

H₂int.

**Full control:
Sensors for
electrolyzers**

**HTWE trade fair:
Hydrogen highlights
in Hamburg**

**Market in transition:
The patterns of
disruptive innovation**



Namibia's grand plan

How green hydrogen is meant to move the country forward

TRENDS, TECHNOLOGIES, AND INDUSTRY NEWS –

curated by our editorial team and delivered straight to your inbox.



**FUEL UP ON
HYDROGEN KNOWLEDGE**
www.h2-international.com/newsletter

Eva Augsten, Editor-in-Chief
Monika Röbiger, Deputy Editor-in-Chief



Gentner
energy media

H2int.
THE HYDROGEN MAGAZINE

The greatest show: people, technology, disruptions

Sometimes the world feels like a circus. You rub your eyes and ask yourself: Did that really just happen? And whoever is sitting in the front row hopes not to be called into the ring for the sawing trick. This issue of H2international also offers reasons for amazement, about people driving innovations forward and about technical progress. Some developments, however, also make you shift uneasily in your seat.

In Namibia, many people are placing great hopes in hydrogen. Our authors met them and got to know projects that are intended to deliver iron, fertilizer, food and fuel locally. It is about more than energy: it is about economic independence.

Technical progress can be seen at the Hydrogen Technology World Expo. Scaling and automation take center stage. For our trade fair preview, we have pre-sorted the innovations so that you can more easily find your way around on your hydrogen world tour. Artificial intelligence is also becoming a highly specialized helper for the hydrogen industry. It not only optimizes project planning but also helps to make plants safer. How important scientific guardrails are for this is shown in this issue.

The major upheavals at the same time raise new questions, which this issue also addresses: Will AI's energy demand become a market for hydrogen? And how can companies build an economic ecosystem that equips them for disruptions?

No question, the opportunities are there. Our article on planetary boundaries, however, reminds us of what we should measure them against: hydrogen is meant to contribute to a better future. AI's hunger for energy can in principle grow infinitely, but the planet's resources cannot. Nuclear fusion will not solve this problem either, even if we succeed in using it (beyond the great central reactor of the solar system) as an energy source on Earth: power plants need material, sites, development and construction time, as well as cooling.

Hydrogen is an important building block for a better world. But we will not achieve that world through the technological scaling of electrolyzers alone. We also have to ask ourselves what exactly that world could look like when we include all planetary resources and their distribution.



Eva Augsten
Editor in chief
augsten@hzwei.info



18

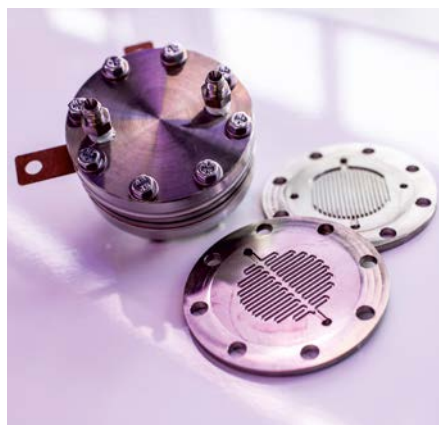
This way to the trade show highlights!

The H2international Travel Guide shows you the way at the Hydrogen Technology World Expo in Hamburg.



© HAZOP / made with AI

- 42 **Hazard check**
AI lends a hand with risk assessment for hydrogen projects.



© Fraunhofer UMSICHT, Mike Hemming

- 28 **In short supply**
Iridium is the most critical of the rare metals. What can ease the squeeze?



© Stadtwerke Stuttgart

- 32 **All in**
Despite tight budgets, Stuttgart is pushing its hydrogen hub forward.

Current affairs

- 6 News
6 What's up, Hyfindr:
AI needs Hydrogen
10 Hydrogen market update:
Firm goal, flexible path
12 Hamburg: From Coal Plant
to Hydrogen Hub
14 Namibia's hydrogen ramp up:
Plenty of sun, plenty of wind,
plenty of space

Market

- 18 Travel guide to HTWE:
What to see Hamburg?
25 Creative destruction:
The cost curve does not wait
28 Ressourcen:
Iridium shortage looms

Best Practice

- 32 Hydrogen hub:
Stuttgart pushes ahead

Mobility

- 34 Shipping navigates climate
targets, crises and new fuels

Technology

- 38 Sensors for electrolysis:
Control is better
42 AI software for HAZOP:
Spot the hazard, stop the hazard
46 Change of perspective:
AI helps with project financing
49 Weil Technology:
From chimney pipe to bipolar
plate

Sections

- 3 Editorial
52 Company directory
56 Preview
56 Imprint

What's up, Hyfindr? AI NEEDS HYDROGEN



Hyfindr Managing Director Steven Oji
shares insights and encounters from the international
hydrogen community

Who noticed that Jensen Huang is calling for H2 investments?

According to Jensen Huang, founder and CEO of NVIDIA, artificial intelligence (AI) is currently bringing about fundamental changes on five levels: energy, chips, infrastructure, models and applications. What is remarkable is what is named first: energy. Without it, neither chips and data centers nor AI models and applications function. If Huang is right with his vision of AI factories, AI will cause demand not only for computing power to explode, but also for energy.

In June, Huang was a guest at Sequoia Capital, one of the most renowned venture capital firms in Silicon Valley. There he explained his model and called the energy level the "biggest opportunity in several generations" for the energy industry, in particular for investments in sustainable energy.

Huang explicitly names the technologies: nuclear energy, wind power, solar energy, and hydrogen.

Of course, Huang is not saying that hydrogen will secure the energy supply for AI on its own. But he makes clear: the build-up of AI infrastructure will trigger enormous investments in new energy generation and infrastructure.

This is where we as the hydrogen industry should look and seek business opportunities. One strength of hydrogen is its ability to store large amounts of energy and provide them as needed.

In this, two megatrends come together: AI needs ever more energy; the energy transition needs solutions to store, transport and flexibly provide renewable energy.

By the way, the newest OpenAI model "Astra 6" is also convinced that hydrogen plays an important role in building a sustainable energy supply. Feel free to ask! ○

Fuel cell reachstacker for container terminal in Tilbury

Hyster delivers the United Kingdom's first fuel cell reachstacker to the Port of Tilbury. In port logistics, battery-electric drives reach their limits, as the vehicles are in operation around the clock and must move heavy loads.

The pre-series vehicle now in operation builds on insights from pilot programs. This includes the test of a fuel cell reachstacker in Valencia completed last year. The Hyster reachstacker is powered by a 60-kilowatt fuel cell system from Nuvera, which works in conjunction with a lithium-ion battery with a capacity of 130 kilowatt-hours. Additionally, the vehicle uses the standardized software architecture that is also used in other electric products from Hyster.

The use of the Hyster reachstacker reduces the CO2 footprint of the port by 107 tonnes. The Port of Tilbury is part of the Forth Ports Group, which aims to achieve net-zero greenhouse gas emissions by 2042. With the hydrogen reachstacker, a solution has been developed "that meets the requirements and offers performance and robustness comparable to an internal combustion engine-driven machine," says Lucien Robroek, President of Global Big Trucks at Hyster.

The vehicles in port logistics move the heaviest loads around the clock. There is no time to charge a battery. High-pressure tanks store 32 kilograms of hydrogen on board. This is intended to enable long operating times and productive use over a full twelve-hour shift. The fuel cell reachstacker can be refueled in less than 30 minutes and is operated exclusively with green hydrogen, which is produced using an electrolyser from GeoPura. ○



Hydrogen
powered
reachstacker

© Hyster

Quantron joint venture to build commercial vehicles in China

The new joint venture Quantron China is to develop locally emission-free commercial vehicles for the Chinese market, and beyond. Behind it stand the Quantron business unit of the German-rooted Haller Group, the young Chinese technology company HyperView from the automotive sector, and Taiwan's Foxconn as manufacturing partner. The joint venture is to develop the Quantron Gen2 commercial vehicle platform for battery electric and hydrogen-powered trucks and buses. The first public presentation of a Gen2 vehicle is planned for the first half of 2027.

Quantron China is headquartered in Shaoxing, China. Quantron is to contribute its German engineering competence, industrial quality standards and international market experience, HyperView its competence in autonomous driving and in intelligent vehicle technologies. In addition, the partners are hoping for scaling and cost advantages from the Chinese industrial ecosystem.

The first target market of the new platform is to be China. For Quantron, however, it is also to be the technological and industrial basis for the expansion of the offering, both geographically and in terms of content. Andreas Haller, CEO of the Haller Group and founder of Quantron: "We are building in China for China and using the same platform to scale internationally. Our goal is to make emission-free commercial vehicle mobility faster, more economical and more scalable worldwide."

HyperView has reportedly already delivered a high three-digit number of hydrogen-powered commercial vehicles, primarily in China. Quantron likewise speaks of a three-digit number of vehicles and systems, with customers in Europe and the Middle East. By the end of 2026, the partners want to have one hundred vehicles in operation with European customers and to build on this experience in the development of the Gen2. The target figure for the entire ecosystem is more than 100,000 emission-free commercial vehicles over the next ten years, with the EU market being attractive given the emissions requirements. Quantron also wants to sell not only vehicles, but a complete package of financing, fleet management and availability guarantee. "We guarantee that our solution offers lower total cost of ownership than diesel from the outset," says Haller. If this succeeds, Quantron will tie its customers in for the long term. Similar approaches on a smaller scale have already been pursued by GP Joule and by H2 Energy from Switzerland. ○



Andreas Haller, CEO of the Haller Group and founder of Quantron, and Dr. Feilong Liu, founder and CEO of HyperView © Quantron

Construction starts on Europe's largest green hydrogen project

Moeve has celebrated the groundbreaking ceremony for the Andalusian Green Hydrogen Valley in Palos de la Frontera (Huelva), Europe's largest project to date for renewable hydrogen.

The first expansion stage bears the name "Onuba" and will comprise an electrolysis capacity of 300 MW at the Moeve Energy Park in Huelva, with an option for a further 105 MW. The annual production capacity is around 45,000 metric tons of green hydrogen, which corresponds to an avoidance of approximately 250,000 metric tons of CO₂ per year. The investment volume of the first phase amounts to more than one billion euros.

Moeve holds a majority stake of 51 percent. New partners are Hy24, the world's largest private equity manager specializing in clean hydrogen, and the Spanish public-private development institution COFIDES. Together they hold 29 percent. The remaining 20 percent is shared between Enagás Renewable and Alter Enersun.

The project has been classified by the EU as a "Project of Common Interest" (PCI) and is receiving 304 million euros from the Spanish Recovery Plan, financed via NextGenerationEU. The hydrogen produced is to support in particular the more sustainable production of fuels for road, air and sea transport, as well as the decarbonization of further industries.

In the long term, the Andalusian Green Hydrogen Valley is designed for a total capacity of 2 GW, distributed across sites in Huelva and San Roque (Cádiz). Together with a second-generation biofuels plant that is also under construction, Moeve is investing a total of 2.4 billion euros in Andalusia, with the aim of developing Palos de la Frontera into Europe's largest green molecules hub. ○



Industrial area in
Kotka, Finland

© Dronekettu

Thyssenkrupp nucera to centralise cell assembly

Thyssenkrupp nucera is setting up its first self-operated central assembly centre for electrolysis cells in Vila Nova de Gaia, south of Porto, Portugal. Until now, the cells have been assembled at the customers' sites. The Assembly Hub is expected to "significantly" increase capacity thanks to faster and more efficient cell assembly, but no numbers are given.

The first step involves cells for alkaline water electrolysis. Until now, the individual cell elements for the standardised 20-megawatt unit "Scalum" for hydrogen production have been assembled in decentralised customer workshops. This is often more time-consuming than central assembly and thus a capacity bottleneck. In the new hub, several cells are to be processed in parallel.

