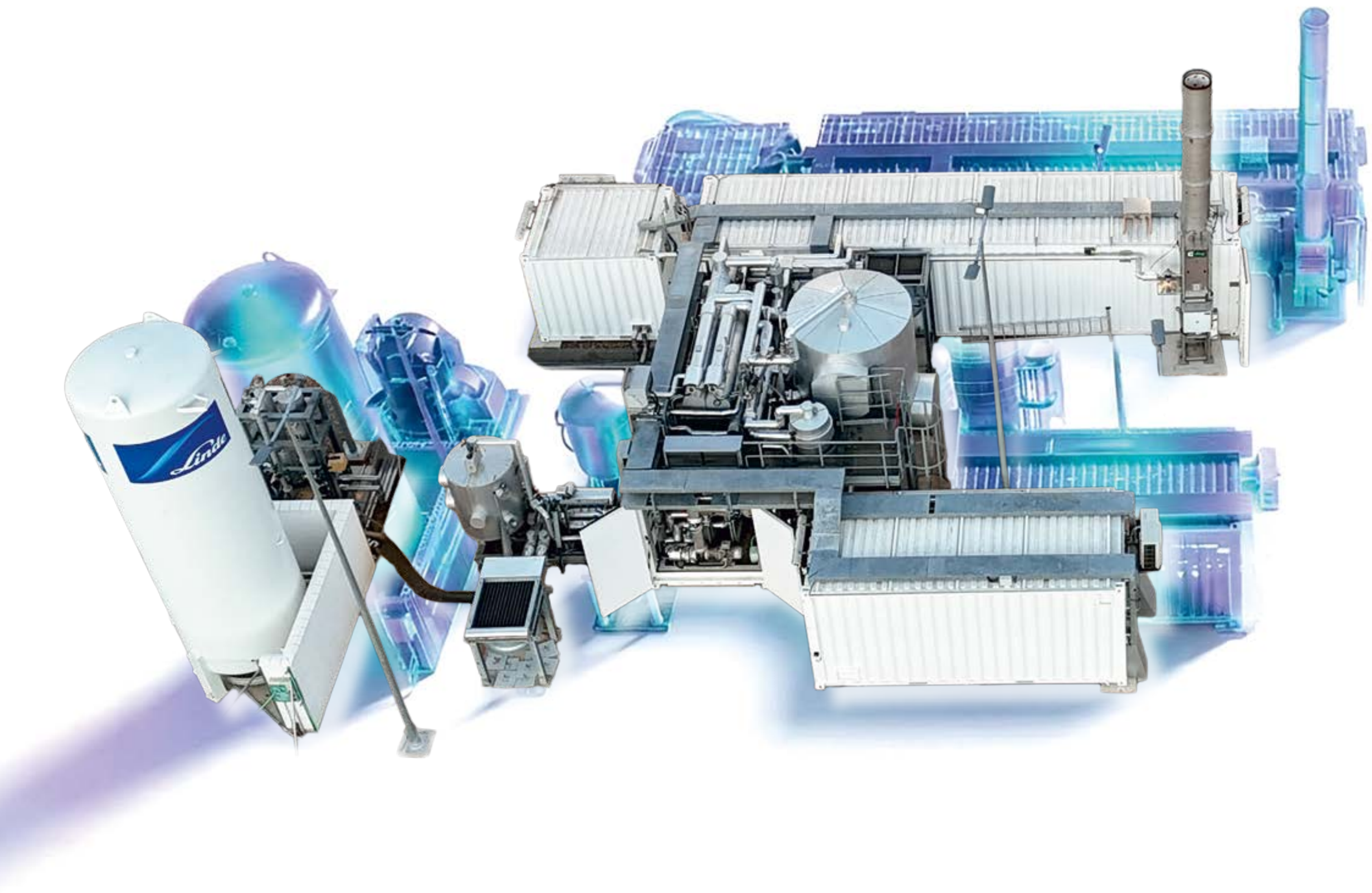
Perspective for a new offshore energy infrastructure Overall, the concept of the offshore H_2 generator, combined with the liquid hydrogen carrier LOHC and the use of existing oil infrastructure, shows a possible path to large-scale and economical hydrogen production at sea.

The combination of proven technologies from the offshore oil industry with renewable energy generation could significantly accelerate the transition from fossil to climate-neutral energy carriers and at the same time create a new industrial value chain in the offshore sector. ○

The younger twin

Text: Philipp Glaser

Siemens has created a digital twin for a Turn2X electrolysis plant in Spain, after the plant was already in operation. This improves the ability to control the plant remotely. A second plant being built next door is set to be digital from the start, offering additional benefits.



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The company Turn2X produces renewable natural gas (RNG) by combining green hydrogen, obtained through electrolysis using renewable energy, with biogenic CO2 from sources such as landfills and organic waste. The synthesized methane is chemically identical to fossil natural gas but has a net-zero carbon footprint.

Turn2X's first commercial plant is located in Miajadas, Spain. There, the company takes advantage of the country's abundant renewable energy supply to operate an electrolyzer. In doing so, the company uses non-potable water, an important consideration in water-scarce Spain. The first customer for the gas produced is a glass manufacturer that uses RNG to improve its carbon footprint.

In addition to industrial applications, RNG can be fed into existing gas grids and blended with conventional natural gas. Another option is to produce RNG at times when renewable energy is available in surplus and at low cost, store the gas, and use it as needed. This makes RNG a strategic tool for energy management with a high share of renewable sources such as solar and wind.

Process control system enables retrofit digitalization The plant in Miajadas comprises systems for water treatment, biogenic CO2 handling, heat recovery, and gas conditioning. The central link from the very beginning was the Siemens process control system, Simatic PCS 7. It is deployed in thousands of installations worldwide. The captured and archived operational data form the crucial foundation for Turn2X's plan to transition to remote operation and maintenance.

To realize this vision, Turn2X, with support from Siemens, created a digital twin of the existing plant, based on Siemens Hydrogen Technology Stack components: standardized engineering templates and blueprints for the hydrogen industry. At the core of this modular solution are Simatic PCS 7 and Comos. The system can be expanded as needed, including with gProms, Simit, Comos Mobile Worker, and the cloud-based Hydrogen Performance Suite. Each of these modules provides additional functions and customization options.

The creation of the digital twin began with data from Simatic PCS 7, which were imported into Comos, the integrated engineering platform from Siemens, to create a consistent digital representation of the entire plant. Existing documentation, detailed process engineering diagrams, and 3D models of the plant were also incorporated. This is how the digital twin was created: a virtual representation of the processes in Miajadas.

Remote operation and maintenance have been a reality since June 2025. No personnel are required for operation; for maintenance, two people are on site every two weeks. Maintenance documentation is centralized and continuously updated, so that technicians, whether on site or on the go, receive precise, up-to-date instructions, for example via Comos Mobile Worker. This means mission accomplished for the Miajadas site, for now. But with the digital twin, this is only the beginning of the digitalization journey.

Second plant digital from the start The new plant, being built directly adjacent to the first, will be digital from the outset. Insights and data from the first plant feed into the design and engineering, with benefits such as shorter project timelines and reduced risk.

Various technologies that have not yet been fully implemented in Turn2X's existing plant are set to play a central role.

For example, the digital twin is intended to support gProms, software that captures deep process knowledge in the form of precise, predictive process models. Plant operators can use these models to make complex design and operational decisions. Thanks to the digital twin, personnel can also work with the simulation platform Simit. It enables comprehensive testing of automation applications without affecting ongoing operations. In addition, Simit provides realistic training environments for operators even before real systems go into operation. This promotes process optimization and knowledge retention, shortens commissioning times, and significantly accelerates time to market.

Additionally, the Hydrogen Performance Suite supports operators in optimizing operations with real-time monitoring and analytics, performance improvements, and predictive maintenance. This allows plant availability and efficiency to be maximized as operations scale.

Beyond integration into the Hydrogen Technology Stack, the digital twin enables the use of SiGreen for managing the product carbon footprint (PCF). This web-based solution collects emissions data along the entire supply chain and delivers verifiable PCF values to support customer reporting and regulatory requirements.

Blueprint for further digital twins From commissioning onward, operators benefit from simulation, training, and performance optimization. Thanks to integrated digitalization, this second plant can also be remotely operated and maintained, just like the first.