On the customer side, this is intended to reduce the effort for planning, personnel, and resources. The assembly-ready cell packages are also expected to reduce complexity on the construction site. The new assembly centre is also expected to bring advantages for customer service, both in ongoing operations and when replacing cells – although the manufacturer does not elaborate on these.

A lease for the hall, which is about 7,500 square metres, has already been signed, and construction of the hall is scheduled to start in winter 2026. Cell assembly is to begin in 2028. The Assembly Hub is intended to serve European and European-adjacent electrolysis projects. The first cells manufactured there are intended for the "Onuba" project by Moeve. ○

Finland: Hydrogen from methane pyrolysis to provide balancing power

GEN-H Energy, a Spanish developer of decentralized energy systems, plans to build a power plant designed for balancing power in Kotka, Finland, which is to use hydrogen from methane pyrolysis. A capacity of 200 to 300 megawatts is envisaged. Hydrogen production using the technology of the Finnish cleantech startup Hycamite is to be integrated into a gas-fired power plant. The companies have signed a letter of intent to this effect. Methane pyrolysis separates the carbon (C) from the hydrogen (H) of methane, in its pure, solid form. The solid carbon can be used industrially, for example in the form of graphite for battery production. GEN-H aims to build up a hub for clean energy, hydrogen technologies and green industry in the Sunila industrial area in Kotka. A former pulp mill is located on the site. Planning and permitting procedures are currently underway in parallel with the dismantling of the old facilities. The large gas connection is already in place, and power generation is to be modernized. Gas turbines are to be used in order to be able to supply electricity in times of low wind and sun, typically cold, windless winter weeks. For Hycamite, this is the second letter of intent for a project of this magnitude within a few weeks. Only recently, the company signed a letter of intent with the British company EnergyPathways, concerning 20,000 metric tons of hydrogen and 60,000 metric tons of graphite annually. ○

Correction

In H2international 3/2026, in the article "Is this growing together?" it was stated that the trade fair The Smarter E had 2,800 exhibitors and expected 2,800 visitors. That is of course wrong. The expected visitor number was 100,000; the actually counted figure (not yet known at editorial deadline for the issue) was 105,000. ○

Hyvolution PARIS

JANUARY 19-21, 2027

PARIS EXPO
PORTE DE VERSAILLES
FRANCE

Planetary boundaries exceeded almost everywhere, a wake-up call for the hydrogen ramp-up?



The “Planetary Health Check 2026” by the Potsdam Institute for Climate Impact Research paints an alarming picture: seven of nine planetary guardrails have already been breached. Even if the study does not explicitly name hydrogen, this industry, just like that of renewable energies, can understand it as an argument for speed in the ramp-up.

The state of the Earth is deteriorating faster than expected. That is the central message of this year’s Planetary Health Check, the annual status description of the Earth system based on the Planetary Boundaries framework. Seven of the nine defined safety limits, from climate stability through biosphere integrity to freshwater cycles, have been exceeded according to current status. The Earth, the authors say, is moving out of its “safe operating space”: from a safe home toward a system full of risks.

Tipping points approaching, faster than modeled Particularly worrying: climate change is progressing faster than previous projections suggested. Marine heatwaves and extreme weather events are increasing, tropical coral reefs experienced their most severe mass bleaching to date, and a collapse of the Atlantic Meridional Overturning Circulation (AMOC) is now considered a real risk even under moderate emissions scenarios. Parts of the Antarctic ice sheet, the finding goes, may already have begun their collapse.

The consequence: abolishing fossil fuels is not enough The authors are unmistakable in their conclusion: the only way to limit global warming to below 1.5 degrees leads via a simultaneous phase-out of fossil energy sources and the restoration of the planetary boundaries, in particular the protection of the biosphere. Individual measures fall short. What is needed is systemic, cross-sectoral action, and that within this decade.

What this means for hydrogen For the hydrogen industry, this finding is not an abstract climate signal, but a direct call to action. Green hydrogen is inconceivable without a massive expansion of renewable energies, and this expansion is in turn a necessary condition for the fossil phase-out that the study calls for. Anyone who delays the H2 ramp-up thereby also delays the decarbonization of those sectors, steel, chemicals, heavy transport, shipping, that cannot be electrified with electricity alone.

The Planetary Health Check 2026 thus provides the industry with a scientifically grounded argument that goes beyond economic opportunities: speed in the hydrogen ramp-up is not a question of market readiness. It is a question of planetary stability.

The narrow window of time that science still sees is closing. The tools, the authors explicitly emphasize, are available. What is missing is determination in action, on both the political and the industrial level. ○

© Planetary Boundaries Science (PbScience), 2026. Planetary Health Check 2026. Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany / NEONBOLD

WHERE THE HYDROGEN MARKET CONNECTS AND SCALES

JOIN US
SCAN THE QR CODE



[PARIS.HYVOLUTION.COM](https://paris.hyvolution.com)



In collaboration with



AN EVENT
greentech⁺

France
Hydrogène
Engagé pour la transition écologique

Firm goal, flexible path



The hydrogen ramp-up is stalling. German energy companies and associations now want, out of “pragmatism”, to weaken the RFNBO criteria and declare targets non-binding.

The EU Commission is once again discussing the hydrogen ramp-up. At the center of the deliberations is the loosening of the RFNBO criteria for green hydrogen. But another topic could weigh even more heavily, as insiders report. The previously binding targets for renewable hydrogen for each member state could be replaced by an indicative target at EU level. That would be a fundamental change of system: nationally attributable responsibility would turn into a common European ambition, for whose non-fulfillment, in the end, no one is responsible.

States have been responsible so far The EU directive RED III has so far stipulated that by 2030 at least 42 percent and by 2035 at least 60 percent of the hydrogen used in industry must be renewable. If these targets have to be met at the member state level, national funding instruments and concrete demand arise. An indicative EU target would eliminate this binding character. States could wait and hope for the achievements of others. This will be a topic when politicians and the hydrogen industry meet in October for the European Hydrogen Week in Brussels.

Yes, green hydrogen is still expensive, many industrial offtakers are shying away from long-term contracts, and infrastructure as well as import chains are emerging more slowly than expected. A national quota can place a particular burden on countries with high hydrogen consumption and energy-intensive industry.

But it does not follow from this that Brussels should abolish national responsibility. The quota was created because a market

for renewable hydrogen does not develop on its own. Investors finance electrolyzers and supply chains only if they can rely on dependable demand. The development in the refinery sector shows that quotas set important incentives for the ramp-up in the member states. A non-binding EU target does not offer this security. In this way, market confidence cannot be (re)established and long-term, bankable hydrogen demand beyond 2030 cannot be secured. Today's relief thus threatens to become tomorrow's investment obstacle.



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.

Flexibility in meeting the targets, but binding commitment to the goal Europe therefore needs neither regulatory rigidity nor a departure from its ambitions. The fulfillment of the quotas can be made more flexible, for example through tradable certificates, joint procurement or the transferability of RFNBO volumes between member states. Flexibility in fulfillment, however, is something different from non-binding goals.

The real answer lies on the demand side: carbon contracts for difference, green lead markets and procurement quotas, as well as secured offtake agreements. Those who instead replace national obligations with an indicative EU target create a classic responsibility problem: everyone commits to the goal, but each waits for the other.

Germany should advocate in Brussels for a framework that is flexible, investment-friendly and nevertheless binding. Green hydrogen will not become competitive by Europeanizing responsibility and abolishing binding commitments at the national level. ○

VOLLE LADUNG FACHWISSEN – IMMER DIENSTAGS UND FREITAGS.

Politik, Recht, Märkte und Technik –
unser-Newsletter liefert fundierte Infos für Energiewende-Profis.



**JETZT LADEN UND
AUF KURS BLEIBEN!**
www.erneuerbareenergien.de/newsletter

Nicole Weinhold
Chefredakteurin
Fachzeitschrift
ERNEUERBARE
ENERGIEN



Hamburg: From Coal Plant to Hydrogen Hub

Text: Monika Rößiger

On the site of Hamburg's former Moorburg coal-fired power plant, the hydrogen future is taking shape, faster than many expected. With the H2 Connector and the 100 MW electrolyzer, an infrastructure is coming together that could turn the Hanseatic city into a central hub of the German hydrogen economy.

Anyone entering the power plant site in Moorburg today finds a construction site in two senses: dismantling work is still underway, while new buildings for the fossil-free energy future are already standing. Heavy-duty transporters deliver the electrolyzer's massive components.

"At present, it is no longer *just* the dismantling of the old power plant facilities that is taking place here, but in parallel also a great deal of new construction," says Christoph Cosler, Head of Hydrogen & Corporate Development at Hamburger Energiewerke.

Hamburg's Senator for the Environment Katharina Fegebank underscores the symbolic value of Moorburg: "The fact that this hydrogen project is being built at a place where coal was burned just a few years ago is a real milestone."

H2 Connector under construction In August 2026, Hamburger Energienetze celebrated the start of construction on the H2 Connector, the technical control center of the Hamburg hydrogen industrial network HH-WIN. The Connector links the local large-scale electrolyzer with the citywide distribution network, which in turn is linked to the nationwide hydrogen core network (Wasserstoff-Kernnetz).

Technically, the challenge lies in the pressure differential: the Hyperlink pipeline, Gasunie's long-distance hydrogen transmission network, runs at a pressure of up to 70 bar. The Hamburg distribution network HH-WIN, by contrast, is designed for a maximum of 25 bar.

The Connector bridges between these two worlds, with a gas pressure regulation facility that steps down incoming hydrogen from 70 to below 25 bar, and a compressor station that boosts pressure to 70 bar for export.



ABOVE: Delivery of the first stacks in sturdy wooden crates.
© HGHH

BELOW: On site in Moorburg: the partners working together to make Hamburg's hydrogen future a reality.
© Monika Röbiger

“For the hydrogen economy to succeed, offtakers need options,” explains Michael Dammann, Technical Managing Director of Hamburger Energienetze. “Our installation hub makes it possible to feed energy from the on-site electrolysis into the grid, but also to source hydrogen from the long-distance transmission network – and, in the future, from the port – or even to export it.”

Bidirectionality by design Hamburg is intended to be not only a consumer but also a redistribution hub. The Connector's transport capacities are considerable: in the first expansion stage, up to 360,000 standard cubic meters of hydrogen per hour can be imported into Hamburg, or up to 200,000 exported into the long-distance transmission network.

The network takes shape HH-WIN, the Hamburg hydrogen industrial network, is the backbone of this infrastructure. Starting in fall 2027, it is to open up key industrial areas around the Port of Hamburg comprising 40 kilometers of network.

By 2031, an expansion to 60 kilometers is planned. Currently, more than half of the first 40 route kilometers has been completed, and all further sections are under construction or in the contract award process.

The projected savings are significant: if industry replaces 6.4 terawatt-hours of fossil natural gas annually via HH-WIN with climate-neutral hydrogen, 1.4 million tons of CO₂ per year can be saved in projected terms from 2032 onward.

36 heavy-duty transporters and a topping-out ceremony In parallel with the network expansion, the 100 MW electrolyzer of the Hamburg Green Hydrogen Hub (HGHH) is taking shape on the Moorburg site, the joint project of Luxara and Hamburger Energiewerke.

The timeline has been remarkably tight: cornerstone laying on December 1, 2025; topping-out ceremony in July 2026; and in August 2026, 36 heavy-duty transporters carrying the massive electrolyzer stacks rolled onto the site from the Siemens gigafactory in Berlin.

“We are all Team Hydrogen – something is actually being built here,” says Holger Matthiesen, Co-Managing Director of HGHH. “That cannot be taken for granted with new technologies and large infrastructure projects.” To date, two out of three types of large components are on site: six transformers and six stacks. The two compressors are expected to follow at the end of 2026.

Starting at the end of 2027, the facility is to produce around 10,000 tons of hydrogen per year. “Our connection to the HH-WIN hydrogen network creates an essential prerequisite for green hydrogen from our electrolysis facility to become available where it is needed, in

Hamburg and beyond,” Matthiesen emphasizes. The grid feed-in is supplemented by a trailer loading station, through which hydrogen can also be dispensed by truck.

Core network and European backbone What is being built in Moorburg is not a Hamburg solo effort. The H2 Connector is embedded in a growing national and European infrastructure. Gasunie, one of the major European long-distance transmission network operators, is building around ten percent of Germany's hydrogen core network with the Hyperlink project, and doing so with remarkable resource efficiency: around 70 percent of the route consists of converted natural gas pipelines.

“We can now see: something is happening. Hydrogen is no longer a distant future,” says Britta van Boven, Managing Director of Gasunie Deutschland. The numbers back her up: six gigawatts have already been reserved on a binding, fee-based basis – meaning capacities that carry a real financial commitment. “There is serious interest, and progress has exceeded what many skeptics expected.”

From the end of 2029, the core network is also to be connected with the Netherlands and Denmark. “Then we will really have a market,” says van Boven. In this network architecture, Hamburg will play a key role as a consumption and import center.

The Hamburg company Tesa came on board in fall 2025 as the first industrial hydrogen offtaker, a development that Fegebank regards as a “strong sign for our industrial location.” The registration process, in which companies can express their non-binding interest in sourcing H₂ from the large-scale electrolyzer, is open until November 13, 2026.

The construction costs for the H₂ Connector alone, without the compressor station, which is still in the project planning phase, amount to around 22.6 million euros, of which about 16.3 million euros are covered by IPCEI funding.

On time, on budget What is being built in Moorburg is being implemented at remarkable speed given the project's complexity. Fegebank highlights that the project is “fully on schedule and on budget. This shows that things can succeed when everyone works well together.”

Indeed, the coalition behind it is unusually broad: a private project developer (Luxara), a municipal energy company (Hamburger Energiewerke), a municipal network operator (Hamburger Energienetze), a European long-distance transmission operator (Gasunie), and Hamburg's state-level politics, all pulling in the same direction.

For a project on a site that just a few years ago stood for the opposite of the energy transition. ○



Plenty of sun, plenty of wind, plenty of space

Text: Klaus Sieg

Namibia has excellent conditions for the production of green hydrogen, and the government has big plans. Iron, fertilizer, jobs: hydrogen is to advance the economy and make the country more independent. The journalist Klaus Sieg and the photographer Martin Egbert traveled through Namibia and got to know projects, hopes and challenges.





Johannes Michels, managing director and co-founder of Hyiron Green Technologies: **“The investment decision for the next phase will be made this year.”**

© Martin Egbert



Hyiron project engineer Kandetu Vetuamuje explains how the hydrogen becomes water again during iron reduction, allowing the pilot plant to get by on just 3 m³ of fresh water per day.

© Martin Egbert

LEFT PAGE: Behind the mountains of the Namib Desert lies Hyiron's pilot plant, the Oshivela Project. In its next stage, it is set to deliver 200,000 tons of iron annually.

© Martin Egbert

The gravel road winds through the mountains of the Namib Desert, over stones, dust and rubble, through hills and peaks full of bizarre formations. Somewhere in this lunar landscape is supposed to be the industrial pilot plant of Hyiron Green Technologies? One of the world's largest production sites for green iron, according to its operator?

The feeling of having gotten lost in the middle of nowhere is one you'll have often in Namibia. The Namib Desert alone stretches two thousand kilometers along the coast from Angola to South Africa. At 81,000 square kilometers, the Namibian part is larger than the Federal State of Bavaria. And that's far from all. Almost half of this southwest African country is desert, an area far larger than Germany.

Then, behind the mountains, Hyiron's solar field suddenly glitters in the glaring sun. The 44,000 modules are hard to miss. The production site itself is also sizable for a pilot plant: numerous containers, tanks, pipes and the large hall housing the two six-megawatt electrolyzers. The facility, known as the Oshivela Project and backed by 13 million euros in funding from the German Federal Ministry of Economic Affairs and Energy (BMWE), could soon grow considerably larger.

Scaling decision on the horizon “The investment decision for the next phase will be made this year,” says Johannes Michels, managing director and co-founder of Hyiron Green Technologies. The 25-megawatt solar field is set to grow to 375 megawatts, with battery storage enabling part of the plant to run around the clock. Today's modest capacity of 15,000 metric tons of iron per year could then rise to 200,000 metric tons. “Every metric ton of iron produced this way replaces 1.8 metric tons of CO₂ from the conventional process,” says Michels, who grew up in Namibia and Germany. Behind him, the view sweeps across the wide plain. Before Hyiron bought the site, this was a sheep and cattle farm. After years of climate-driven droughts, it had to be abandoned. Now the focus here is on future technology.

Iron ore is an oxide. Separating it from its oxygen content requires a reducing agent, which until now has usually been carbon, mostly in the form of coking coal. Hyiron uses green hydrogen instead, produced in two electrolyzers that run exclusively on solar power. The green hydrogen is fed into a rotary kiln at 800 to 950 degrees. A chain turns the kiln's large cylindrical chamber at just one revolution per minute. From the other end, coarse-grained iron ore enters, mostly as iron (III) oxide. “The hydrogen pulls on the oxygen atoms more strongly than the iron does,” explains Kandetu Vetuamuje.

That's how the iron is reduced. The by-product is water, which, after extensive

purification, is fed back into the electrolyzers. “This way we need no more than three cubic meters of water per day for the plant,” the engineer explains during a tour of the site. The water is delivered by tanker truck, which comes once or twice a month along the gravel road from Arandis. The town was founded in 1972 by the Anglo-Australian mining company Rio Tinto for its uranium mining employees. Many of the Black mine workers are said to have fallen ill. Even so, the open-pit mining sites continue to be operated by the subsidiary Rössing. To this day, they rank among the largest in the world.

Green iron sounds better than uranium. But who's buying the product? Part of the annual production has been secured by the international steel and pipe manufacturer Benteler, for which Hyiron presses the green iron into pellets. Other European customers buy the green iron to produce powder for 3D printing. Demand from Europe is likely to rise. Earlier this year, the EU Commission revised the rules for green steel quotas in public procurement: the steel no longer has to be produced in Europe. “Our price is only slightly above that of conventional iron,” says Johannes Michels. Once the expansion is up and running, there is expected to be no price difference at all. This is thanks to the low cost of coarse-grained iron ore, a by-product from mines in neighboring South Africa, and the sharp drop in battery storage costs. Above all, though, Namibia has a lot of sun. At 2,200 to 2,700 kWh/m²/year, solar irradiation here is more than twice as high as in Germany and still a third higher than in Spain.

Plenty of energy, little electricity, scarce water

“The world's best solar potential, excellent wind along the long coastline and plenty of space, these are the advantages we want to tap into,” says Jona Musheko. The spokesperson for the state-run Namibia Green Hydrogen Programme welcomes visitors to his air-conditioned office in a new building in the capital, Windhoek. The program was launched five years ago with support from Germany, among others. This year, it is coming to an end. “We've only been the midwives of Namibia's hydrogen industry,” Musheko says. “Now promising pilot projects are off the ground.”

Namibia's government, led since March 2025 by its first female president, Netumbo Nandi-Ndaitwah, aims to use green hydrogen to diversify the country's economy. Until now, that economy has depended mainly on exports of diamonds, uranium and other raw materials, on agriculture and fisheries threatened by the climate crisis, and on tourism, which benefits only a very small share of the population. One third of Namibia's roughly three million inhabitants are unemployed. Investments in hydrogen projects are expected to create ➤

tens of thousands of jobs and bring the country improved energy supply as well as substantial tax revenues. Sounds promising, at least at first.

But hydrogen uses a lot of water, and Namibia suffers from water shortages and recurring droughts. In most hydrogen applications, water cannot be recycled the way it is at Hyiron. Producing one metric ton of hydrogen requires nine cubic meters of ultrapure water. That translates into 12 to 13 cubic meters of surface or groundwater, or 20 to 30 cubic meters of seawater.

Electrolysis also consumes a lot of electrical energy, 47 to 55 megawatt hours per metric ton of hydrogen. And this in a country where less than 60 percent of the population is connected to the electricity grid. On top of that, Namibia has to import two thirds of its electricity from neighboring countries, most-

ly generated by coal-fired power plants. Will the green hydrogen industry improve this situation and benefit the local population? Or will the opposite happen?

The country's first fertilizer plant Jeremia Petrus of the Daures Green Hydrogen Village is a firm believer in green hydrogen made in Namibia. "With nitrogen fertilizer from green hydrogen, we want to produce something the country badly needs, this will be the very first fertilizer production in Namibia." Until now, Namibia has had to import its nitrogen fertilizer from South Africa and Zimbabwe. The sharp spike in fertilizer prices in the wake of the war in the Middle East, if nothing else, has made clear just how important domestic production can be. "My grandchildren will be proud of me for having been part of this future project," says the engineer in blue overalls.





Jona Musheko, spokesperson for the state-run Namibia Green Hydrogen Programme, sees his organization as the “midwife of Namibia’s hydrogen industry.” Now the pilot projects are set to find their own footing.

© Martin Egbert

The Daures Green Hydrogen Village, run by the energy company Enersense Namibia, lies about a five-hour drive northwest of Windhoek, between the Brandberg Massif and the Atlantic. The drive, too, offers fascinating steppe and desert scenery. Antelopes dart past. A family of ostriches crosses the road. Next to the Hydrogen Village’s solar field, fifteen modern greenhouses gleam in the sun. Peppers and cucumbers grow here, and will soon be nourished with climate-neutral nitrogen fertilizer. “We’re currently commissioning the plant for the Haber-Bosch process,” Jeremia Petrus explains. Behind him, female workers are painting the last pipes. The smell of paint hangs in the air. Next to the hall housing the electrolyzer and the ammonia plant, other female workers are laying the foundation for a hall that will house the production unit for solid fertilizer, funded by the United Nations Industrial Development Organization (UNIDO). They wear masks against the dust and the biting wind. Most are from surrounding communities. Daures Green Hydrogen Village has committed to filling at least half of its current 50 jobs locally. Representatives of the ethnic group living here also hold a 10 percent stake in Daures Green Hydrogen Village, which was launched in 2023 with around 12 million euros in funding from the German Federal Ministry of Research, Technology and Space. This also underpins the research partnership with the University of Stuttgart, with its counterpart in Windhoek, and with the German consulting firm Fichtner. There is a laboratory and a training center on site. Researchers and interested visitors can book accommodations at the guesthouse. Employees like Jeremia Petrus, who actually lives in Windhoek, also stay on the premises.

Hydrogen brings food, and needs water Once commissioning is complete, Daures plans to produce 100 metric tons of green ammonia per year, a modest amount. “This is just a pilot plant that doesn’t run around the clock, but it will at least cover our own nitrogen fertilizer needs.” Wind measurement stations are already in place in the surrounding area. Five wind turbines with battery storage are planned, to enable round-the-clock operation. “We want to show that nearly climate-neutral fertilizer and vegetable production is possible in the desert, and then expand it step by step,” Jeremia Petrus explains. Namibia currently has to import the vast majority of its food from South Africa. Daures Green Hydrogen Village is already supplying supermarkets in Swakopmund and Walvis Bay. And at a price that, according to greenhouse manager Jason Angula, is a fifth cheaper than the imported goods.