Through remote operation and maintenance, personnel can use their experience more effectively to continuously optimize the plant. This enables the scaling of Turn2X's RNG business model. With the partnership between Siemens and Turn2X, and the implementation of the Digital Hydrogen Plant in the project, there is now a blueprint for other companies looking to follow the same path. ○

Philipp Glaser
Vertical Architectures at Siemens

The critical juncture

Text: Kurt Klauke, Matthias Fritzsche

Solid oxide cells could make electrolysers and fuel cells more efficient, more robust and easier to integrate thermally. But for the technology to truly play a role in climate protection, production would need to increase by factor 1,000 until 2035. A key bottleneck: the joining process. Multi-stack joining systems from Horiba are designed to help overcome it.

Multi-stack joining machine by Horiba © Horiba

Kurt Klauke
Product Manager SOFC/SOEC at Horiba

Matthias Fritzsche
Technical Sales Engineer at Horiba

Solid oxide cell technologies (SOC) are efficient and well suited for thermal integration. Solid oxide electrolysers can also be used to produce synthesis gas from carbon dioxide in the chemical industry.

A thousandfold increase needed The current annual output of SOC is in the low hundreds of megawatts range and would need to rise to the high hundreds of gigawatts by 2035 in order to meet climate targets such as the Paris Climate Agreement (UN) or the European Green Deal. Despite uncertain data on the demand required for this, it is clear that the expansion of global production capacities would need to be exponential. Technologically, time-consuming and cost-intensive joining and reduction processes have so far stood in the way.

The automated manufacturing of SOC stacks is technically demanding. For efficiency reasons, the parallel processing of multiple stacks in a single furnace appears sensible. Uniform temperature distribution is essential in order to keep stack quality high while simultaneously keeping the reject rate low. Deviations of more than ±5 Kelvin can already have serious effects on the production result. In addition, the mechanical load plays a central role when joining and reducing multiple stacks, as it determines the tightness and thus the functionality of the stack. Automated and reproducible production with integrated quality control avoids such problems.

Four stacks in a single operation The multiple-joining stations from Horiba FuelCon enable an automated joining, reduction and quality assurance process for SOC stacks within a single system. Depending on stack design and desired output, up to four stacks can be processed simultaneously in the respective process steps within a single production line. If higher production volumes are needed, multiple production lines are required. The Horiba TestWork automation system controls the process steps and continuously monitors and regulates setpoint and actual parameters such as temperature, pressure, media flow rates as well as test specimen current and voltage in real time. The setpoint values are freely configurable by the user.

The standardised automation software and system architecture ensure that optimised production processes can be transferred to additional systems. The MQTT interface enables integration into an MES (Manufacturing Execution System) in order to control and monitor multiple systems during production ramp-up. Optionally, quality assurance can also be integrated directly into the process.

In a real pilot plant, an error-free production rate of around 95 % was achieved, with the remaining 5 % rejects not necessarily attributable to the systems themselves.

Capex drops by almost a third Compared with previous individual solutions, capital expenditure (capex) has been reduced by approximately 32 % with the current generation of multiple-joining stations. At the same time, operational expenditure (opex) has decreased by around 24 %. Over the same period, overall equipment efficiency (OEE) has increased by 3 %.

In addition, process steps are eliminated, which reduces personnel costs. Monitoring and electronic documentation work more efficiently and increase the transparency of production processes.

For manufacturers, multiple-joining stations offer an opportunity for a cost-effective ramp-up of SOC stack production with reliably plannable investments. Even when used for high volumes, the systems remain individually customisable. In this way, multiple-joining stations can help solid oxide cells leverage their advantages in the hydrogen ramp-up. ○

Ceramic technology from Japan for the German hydrogen industry

Text: Sven Vogt

Japan, a leading hydrogen nation, frequently uses fuel cells in heating systems and vehicles. Germany, by contrast, focuses primarily on large industrial processes involving hydrogen, such as in the steel, chemical, or basic materials industry. Ceramics specialist Kyocera is convinced that its materials, proven in Japan, offer advantages in Germany as well, despite the differences.