So, all in the green at Daures Green Hydrogen Village? Not quite. Even the modern greenhouses with their efficient semi-hydro-

ponic technology use 10 to 13 cubic meters of water per hectare per day. Producing 100 metric tons of ammonia requires nearly 18 metric tons of hydrogen. That translates into a water demand of around 0.6 cubic meters per day.

Daures draws its water from seven boreholes, which the company says deliver 70 cubic meters per day. So far, no problem. But what happens once the village grows to the planned size? The first expansion step envisions an annual production of 20,000 metric tons of green ammonia and significantly larger greenhouse areas. Enersense Namibia has a 15,000-hectare site at its disposal.

Pressure on this already scarce desert resource is also mounting from other sides. The area around the Brandberg Massif holds deposits of tin, copper, uranium, rare earths and lithium, which are being, or are set to be, extracted. According to research by the South Africa-based NGO Oxpeckers Investigative Environmental Journalism, there are around fifty licenses for projects in the region. Mines consume large quantities of water. Only about 90 kilometers from Daures lies the mining town of Uis, where there are reportedly already significant problems with drinking water supply. ○



RIGHT: Engineer Jeremia Petrus from the Daures Green Hydrogen Village is working on Namibia’s first fertilizer production. “My grandchildren will be proud of me for having been part of this future project,” he says.

© Martin Egbert

LEFT PAGE: The vegetables from the Daures Green Hydrogen Village greenhouses are already being sold in local supermarkets.

© Martin Egbert

The hydrogen industry holds great opportunities for Namibia, but also challenges for nature conservation and the use of water. The colonial past comes on top of that. How is Namibia dealing with it all?

Read the continuation in issue 1-2027 of H2international.

What to see in Hamburg?

Text: Eva Augsten

A visit to the Hydrogen Technology World Expo is like a world tour through the hydrogen industry. From the bipolar plate to the gigawatt-scale project, you can find everything here. The H2international Travel Guide helps you quickly find what matters most.

Do you already know which booths you want to visit at the hydrogen trade fair in Hamburg? Planning a trade fair visit can be tedious. That is why our editorial team has pre-sorted things for you and presents the trends and innovations here in the magazine in compact form, and in more detail in our newsletter. From the electrochemical core of the cell through the often underestimated periphery to tangible fields of practical application: with the H2international (H2int.) Travel Guide, you will more quickly find the innovations that are important to you.

Practical tip on booth numbers

The hydrogen section of the fair is located in halls B5, B6 and B7.

The booth numbers given by the organizer start with the hall number without the "B." So the "B" in 7B30 refers to aisle B in hall B7, and there you will find the German Hydrogen Association (Deutscher Wasserstoffverband) as well as H2int.



Innovations inside the stack

H2INT. AT THE TRADE FAIR

The team from Gentner Energy Media is of course also represented at the leading hydrogen trade fair. H2int. editor-in-chief Eva Augsten, deputy editor-in-chief Monika Rößiger and Mariana Nahirna from Media Sales will be out and about on the fairgrounds. We will be supported at times by Nicole Weinhold, editor-in-chief of our sister magazine Erneuerbare Energien, and Fabian Kauschke, editor for Erneuerbare Energien. As a co-exhibitor, we have our "headquarters" at the booth of the German Hydrogen Association (Deutscher Wasserstoffverband, DWV) e.V. at booth 7B30.



Eva Augsten



Monika Rößiger



Mariana Nahirna

Tanaka: catalysts, membranes and recycling processes Tanaka Precious Metal Technologies is participating in the Hydrogen Technology World Expo in Hamburg for the first time. The focus of its trade fair presentation is on precious metal technologies for hydrogen production, gas purification and precious metal recycling. The precious metals platinum (Pt), palladium (Pd), iridium (Ir), rhodium (Rh) and ruthenium (Ru) are indispensable for many hydrogen technologies and a significant cost factor. Using them sparingly and recycling them is therefore essential.

Tanaka's expertise covers electrode catalysts for fuel cells and electrolyzers, various catalysts beyond cell stacks (for example for steam reforming, for shift reactions, for exhaust gas treatment), hydrogen-permeable membranes and plated electrodes, as well as the recovery and processing of precious metals from hydrogen technologies.

Booth 7J54

APJeT brings plasma processes for GDL and PTL coatings APJeT Plasma Technologies is new to the hydrogen industry. At the trade fair, the company is showing a new coating and curing process for gas diffusion layers and porous transport layers. The technology combines the water-repellent coating GreenFIX-GDL with the plasma curing APCure. The coating is intended to encase the fibers of the base material without blocking its pores. According to APJeT, the APCure equipment can cure the GreenFIX chemicals directly at room temperature and atmospheric pressure, thus saving time and energy.

Booth 7G60

Bekaert: new functional layer for PEM electrolyzers

With the Currento Microporous Layer, or MPL for short, Bekaert is presenting an additional functional layer for PEM electrolyzers. The microporous layer is applied to the porous transport layer substrate. The layer is intended to establish particularly uniform contact conditions between the cell components, support ultrathin membranes and increase operational stability under demanding conditions. In addition, lower iridium loadings and higher operating current densities should become possible.

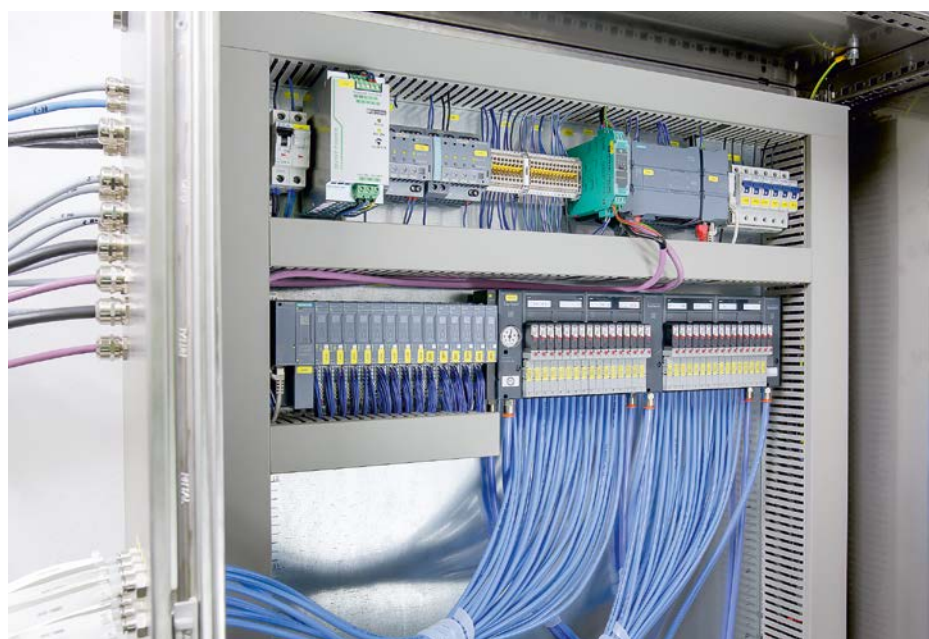
Booth 6J76

Metacon: new electrolysis stacks from PERIC

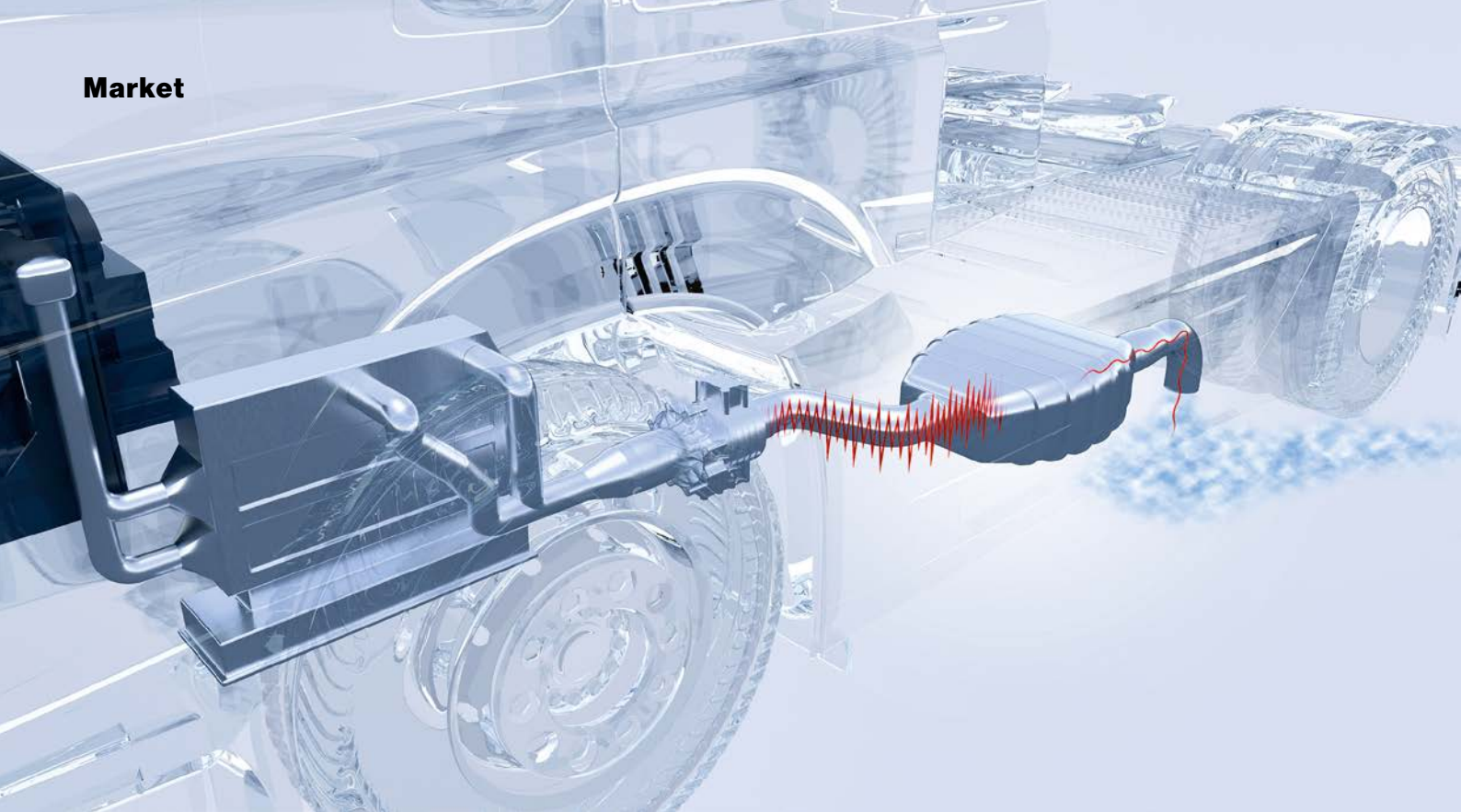
The Swedish company Metacon AB, together with the state-owned Chinese research institute PERIC Hydrogen Technologies, is bringing a new generation of pressurized alkaline electrolysis stacks to the European market.

The new stack design is said to have an operating current density up to 17 percent higher than the previous reference design. At the same time, the weight of the cell plates is to be reduced by up to 13 percent. The stacks are also intended to be suitable for flexible power ratings. Metacon plans to use the technology in its current and future commercial projects. According to Metacon, PERIC produces electrolysis stacks with up to 15 MW of capacity, although the 5 MW class is currently the common one in the industry. According to its own information, PERIC has an annual production capacity of around 6.5 GW.

Booth 7C27



Fluidic solutions from Bürkert © Bürkert



Balance of plant: fluidics, gas purification and automation

No stack works without its functional periphery: only the interplay of precise media supply, exact pressure control, modular automation and downstream gas purification turns an electrochemical cell into an industrially manageable overall system.

Bürkert: fluidic solutions for scaling hydrogen applications Bürkert Fluid Control Systems is presenting intelligent fluidic solutions that are necessary for stable processes in electrolyzers, fuel cells, test benches and H2 infrastructure.

Intelligent valve islands, communication-capable components and preconfigured system solutions enable end-to-end process automation and support the digitalization of hydrogen-based applications. For demanding operating conditions, solutions for dry and humidified gases as well as ATEX-compliant components for potentially explosive areas are also available.

For electrolyzers, Bürkert offers, for example, solutions for ensuring the quality of the feed water, for continuously monitoring the ultrapure water and for providing stable pressure conditions on the anode and cathode side. For stable plant operation, Bürkert offers solutions for safe shut-off of hydrogen, oxygen and liquids as well as energy-efficient cooling and temperature control systems.

For fuel cells, Bürkert offers precise fluidic solutions for the controlled supply of hydrogen and air as well as for the reliable regulation of pressure and volume flows. The control of purging and drainage processes and the re-

gulation of recirculation circuits are also part of Bürkert's range.

Booth 6J50

Purem by Eberspächer: de-hydrator for fuel cell exhaust air At the Hydrogen Technology World Expo in Hamburg, Purem by Eberspächer is showing, among other things, the de-hydrator. This reduces the moisture content in the exhaust air of fuel cell systems and thus reduces visible vapor formation. The component complements the modular exhaust air system consisting of a water separator (which removes water from the cathode path) and a silencer for intake and exhaust systems of fuel cell vehicles and systems. It is also intended to improve operational safety.

The second focus topic is the direct air capture system for separating CO2 from the ambient air.

Booth 7C39

Envirofalk: ultrapure water for electrolyzers up to 100 MW The water technology company Envirofalk has expanded its Envigreenpure PtX product platform. Until now, the series for ultrapure water supply for power-to-X applications (PtX) has covered capacities of up to 5 megawatts (MW). The portfolio now also includes standardized designs for 20 MW, 50 MW and up to 100 MW. According to the company, this makes it possible to realize projects in the capacity range between 2.5 and 100 MW on a uniform technological basis.

Die Reinstwassersysteme sind für verschiedene Elektrolyseverfahren ausgelegt wie alkalische Elektrolyse (AEL), die Anionen-

De-hydrator from Purem by Eberspächer © Purem



Modular water treatment system from Envirofalk

© Envirofalk

austauschmembran-Elektrolyse (AEM) sowie die Protonenaustauschmembran-Elektrolyse (PEM). Ein modulares Konzept ermöglicht dabei die Anpassung an unterschiedliche Rohwasserqualitäten und Standortbedingungen.

Booth 7D39

Omega Air: hydrogen purification in a container

With the H2 BOX, Omega Air is presenting a containerized complete system for hydrogen purification. It is intended for applications that permanently require consistent hydrogen quality.

The system continuously removes water vapor, oxygen and solid particles from the hydrogen stream. It can be integrated, among other things, into electrolyzer systems and, according to the company, is also suitable for fuel cells, hydrogen refueling stations as well as chemical and petrochemical processes. A DeOxo unit is optionally available, which is intended to reduce the oxygen content to below 5 ppm.

Booth 6J05

Marquardt and Murrelektronik: decentralized automation meets stack monitoring

The automation specialist Murrelektronik and the Marquardt Group, which comes from the automotive sector, are placing their new cooperation at the center. They are showing a joint approach to the automation and monitoring of modular hydrogen systems. The focus is on combining measurement and safety technology near the stack with decentralized distribution of energy, signals and data.

Marquardt is contributing components from its hydrogen and energy management portfolio for this: Cell Voltage Monitoring continuously monitors cell voltages and can thus make anomalies in the stack visible at an ►



20/21/22 OCT 2026

HAMBURG MESSE
GERMANY

Meet us at Stand 5D34



plating electronic
we care for power

Your Reliable Partner for Electrolyzer Power Supplies

From engineering and system design to commissioning and long-term service, we support your project throughout the entire lifecycle.

Reliable DC power supply solutions for electrolysis and Power-to-X applications.

- Technical expertise
- Engineering support
- Project execution
- Long-term service

DC Power Supplies for Electrolysis & Power-to-X

Learn more: info@plating-electronic.com • www.plating-electronic.com

Market

early stage. It is complemented by the Cell Voltage Pick-Up for contacting bipolar plates, a high-voltage sensor for current and voltage measurement, and an H₂ leakage sensor. The latter detects hydrogen concentrations from 0 to 4 percent by volume and is, according to the manufacturer, designed, among other things, for electrolysis plants.

Murrelektronik relies on the decentralized automation platform Vario-X. Control, sensor and actuator functions are integrated closer to the process, which is intended to reduce central control cabinet structures and wiring effort. For manufacturers of modular electrolyzers and for operators of growing plant fleets, this is relevant above all with regard to installation, scalability, commissioning and service.

The cooperation follows a co-creation approach: according to their own statements, both companies are working on interfaces, hardware and software integration, as well as on transferring experience from the automotive and industrial automation sectors to hydrogen applications. At the joint booth, it is intended to show how measurement data from the stack and the plant can be integrated into an end-to-end, scalable automation architecture.

Booths 6M40A and 6M40B



Festo: modular automation for hydrogen skids

In Hamburg, Festo is showing solutions for automating hydrogen plants in a modular and process-oriented way. The focus is on the CPX-AP-I remote I/O system. It integrates automation components such as the VTUG valve island, individual valves and sensors in a decentralized manner directly in the plant environment. This reduces wiring effort and control cabinet sizes for electrolyzers, gas purification stages such as PSA and skids. In addition, the company is presenting preconfigured system solutions with a focus on explosion protection and functional safety, in order to minimize interfaces during ramp-up to industrial scale.

Booth 6L40

WEH FluidTech: components for high-pressure systems

WEH FluidTech is expanding its hydrogen portfolio with new solutions for refueling, infrastructure and testing processes in the high-pressure range.

New at WEH is, for example, the TK200 H₂ fueling nozzle for refueling vehicles. It combines field-proven technology with greater ease of use and modern design. The single-handed nozzle with push-and-pull locking is designed for flow rates of up to 90 grams per second and is available in the H35, H35MF and H70 versions. For applications with particularly high hydrogen throughput of up to 300 grams per second, the new hydrogen high-flow fueling nozzle TK500 H70HF is added. The likewise new TW850-S50 and TW850-S60 H₂ quick adapters enable safe and fast connection of hydrogen containers.

Booth 6G55





ABOVE: Automation solutions from Festo © Festo

LEFT: Cooperation of Marquardt and Murrelektronik

© Murrelektronik

Research: innovations with practical impact

Research institutes are also showing innovations at the hydrogen trade fair. These involve technologies as well as service offerings.

ZBT: tests for PEM electrolyzers up to 40 kW

The Center for Fuel Cell Technology, ZBT (Zentrum für Brennstoffzellentechnik), has commissioned a new 40 kW test bench for PEM water electrolysis. Customers can use the institute's test benches, among other things, to investigate performance, efficiency, aging and degradation mechanisms.

PEM electrolysis stacks can be tested on the test bench with capacities of up to 40 kW and currents of up to 2,000 A. Long-term tests of up to 5,000 operating hours under application-oriented conditions are also planned.

Booth 5B40

Fraunhofer LBF (GreenMat4Hy): reality check for pipelines and plasma pyrolysis The Fraunhofer Institute for Structural Durability and System Reliability LBF in Darmstadt, part of the Fraunhofer Performance Center for Hydrogen in Hesse (GreenMat4Hy), is devoting itself to the retrofitting of existing gas networks.

Thin internal coatings are intended to reduce direct contact between hydrogen and steel, thus preventing the feared hydrogen embrittlement. Fraunhofer LBF is developing methods to evaluate the adhesion, durability and service life of these coatings under realistic loads, and to make better investment decisions. A section of pipeline can also be seen at the trade fair.

The Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS in Hanau is showing the model of a reactor for microwave-based plasma pyrolysis. The input materials can be, for example, plastic waste, oils or biogas. What is important is that hydrocarbons are present. With the help of the highly reactive microwave plasma, the substances are broken down without complex pretreatment. The result is hydrogen, synthesis gas and high-quality carbon. According to Fraunhofer, CO₂ is not produced in the process itself.

Booth 6B25

The big picture: systems, marketplace, practical projects

How the hydrogen technologies become a common ecosystem is shown in applications, platforms and practical projects. ➤

SPONSORED BY

HORIBA

TOYOTA



**10 - 11
NOV 2026
CHEMNITZ**



**REGISTER
NOW!**

**HYDROGEN TECHNOLOGIES.
EFFICIENTLY PRODUCED.**

The conference will feature over **60 high-level presentations!** Don't miss this opportunity to exchange ideas directly with leading international experts in the field!

The key topics for scientific submissions include:

- **H₂-production:** electrolyzers, components, balance-of-plant, materials, simulation models, test methods, production processes
- **H₂-storage and transport:** safety, mobile and stationary storage, distribution systems, logistics, hydrogen compression, refueling,
- **H₂-applications:** fuel cells, components, balance-of-plant, materials, vehicle drives, stationary applications, simulation models, test methods
- **Production and scaling:** automation, factory and process planning, production processes and systems, (series) manufacturing technologies

SCIENTIFIC PARTNERS



**MORE INFORMATION
WWW.FC3CHEMNITZ.DE**



**HYDROGEN
TECHNOLOGY
CLUSTER**





Tyczka: hydrogen producer presents its latest projects The hydrogen producer Tyczka covers the entire value chain from production through compression and filling, transport and logistics to filling and application technology. At the trade fair, Tyczka is focusing on three current projects.

In May 2026, Tyczka opened the Schweinfurt-Hafen hydrogen refueling station. It is intended to become the core of the Tyczka H2 hub. It has a capacity of 1,000 kilograms of hydrogen per day. In the fourth quarter of 2026, the commissioning of a 6 MW electrolysis plant is to follow at the same site. It is expected to be able to deliver about 600 metric tons of hydrogen per year. RFNBO certification is in preparation.

The 5 MW electrolysis in Hünfeld near Fulda has already been in operation since 2025. The plant in the logistics park on the A7 highway, with a capacity of 500 metric tons of hydrogen per year, was built by Abo Energy and taken over by Tyczka in August 2026. It has two trailer filling facilities with 200 and 300 bar as well as two dispensers for 350 bar. The electrolysis plant also has RFNBO certification.

Booth 6M48

EODev and Baudouin: SOFC power supply EODev and Baudouin want to jointly bring stationary power supply based on solid oxide fuel cells, or SOFCs for short, to the industrial market. Targeted applications are data centers, industrial sites and critical infrastructure. Each standard system is to deliver 600 kW; several units can be combined for applications in the multi-megawatt range. The SOFC systems are to be able to run on natural gas, renewable gases or hydrogen, and to deliver electricity and heat.