Japan has had a national hydrogen strategy since as early as 2017. There, household and mobility applications dominate. These are strongly cost-driven and must simultaneously meet the highest safety requirements, including safe handling by non-experts. Fuel cell heating systems or hydrogen-powered vehicles are frequently used in residential environments and are subject to strict standards. In addition, materials are exposed to strong and fluctuating mechanical loads that are sometimes unpredictable, for example due to potholes and varying loads. What is needed, therefore, are compact, dense, corrosion-resistant, and economically viable solutions. Added to this is the high importance of miniaturization: particularly in household and mobility applications, the available installation space is limited, which is why space-saving, integrated components play a central role.

In Germany, large-scale industrial plants pose different requirements. High-temperature electrolyzers and fuel cells or chemical reactors are usually designed for continuous operation and are exposed to extreme conditions: high temperatures, high pressures, and aggressive process gases. Here, long-term stability, scalability, and process reliability in the industrial sense are the primary concerns. Materials must also function reliably here over years without losing performance or developing safety-relevant weaknesses.

Conducting heat: Ceramic heat exchangers are not only highly temperature-resistant but also have high thermal conductivities of up to 180 W/mK. In hydrogen applications, this combination makes them predestined for thermal management. © Kyocera

Largely unaffected by embrittlement Regardless of the market, the same principle applies: hydrogen poses particular challenges for materials. Metallic materials can become embrittled under the influence of hydrogen, lose their tightness, or age more rapidly. In industrial plants, this can lead to efficiency losses, unplanned downtime, or increased safety risks, factors that significantly impair economic operation. Technical ceramics are inert to hydrogen, exhibit very low permeability, and retain their mechanical and chemical properties even under extreme operating conditions. They thus offer a robust option for applications in which conventional materials reach their limits.

High-performance ceramics combine properties that are particularly in demand in hydrogen environments: high temperature and corrosion resistance, electrical insulation, dimensional stability, and a long service life. Ceramics are less susceptible to hydrogen embrittlement than metals and thus enable greater operational safety, especially in demanding industrial processes with high thermal and chemical loads.

As a materials specialist with decades of experience, Kyocera supplies ceramic components for precisely these fields of application. The portfolio ranges from tubes, seals, and insulators to pump components, heat exchangers, and ceramic substrates.

Insulating heat: Containment shells made of ceramic materials serve to provide thermal insulation while also offering high electrical insulation. © Kyocera

Material for membranes, seals, heat exchangers ... In the German market, there are several fields of application in which ceramic materials can demonstrate their strengths. These include fuel cells and electrolyzers, where ceramic components such as membranes, seals, tubes, or heat exchangers contribute to increased efficiency and extended service life. Particularly in high-temperature processes, their thermal and chemical stability is a significant advantage.

Ceramic components are also used in chemical plants, for example in the form of tubes, valve seats, or sensor housings. They offer a long service life, high resistance to corrosive media, and enable the miniaturization of sensitive components. In addition, there are applications involving cryogenic hydrogen: ceramic feedthroughs, insulators, and pump components meet the stringent requirements for tightness, insulation, as well as temperature and pressure resistance.

A further application example is ceramic substrates as carrier materials for catalysts, for instance in ammonia cracking. They enable a large active surface area, extend catalyst service life, and increase their efficiency.

Ceramics for high demands, metals for the masses The numerous technical advantages of ceramic components are also reflected in a higher acquisition cost compared to metallic or polymeric alternatives. Viewed over the entire life cycle, however, their use can pay off, for example in plants with high downtime costs, extreme process conditions, or limited installation space.

At the same time, ceramics are not a universal replacement for other materials but rather deliver their added value primarily in the demanding fields of application described above. For high-volume mass applications such as pipelines or simple piping systems, metals or polymers generally remain the more economical choice. A realistic, application-specific material selection is therefore crucial.