Booth 6G4

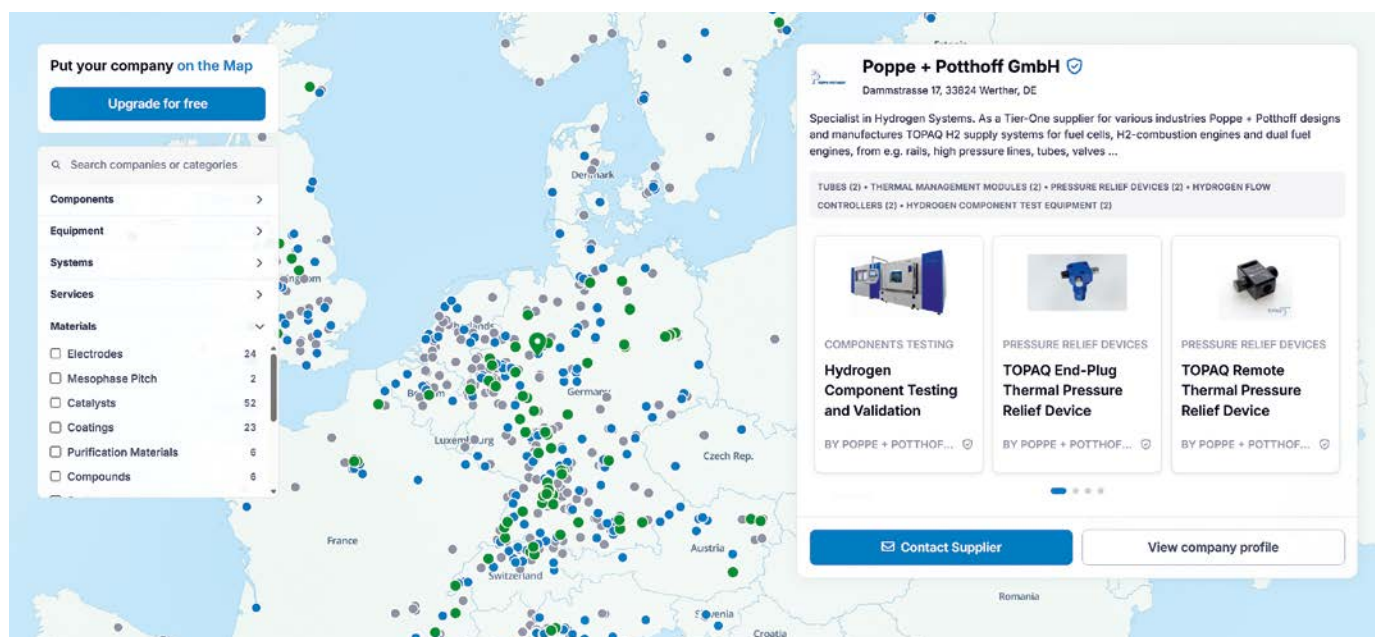
Hyfindr: world map of the hydrogen economy

The hydrogen B2B marketplace Hyfindr has developed a Hydrogen Supplier World Map. It shows more than 1,200 suppliers of hydrogen technologies, filterable and with detailed information on each supplier. From electrode materials to the complete hydrogen refueling station, everything can be searched for and found here. Registration on the map with a basic entry is free, as is its use. Those who want to query details about the companies, however, must create an account.

Booth 5E60

ABOVE: Tyczka electrolyzer construction site in Schweinfurt © Tyczka

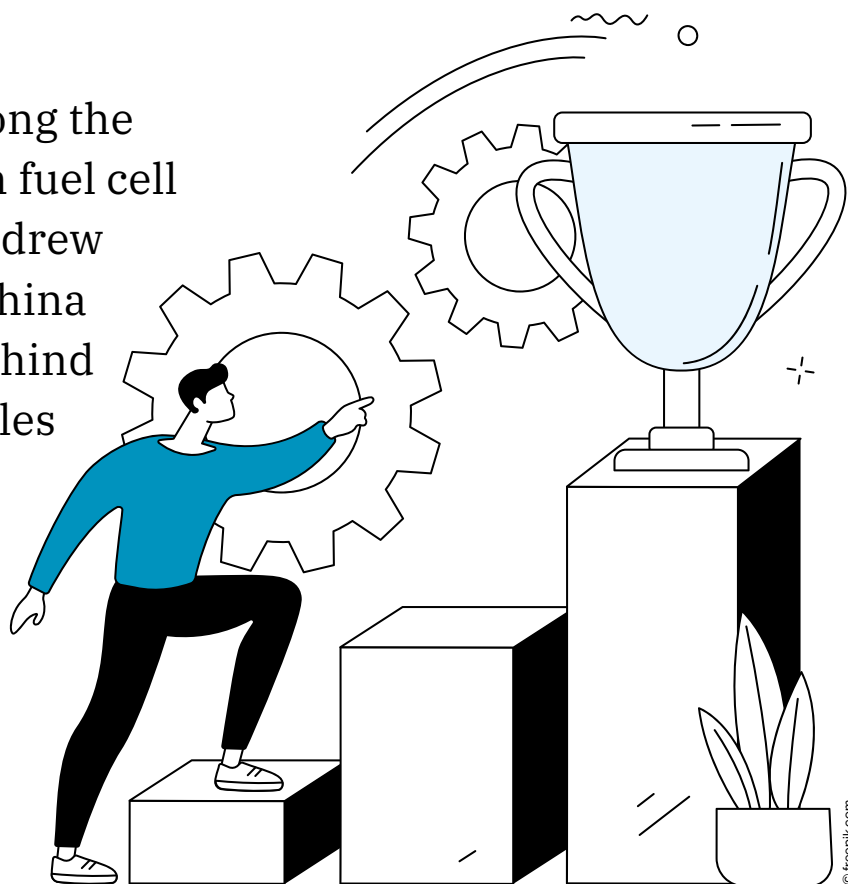
BELOW: World map of the hydrogen economy from Hyfindr © Hyfindr



The cost curve doesn't wait

Text: Werner Tillmetz

In 2003, Daimler was among the world leaders in hydrogen fuel cell technology, and then withdrew for twenty years. Today, China dominates the market. Behind this are economic principles that have been known for decades, explains our guest author Werner Tillmetz. The hydrogen sector should take careful note of them.



In 2003, Daimler was the world leader in hydrogen propulsion: 36 fuel cell city buses proved their everyday suitability over years, and the bus operators were highly satisfied. And then? Nothing.

The traditional bus manufacturers insisted on diesel. More than 20 years later, Daimler took a tentative step back into the market, with the hydrogen Citaro and a fuel cell from Toyota. Even though there was a series-ready product with comparable properties in-house.

While Germany hesitated, China acted: today, more than 7,000 fuel cell buses and 28,000 hydrogen commercial vehicles are in operation there. The green hydrogen required for this is produced in the sun- and wind-rich regions of Mongolia and transported via newly built pipelines to the country's industrial centers.

German truck manufacturers, meanwhile, have postponed their market entry to 2030. The question is why it keeps happening, and what the hydrogen sector can learn from it. What is behind this development?

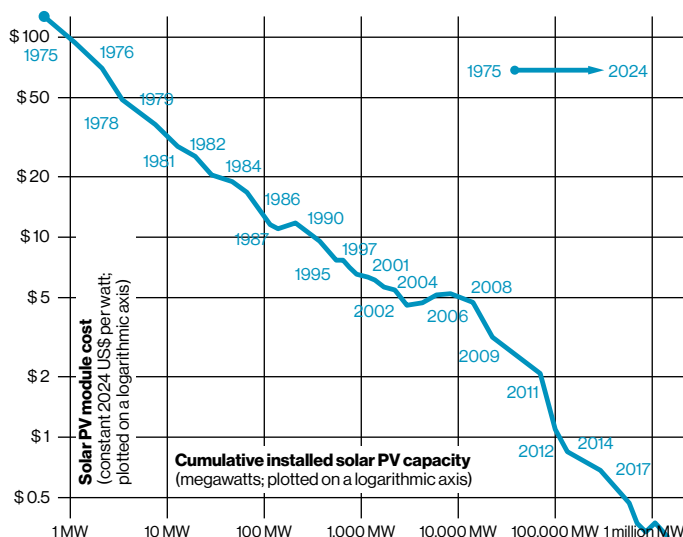
It is not due to the inability of the traditional corporations, and certainly not to their excellent engineers. Behind it are historically well investigated principles for which three economists received the Nobel Prize last year.

One half went to Joel Mokyr for the insight that technological innovation is a prerequisite for sustainable growth; the other half to Philippe Aghion and Peter Howitt for the development of a mathematical model of "creative destruction." This term, first coined by Joseph Schumpeter for macroeconomics, finds its counterpart at the micro level of companies and their market as "disruptive innovation."

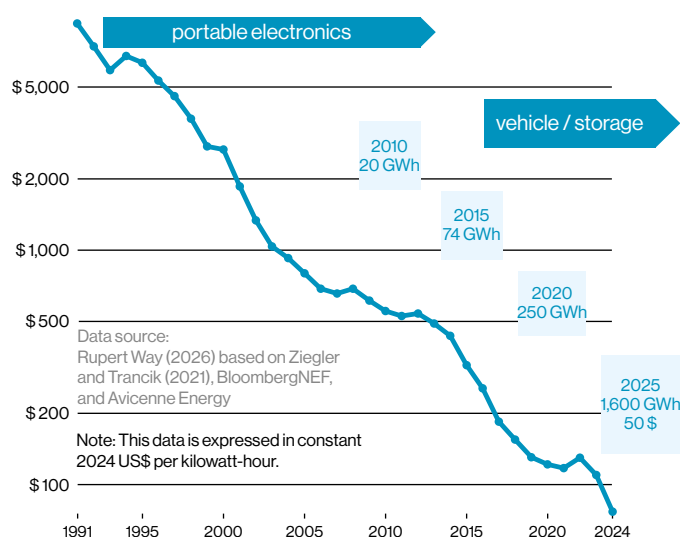
A pattern that has been repeating itself for 100 years Henry Ford and John D. Rockefeller once displaced horse-drawn carriages and their entire infrastructure, not through better horses, but through horseless carriages and a fundamentally different system. That is the essence of disruptive innovations: they replace not only a product, but the entire ecosystem.

Today, hydrogen, e-mobility, renewable energies and digitalization face the same task vis-à-vis the fossil vehicle and fuel industry. The pattern is known. Nevertheless, the consequences are regularly underestimated, also because disruptive innovations have an uncomfortable property: they cannot be planned and cannot be stopped by the established players.

Kodak co-invented digital photography, and yet went under. Digital ►



Costs for solar modules compared to cumulative installed capacity in US dollars, inflation-adjusted. © Our World in Data/NEONBOLD



Cost reduction for lithium-ion battery cells from 1991 to 2024.

© Our World in Data/NEONBOLD

cameras from Asia took over the market before Kodak could react. Then came Apple: the iPhone of 2007 made the digital camera obsolete within a few years. More than 100 million smartphones were hereinafter being produced monthly. Who would have thought that possible in 2005?

Wright's law also applies to fuel cells. Disruptive innovations do not follow chance, they follow laws. As early as 1936, aircraft engineer Theodore Paul Wright established: with every doubling of total production, the labor input decreases by 20 percent. "Wright's law" has since been considered the most reliable predictor of cost developments in new technologies.

For electrolyzers and fuel cells, this means: the cost curve will fall, quickly and inexorably. The decisive question is only who builds up the production volumes that set this process in motion.

The chicken-and-egg problem is real: to get from high costs with small quantities to low costs at large quantities, massive upfront investments are needed. Chinese companies have drawn this consequence. Despite temporary pressure on earnings, market advantages are created in this way that can hardly be caught up with later.

Added to this is the learning effect in operation: only in real customer use do weaknesses become visible. Those who are in the market early improve their products faster; a mechanism that Bruce Henderson described as the "experience curve." Those who wait do not learn.

Solar modules as a blueprint, and a warning The cost learning curve of photovoltaics is the most striking example of recent industrial history: 20 years ago, a solar module cost around 5 USD per watt. Today it is 0.10 USD. The efficiency rose in the same period from 15 to almost 25 percent. In 2024, 600 GW were newly installed worldwide.

Hydrogen technology will go through the same curve. The question is not whether, but who will benefit from it. Cheap PV electricity becoming a game changer for electrolysis is no longer speculation. In the sunniest regions on earth, large-scale plants already enable electricity prices of around 1 US cent per kWh, cheaper than any fossil alternative.

If one adds CO₂ taxes and the geopolitical risk costs of fossil energy imports, the calculation shifts further in favor of green hydrogen.