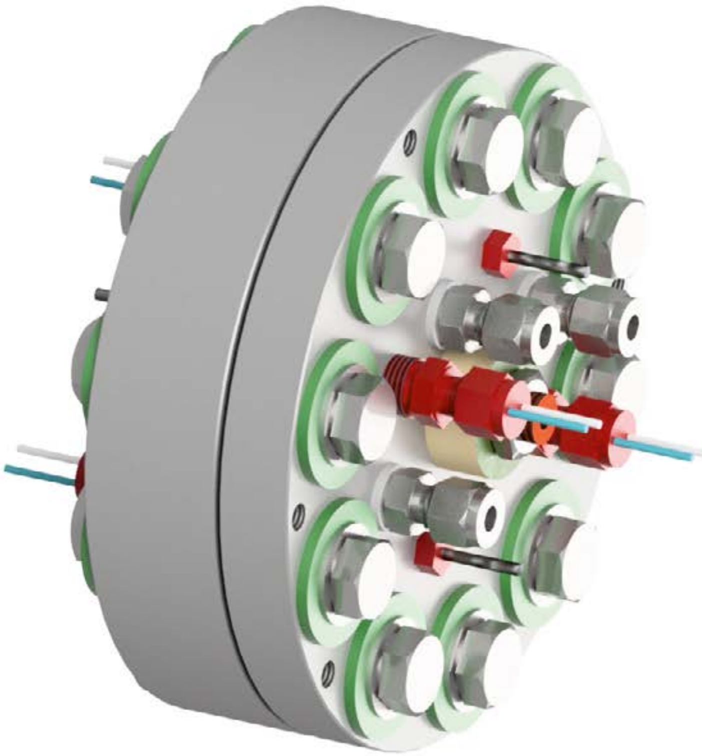
Hydrogen markets are developing differently, yet technological experience can be transferred. High-performance ceramic components that have proven themselves in household and mobility applications in Japan can also play an important role in the German industrial market, provided they are deployed in a targeted and realistic manner. ○

Sven Vogt
Market Analyst at
Kyocera Europe GmbH
info@kyocera.de

Whisper compressors for residential areas

Text: Anette Weingärtner

Mechanical compressors are maintenance-heavy and noisy – a real problem in residential areas. The ELCHPEM 2.0 project is developing an electrochemical alternative based on hydraulic cell compression that aims to eliminate both drawbacks while reaching pressures of up to 300 bar.



The electrochemical compressor is to be further optimized in the ELCHPEM 2.0 project.

High pressure is as much a given in hydrogen applications today as its low volumetric energy density. To reach common pressures, often 200 to 1,000 bar, mechanical compressors are used, for example diaphragm compressors. The disadvantage: they are not only maintenance-intensive but also very noisy. The latter makes them unattractive for use in residential areas, especially in small energy systems for single-family homes.

This is where the ELCHPEM 2.0 project (Elektrochemische Zellen auf Basis der neuartigen hydraulischen Verpressung von Einzelzellen zur Verdichtung von Wasserstoff, i.e. electrochemical cells based on novel hydraulic compression of individual cells for hydrogen compression) comes in. The project is coordinated by the company Obitronik, with the Fraunhofer Institute Umsicht, the company ProPuls, and the Westfälische Hochschule Gelsenkirchen (Westphalian University of Applied Sciences Gelsenkirchen) participating as project partners. “Our goal is to further develop and test a reactor for the electrochemical compression of hydrogen based on hydraulic compression that was created in the predecessor project ELCHPEM 1.0, and thus to offer an alternative to the use of mechanical compressors with our product for decentralized energy storage,” explains Professor Ulrich Rost, chair holder for hydrogen technology and energy storage at Hochschule RheinMain (RheinMain University of Applied Sciences) and employee of ProPuls. The initial aim is to compress 90 g of hydrogen per hour. This corresponds to 1 m^3 of hydrogen at ambient conditions, sufficient for a residential system.

Compressor also suitable for H2 separation Electrochemical compression is still in its early stages compared to mechanical compression. But it offers considerable advantages: “Mechanical compression involves friction of moving parts that require maintenance,” says Professor Rost. This leads to regular downtimes at hydrogen plants because the compressors need to be inspected. A low-wear system could eliminate this problem. In addition, contami-

ELCHPEM test stand: The test stand is intended to be used to test the novel reactor for the electrochemical compression of hydrogen.

POWDER-TO-ROLL PROCESS

The powder-to-roll process was developed by the Fraunhofer Institute Umsicht. It is a solvent-free technology for coating flexible carrier materials (films, strips) through electrostatic deposition of functional powders, for example to produce battery materials or other functional layers. The material is continuously unwound from a roll, coated, and wound up again. This saves energy and reduces costs.

nation of the hydrogen by lubricants, as used in mechanical compressors, could be avoided. What is more: in electrochemical compression, only hydrogen is compressed, because a membrane in the compressor prevents other gases from being included in the compression process. This means the electrochemical compressor could also be used for separating hydrogen from gas mixtures. Furthermore, the noise level of an electrochemical compressor is significantly lower than that of a mechanical one.

Design resembles a PEM fuel cell The electrochemical compressor used in this project resembles a PEM fuel cell in its design. It consists of two electrodes (anode on the low-pressure side, cathode on the high-pressure side) and a proton-conducting membrane (PEM) arranged between them. The membrane is gas-tight and electrically insulating and is coated on both sides with a catalyst (CCM, catalyst coated membrane). Using an electric field, a mass flow is generated through the catalyst-coated membrane. Hydrogen is catalytically split on the anode side of the CCM. Due to the electric field, the protons flow through the membrane to the cathode, where they are reduced to hydrogen and leave the electrochemical compressor at a higher pressure level. Currently, the compressor achieves efficiencies of a good 50 %, meaning it converts slightly more than half of the energy input into compression work. For comparison: mechanical diaphragm compressors achieve approximately 50 to 70 %.

Industrial prototype as the goal In the predecessor project ELCHPEM 1.0, the researchers succeeded in achieving electrochemical hydrogen compression from 0 to 60 bar based on a hydraulically compressed cell concept. ProPuls also designed a reactor with a single cell in this project.

The ELCHPEM 2.0 project, which started in April 2025, is now intended to scale up the reactor. ProPuls is responsible for reactor designs, the Westfälische Hochschule Gelsenkirchen for the process and the system into which the reactor is integrated, as well as the experimental setup and operation. Obitronik is responsible for power electronics and plant management.

The goal is to develop and test a near-industrial prototype. A multi-stage compressor system is planned, with the individual stages to be operated dynamically and in coordination with one another via intelligent power electronics from Obitronik.

The targets for the project's completion in April 2028: a pressure differential of 100 bar per stage, a fully modular functional demonstrator with output pressures of up to 300 bar, and nearly arbitrarily large cells (over 1,000 cm^2).

Challenge: bipolar plates One problem is the heavy and expensive bipolar plates that serve as wear protection. A bipolar plate based on a polymer-graphite composite is therefore intended to reduce costs, weight, and volume and is to be developed by the Fraunhofer Institute Umsicht within the project.

The high pressure differentials also pose a design challenge. The membrane is only 100 micrometers thick. "Pressure differentials of 100 bar place enormous stress on the membrane. It must not be damaged. Therefore, the forces must be distributed as homogeneously as possible within the cell so that the membrane is not subjected to such high stress," says Rost. Current, temperature, and waste heat should also be distributed as homogeneously as possible. Improved long-term stability of the overall system leads to cost reduction.

Interim results on overall functionality are expected by summer 2026.

The first area of application is intended to be the compression of small gas volumes for energy systems in single-family homes. Decentralized compression at fueling stations is also conceivable, as is filling standard gas cylinders at 200 bar. In the semiconductor industry, the electrochemical compressor could be used as a gas purifier. The researchers even see a potential application in the future German hydrogen core network, at least in the longer term. ○

See also the H2international video on thermal compression: t1p.de/H2int-video-eifhytec

Anette Weingärtner
Anette Weingärtner is a freelance journalist covering hydrogen topics, renewable energies, and robotics applications.

Precise measurements at high current

Text: Martin Sochor, Andreas Zeiff

Electrochemical impedance spectroscopy is a well-established method for rigorously testing electrolysis stacks in the lab. But when it comes to fully scaled industrial stacks, delivering several thousand amps while maintaining precise AC signal modulation is a major challenge.

Electrolysis cells have outgrown laboratory scale. Cells of industrially deployable size now need to be characterized, for example with regard to efficiency and degradation. As at laboratory scale, electrochemical impedance spectroscopy, or EIS for short, is well suited for this purpose. In this method, the impedance, i.e. the AC resistance of electrochemical systems, is determined as a function of the frequency of an alternating current. This concerns, for example, changes in the resistance of an electrolyte, a membrane, or the catalyst or the layer structure of the cells in the stack.