The frequently cited argument of supply interruption through fluctuating solar and wind energy also loses force: falling battery storage costs and dynamically operable electrolyzers, which convert surplus electricity directly into storable hydrogen, are increasingly closing this gap.

Vertical integration: whoever builds the entire system wins In the early phase of disruptive innovations, there is regularly a lack of reliable suppliers, standards and regulatory frameworks. Those who still want to scale quickly have to build the overall system themselves, or secure it through strategic cooperation.

Tesla has demonstrated this for e-vehicles. The result: a closed, scalable system consisting of the vehicle, its energy system and charging infrastructure. Through the traditional supplier industry, neither the desired product nor the necessary speed could have been achieved.

In battery manufacturing, too, Tesla built up its own competency and optimized route planning via internet-based services. Since then, the company has had a market lead that the established manufacturers have not yet fully caught up with. Early market entries namely bring about an advantage that is difficult to copy: learning effects from real customer use that flow into the next product generation.

With hydrogen, the same development is taking place, only faster and with even larger players. PV world market leader Longi is expanding battery storage and electrolyzers in order to position itself as an integrated system provider. Wind turbine market leader Goldwind is pursuing an analogous strategy. In this way, established champions of renewable energies are consistently diversifying into the hydrogen and e-methanol sector.

China is already today the world's largest methanol producer and a leader in green methanol; the technologies for producing e-gasoline from methanol are also available. Behind this strategy are two clear political drivers: first, the reduction of geopolitical dependence on oil producers; second, the positioning of China as a climate-friendly industrial nation.

Further examples: Toyota is planning a 3 GW electrolysis production to secure its own hydrogen supply. And BYD as well as CATL, originally a battery manufacturer, today dominate the global market for e-buses, e-cars and energy storage systems. The pattern is clear: whoever controls the overall system controls the market.

As long as the European commercial vehicle manufacturers could divide the market among themselves and reliably had their regular customers, little moved here. But since Chinese companies as well as Tesla, Toyota and Hyundai have been competing with the established players, things are changing.

At IAA Transportation in Hanover in September, Daimler presented, together with partners from vehicle construction, the energy industry and infrastructure, the plan for a scalable deployment of hydrogen trucks in Europe by 2030. Participating are Bosch, Daimler Truck, the Volvo Group, Toyota, Air Liquide, TotalEnergies, TEAL Mobility and MB Energy. According to the companies, the German ecosystem is thereby creating, for the first time in Europe, the conditions for a broad market ramp-up.

It is also worth mentioning that the autonomous truck will bring further radical changes: the short refueling times with hydrogen are an unbeatable advantage, since the drivers' rest periods for charging the batteries are eliminated.

97 percent of the fleet is still waiting Worldwide, more than 1.6 billion vehicles are on the road. E-vehicles account for around three percent of these, but are growing by over 30 percent annually, while the overall market, at around three percent, is almost stagnating.

In China, the world's largest vehicle market, the growth rates are even higher, driven by registration restrictions for combustion engines and low charging costs. BEV and EREV have reached cost parity with the combustion

engine. Fuel cell vehicles are following. Due to the many buses and commercial vehicles already operating in China, the cost curve is falling. Germany has 211 hydrogen commercial vehicles and around 630 hydrogen buses. The pace has to change.

How dynamic disruptive markets can be is shown by Xiaomi: the smartphone manufacturer entered the market for electric sports cars and sold approx. 500,000 vehicles within two years. No established automobile manufacturer would have thought that possible.

China is pushing the cost curve downward through its huge domestic market, and subsequently exports the new technologies all over the world. Unlike Western corporations, Chinese market participants deliberately forego high short-term returns.

For the export-oriented German vehicle manufacturers, this is an existential threat. The massive job cuts in the German vehicle industry are not a cyclical dip, they are the direct consequence of a global disruptive innovation.

And yet: 97 percent of the global vehicle fleet still have to be replaced. The transformation has only just begun.

Hydrogen as the backbone of the future energy supply

Electricity from sun and wind is already cheaper in the earth's desert regions than fossil electricity. The catch: it is produced far away from the major industrial centers, and its generation fluctuates.

Hydrogen and e-fuels solve both problems at the same time: they transport energy over long distances and store it over long periods.

While China is building new hydrogen pipelines, Europe is converting its existing natural gas network to hydrogen, one of the most important infrastructure decisions for the energy security of the coming decades.

With electrolyzers as well, China has taken the lead: 4 GW of production capacity are already in operation. The government-supported industry association China Hydrogen Alliance has set itself the goal of expanding production capacity to 100 GW by 2030.

By then, the European Union wants to have reached 120 GW (REPowerEU); of which 10 GW are planned for Germany. However, these ambitious targets are stalling due to slower approval procedures and high investment costs.

The principles of disruptive innovation are known. The learning curves are calculable. What is missing is pace.

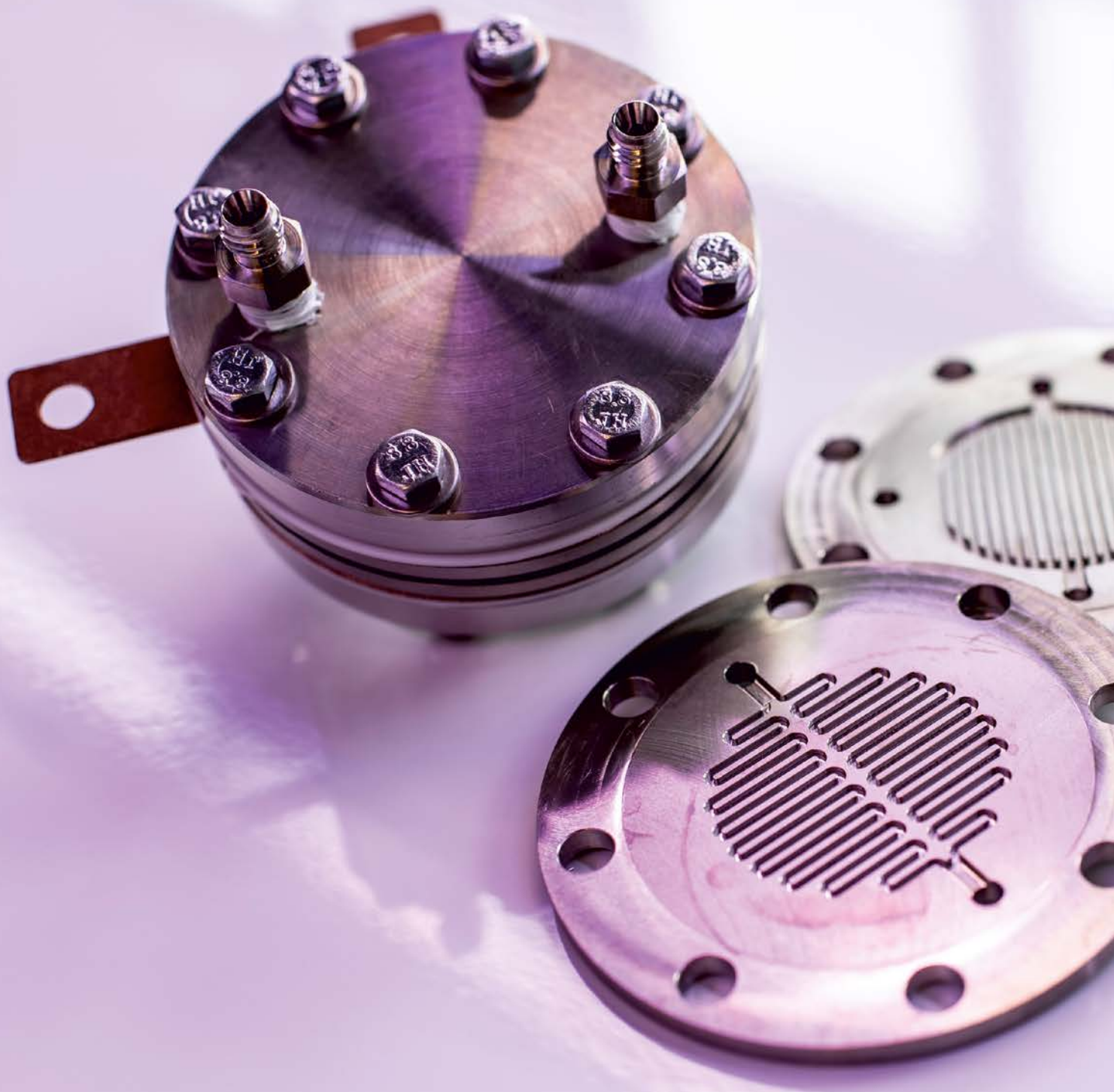
Whoever invests, scales and learns now will shape the hydrogen economy of tomorrow. Whoever waits will, like Daimler in the year 2003, eventually enter again a market dominated by technology that others have long since built up. ○



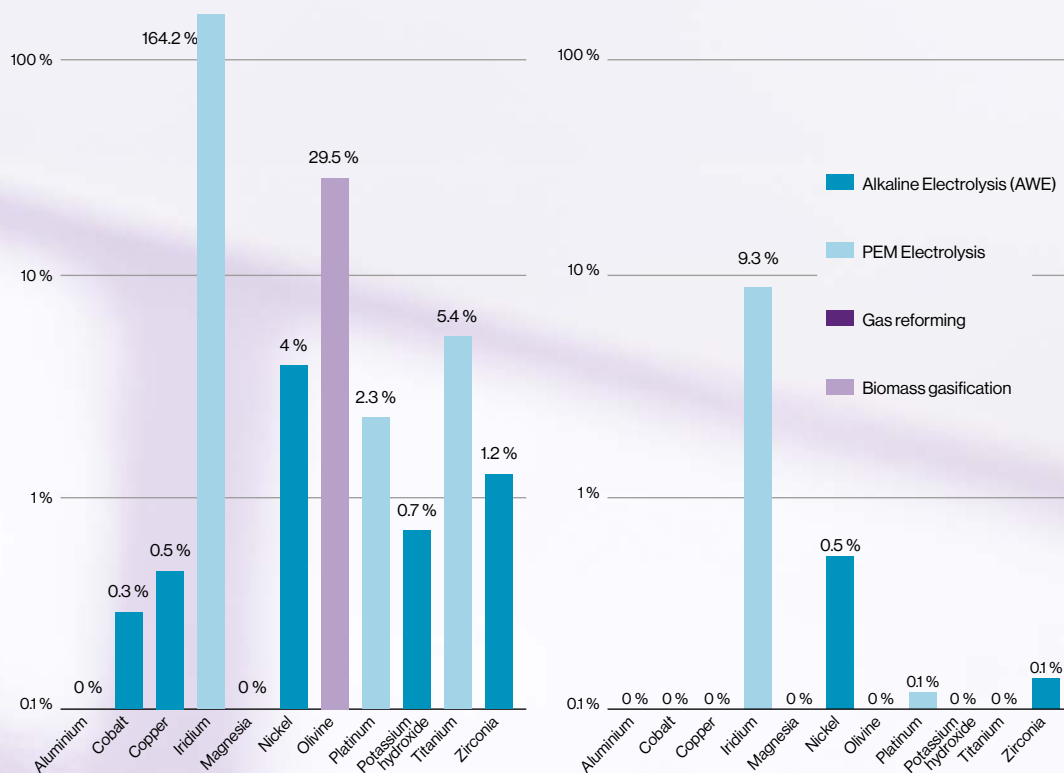
PROF. DR. WERNER TILLMETZ worked in the automotive and chemical industry for 20 years. At Daimler-Benz and Ballard Power Systems, he headed fuel cell development for vehicles until 2002. The electrochemist, who holds a doctorate, taught at the University of Ulm from 2004 to 2018 and was a member of numerous bodies, such as the National Platform for Electric Mobility and the German Federal Government's National Organisation Hydrogen and Fuel Cell Technology (NOW). To this day, he is a member of, among others, the Science Council of TotalEnergies (Paris) and the Advisory Council of Emerald Technology Ventures (Zurich).