What works as a test specimen in the laboratory may exhibit different properties at large scale. What is therefore decisive is the interplay of the cells in the assembly, from mechanical stability to variations among individual cells and their influence on the overall stack. One objective is reliable monitoring of the state of health (SoH) under provoked aging, and, in the longer term, end-of-line inspection directly in production.

EIS is a non-destructive method for characterizing electrochemical processes such as corrosion, supercapacitors, batteries, fuel cells and electrolysis cells. It offers a good way of observing the processes in the stacks during operation. It thereby opens up new insights into stack design, provides a view of the voltage differences between cells, and allows a description of stack components such as bipolar plates and their influence on stack performance. In addition, data on the state of health of cells and stacks and their aging behavior can be obtained.

The researchers at HyCentA Research, based in Graz, Austria, specialize in the evaluation of data from large stacks. A reliable, dynamic, and very accurately reproducible DC high-power supply with superimposed, precisely adjustable AC frequencies is essential for meaningful measurements. For this purpose, HyCentA Research collaborates with the Austrian company Ing. Erhard Fischer, which, as an OEM and specialist for power supplies and power units, in turn supplies power supply modules from the Swiss manufacturer Regatron.

High-current supply versus small measured values Large-scale hydrogen production requires high voltages and high currents with power levels reaching into the megawatt range. For scientific investigations and development work, however, approximately ten of the otherwise up to 160 cells connected in series are sufficient. This reduces the required power. The currents, however, are still in the range of several thousand amperes of direct current. Joshua Eder, research associate and doctoral candidate at HyCentA Research, elaborates: “For reliable measurement at these high current levels, in addition to a well-designed test bench setup, very constant AC amplitudes are indispensable in order to avoid errors caused by nonlinear behavior.”

For the measurement, a small alternating current with a frequency of up to 10 kHz is superimposed on the strong direct current, causing the voltage at the cells to oscillate as well. In this process, the current and the phase angle relative to the respective voltages are measured. There is a linear relationship between voltage and current when the amplitude is chosen small enough. These can be amplitudes in current levels from a few am-

BELOW: Test bench setup for the electrolysis cells
© Ing. Erhard Fischer GmbH, HyCentA Research GmbH

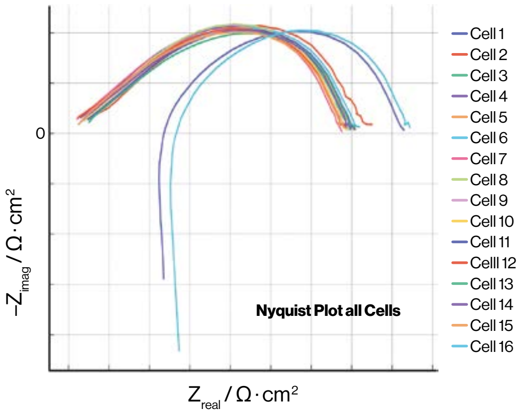
RIGHT: Reference curves allow rapid quality inspection for deviations from the norm.
© HyCentA Research GmbH

peres to over one hundred amperes, depending on the active cell area of the cells. Smaller cell areas have higher resistances and therefore require less excitation current to deliver a measurable voltage response. "For this, the G5 power supplies with the G5 function generator from Regatron are used, which, ideally matched to each other, deliver both the high operating currents and the superimposed AC modulation. Time-consuming adjustments and analyses of interferences, as they occur with separate DC and AC sources, are thereby eliminated," says Eder.

At the HyCentA Research test bench, stacks of different designs and power ratings can be examined. Depending on the current demand, the modularly designed power units can be interconnected to form a power supply of up to 8,000 amperes.

Load changes precisely programmable Many measurements place further demands on the supply modules. To provoke aging processes in the cells, for example, the stacks must be ramped up in frequent cycles and then quickly shut down again for special investigations. Switchable resistors are not ideal for this, since variable discharges are very complex to implement.

The modules used in Graz therefore operate in bidirectional mode. Unlike resistor-based solutions, this provides full freedom in programming the current ramp-up or ramp-down. Joshua Eder explains: "The modules are the foundation for us to be able



to carry out efficient measurements. They do cost more than standard supply modules, but they save enormous labor costs for preparation time and calibration work. The versatile interfaces also facilitate integration into the test bench and programming of the desired sequences. Only in this way can long test series be carried out reliably and the acquired data be stored as free of interference as possible for subsequent evaluation."

Developing more effectively Modern electrolysis cells are operated at internal pressures of up to 40 bar. Purely mechanical changes to cell components and seals can therefore also have major effects. EIS measurements can provide information on these sources of error as well. HyCentA Research is currently working on generating evaluation curves for different operating scenarios from the measured values that can be used for quality control.

For industrial deployment as end-of-line inspection, further extensive test series are required. While operating and control parameters can still be adjusted on test benches when measurement accuracy is insufficient, a stable measurement system is indispensable for automatic inspection, ideally with a supply module that integrates all requirements. The work of HyCentA Research thus provides important prerequisites for reliable quality testing of electrolysis stacks at industrial scale. ○

Ing. Martin Sochor
Project Engineer & First-Level Support at Ing. Erhard Fischer GmbH
powersupply@ing-fischer.at

Dipl. Chem. Andreas Zeiff
Redaktionsbüro Stutensee

Companies

Bipolar Plates

SITEC Industrietechnologie GmbH, prototypes, series production, production systems for your bipolar plates, stack assemblies and balance of plant, *info@sitec-technology.de, www.sitec-technology.com*

Whitecell Eisenhuth GmbH & Co. KG, Friedrich-Ebert-Str. 203, 37520 Osterode am Harz, Germany, Phone +49-5522-9067-14, Fax -44, *www.eisenhuth.de*

Coating

Holzapfel Metallveredelung GmbH, Unterm Ruhestein 1, 35764 Sinn, Germany, Phone +49-2772-5008-0, Fax -55, *www.holzapfel-group.com*

Compressors

Neuman & Esser, Werkstraße o. Nr., 52531 Übach-Palenberg, Germany, Phone +49-2451-481-01, Fax -100, *www.neuman-esser.de*

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

Consulting

Bernard Gruppe ZT GmbH, Bahnhofstr. 19, 6060 Hall in Tirol, Austria, Phone +43-5223-5840-118, Fax -201, *www.bernard-gruppe.com*

Distribution

Kälte- und Systemtechnik GmbH, Refrigeration systems for cooling hydrogen according SAE, Heavy duty refueling, Strassfeld 5, 3441 Freundorf, Austria, Phone +43-2274-44109, *office@kustec.at, www.kustec.at*

Electrolyzers

Asahi Kasei Europe GmbH, Fringsstr. 17, 40221 Düsseldorf, Germany, Phone +49-211-3399-2000, *info@asahi-kasei.eu, www.asahi-kasei.eu*

Cummins Inc., Am Wiesenbusch 2 – Halle 5, 45966 Gladbeck, Germany, Phone +49-2043-944-133, Fax -146, *powersales@hydrogenics.com, www.cummins.com*

FEST GmbH, Experience for future, Gerhard-Weule-Str. 10 38644 Goslar, Germany, *kontakt@fest-group.de, www.fest-group.de*

iGas energy GmbH, Cockerillstr. 100, 52222 Stolberg, Germany, Phone +49-(0)2402-9791600, *info@igas-energy.de, www.iGas-energy.de*

JA-Gastechnology GmbH, Albrecht-Thaer-Ring 9, 30938 Burgwedel, Germany, Phone +49-5139-98550, *www.jag.de*

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

Manufacturing

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Organizations

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Organizers (Events)

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Test Stands

AIP Automotive GmbH & Co. KG, Hojen 30, 87490 Haldenwang, Germany, Phone +49-8374-24090, *info@aip-automotive.de, www.aip-automotive.de*

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PUBLISHER
Robert Reisch

EDITORIAL TEAM
Editor-in-Chief:
Dipl. Ing. Eva Augsten
Phone: +49 155 62 95 92 70
Email: augsten@hzwei.info

HEAD OF SALES
Mariana Nahirna
Telefon +49 711 63 672-833
Mobil +49 159 062 246 48
Email: nahirna@gentner.de

ORDER MANAGEMENT
Melanie Schweigler
Phone: +49 711 63 672-862
Email: schweigler@gentner.de

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www.neon-bold.de, Berlin

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