Iridium shortage looms

Text: Niels Hendrik Petersen



Rare metals are indispensable for the expansion of electrolysis and fuel cells. Iridium in particular is considered critical: by 2045, demand could rise to twelve times current mine production. Recycling and circular concepts are intended to boost the supply of these scarce raw materials.



Iridium, platinum, titanium and nickel are essential to achieving the expansion targets for electrolysis capacity and fuel cells. Supply bottlenecks for these materials are thus developing into the Achilles' heel of a successful energy transition in Germany and all of Europe. Model calculations for net-zero emissions scenarios identify iridium in particular as the most critical raw material for the European hydrogen industry. The chemical element has the atomic number 77 and belongs to the group of platinum metals. Annual demand in 2050 could amount to up to 164.2 percent of today's worldwide mine production. In the best-case scenario with technological improvements, annual iridium demand is reduced to 9.6 percent.

Annual demand for nickel, platinum and titanium is projected to be below today's global mine production for the year 2050. "In addition to annual raw material demand, however, cumulative resource consumption is especially decisive," emphasizes Professor Ulf-Peter Apfel, head of the Power-to-Chemicals department at Fraunhofer Umsicht. By 2054, the expansion of PEM electrolyzers in Europe alone is projected to lay claim to around 9.3 percent of estimated global iridium resources. Nickel accounts for 0.5 percent and platinum for 0.1 percent of global resources (see graphics p. 29).

Iridium is one of the rarest elements "Estimates suggest that only around 2,000 metric tons of iridium exist worldwide in total," Professor Apfel reports. For comparison: for nickel, the figure is 130 million metric tons. Iridium, he explains, is currently extracted almost exclu-

sively as a by-product of platinum mining and is thus directly coupled to its production volume. At current platinum prices, mining is not economically viable and mines are already being operated at a loss. Supply bottlenecks up to and including structural supply shortages are therefore considered likely for iridium; but there is also a risk of future bottlenecks for platinum in the overall system.

In particular with a view to an expansion of PEM electrolysis capacity for the production of green hydrogen, it is assumed that demand for iridium will reach up to 1,250 percent of 2023 mine production by 2045. This is the conclusion of the study Raw Materials for Future Technologies 2026 (Rohstoffe für Zukunftstechnologien 2026), commissioned by the German Mineral Resources Agency (Deutsche Rohstoffagentur). Intensive efforts are therefore required to use PEM electrolyzers for as long as possible and to efficiently recycle the raw materials they contain in order to avoid supply bottlenecks.

Among the raw materials, nickel and zirconium are particularly critical in alkaline electrolysis. In PEM fuel cells it is mainly platinum, and in PEM electrolysis titanium is added in addition to iridium. In solid oxide electrolyzers and fuel cells, nickel, zirconium, strontium and the rare earths yttrium and lanthanum are especially critical.

Which components are recovered? Since PEM technology has the highest level of maturity, the first industrial recycling processes are emerging for this technology. "Recycling fo- ➤

RIGHT: (a) Expected annual material consumption in 2050 (b) Expected cumulative material consumption in the period 2015–2054. Figures relative to global production in 2021.

© Fraunhofer UMSICHT / NEONBOLD

LEFT: A PEM test cell for screening different membrane electrode assemblies (MEAs) at laboratory scale for novel catalysts.

© Fraunhofer UMSICHT, Mike Henning
(background extended with generative AI)

Market

cuses on the most valuable stack components. In the case of PEM electrolysis, around 48 percent of stack costs are attributable to the precious metal catalysts iridium and platinum, while titanium accounts for 32 percent of the costs,” Apfel explains.

Industrial recyclers such as Heraeus Precious Metals and Umicore already accept complete stacks, membrane electrode assemblies (MEAs) and production waste for precious metal recovery. Heraeus offers a hydrometallurgical process in which platinum, iridium, ruthenium and palladium are chemically dissolved and subsequently separated from one another and refined into high-purity precious metals. Umicore relies on the recycling of fuel cell stacks using pyrometallurgy. In this process, the components containing precious metals are melted down and subsequently refined.

Why isn't more being recycled? There are currently several challenges that stand in the way of efficient recycling. “A fundamental problem is that stacks have so far been designed primarily for performance and efficiency and not for easy disassembly and recyclability,” says Dr. Kevinjeorjios Pellumbi, senior scientist at Fraunhofer Umsicht. As a result, the disassembly of the compressed stack structures is particularly complex; numerous individual cells, seals, bipolar plates and MEAs have to be separated.

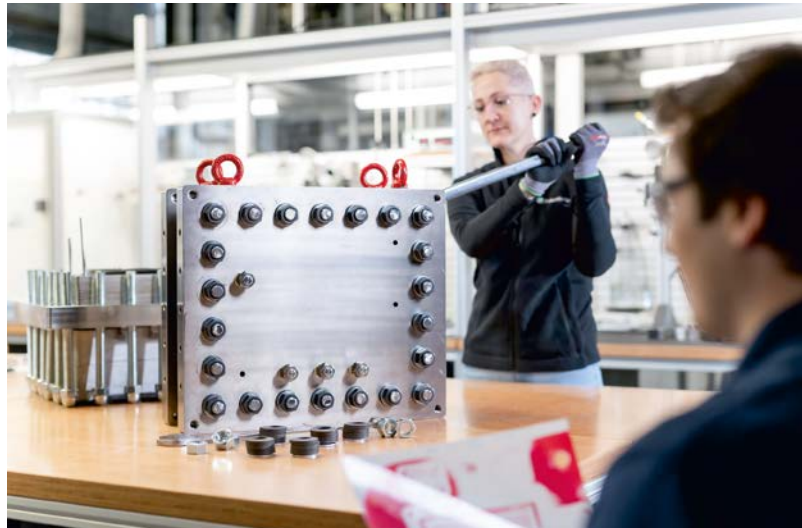
“Corrosion and deposits caused by operation additionally complicate low-damage disassembly,” the scientist illustrates. In addition, the composite material of the MEA represents a central challenge. In the case of PEM electrolysis, for example, iridium and platinum catalysts are firmly bonded to the Nafion membrane. That is a problem. Hydrometallurgical and pyrometallurgical processes are designed to recover the precious metals and destroy the Nafion membrane. They are also energy- and chemical-intensive, and thus disadvantageous from an environmental perspective.

Fluorine in particular, as a component of PEM fuel cells and electrolyzers, is problematic in terms of health and ecology, Pellumbi explains. A gentler separation while preserving the membrane would therefore be desirable, but this requires additional technical developments. “Ultimately, current precious metal recovery is predominantly raw material recycling, i.e., the stack is first chemically or thermally broken down and the precious metals are then refined in a manner similar to how they are refined from an ore.” A direct return into new catalysts, and thus true closed-loop recycling, is therefore not provided.

Recycling streams mostly from waste The hydrogen industry has thus not yet reached the end-of-life point. According to Pellumbi, the

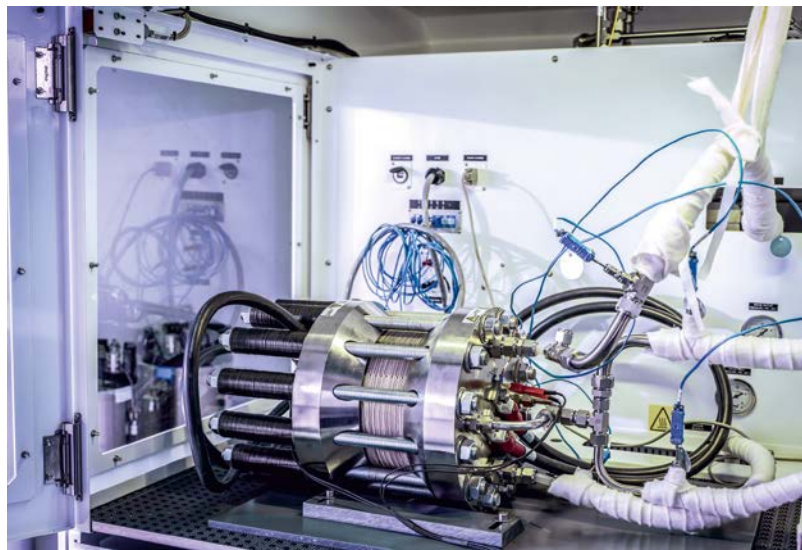
systems are still in operation or are only now being developed and scaled up. Today's recycling streams therefore come predominantly from production waste, reject parts and defective stacks. If these are not fed into industrial processes for the recovery of the precious metals, they can instead be used as starting materials for research projects investigating future circular concepts.

A cornerstone for the build-up of the German hydrogen industry was laid by the hydrogen lead projects of the German Federal Ministry of Education and Research (BMBF). With the recycling project ReNaRe, questions of recyclability were already addressed in H2Giga. Current research projects, in which Fraunhofer Umsicht is also involved, place a clear focus on recycling and circularity: CircuPEM is developing a holistic concept for circular product and process design in PEM electrolysis, while RoboCircEL is implementing automated disassembly and chemical recycling of end-of-life PEM electrolyzers.



TOP: Final assembly of an electrolysis stack at Fraunhofer Umsicht.

© Fraunhofer UMSICHT, Mike Henning



BOTTOM: A 10 kW PEM electrolyzer on the test stand at Fraunhofer UMSICHT for conducting stress tests and further processing in the recycling loop.

© Fraunhofer UMSICHT

The goal of RoboCircEL is the complete circularity of the materials from end-of-life PEM electrolysis stacks. For this purpose, tailored recycling methods are specifically adapted to different degradation states of the stacks, and chemical separation processes with solvents that are as mild and environmentally compatible as possible are investigated. Aggressive acids or thermal decomposition are to be avoided as far as possible in order to reduce environmental impact and to recover, in addition to the precious metals, further materials such as the membrane.

PEM Circle works with digital twin At least intensive work is already being done on the topic of recycling. In March 2026, the partners came together for the launch of the research project PEM Circle at the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) in Stuttgart. The project is funded by the German Federal Ministry of Research, Technology and Space (Bundesministerium für Forschung, Technologie und Raumfahrt, BMFTR). Together with the German Aerospace Center (DLR), the aim is to develop digital solutions in order to use PEM electrolysis stacks more circularly over their entire life cycle, from repair through remanufacturing to recycling. In terms of content, component-specific sensor technology, a forecasting tool for remaining service life and digital twins are combined with ecological and economic assessment approaches. The researchers aim to enable data-based decisions for the circular economy and thus to keep critical raw materials such as iridium and platinum in the loop. The old adage applies: better to have iridium, platinum, titanium and nickel than to need them. The final report of PEM Circle is expected in early 2029.

Disassembly processes mostly manual At present, there are only a few electrolyzers slated for recycling, Dr. Ludwig Jörissen, head of fuel cell research at the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) in Ulm, also knows. In addition, the design variants are still very diverse. "Accordingly, disassembly processes and the separation of composites are predominantly characterized by manual labor and are correspondingly time-consuming."

A general answer to the question of what happens to used electrolyzers today is hardly possible. "High-quality components such as precious metals or metallic structural materials can be fed into the regular recycling processes after disassembly. Polymers are generally thermally utilized," the ZSW researcher explains.

In addition to the purely thermal utilization of plastic waste from the electrolysis industry, for example cell frames from the electroly-

sis stacks, processes for raw material recycling are also under development. One example is the research project CarbonCycle, funded by the German Federal Ministry of Economic Affairs and Energy (BMWE), in which ZSW is developing a pyrolysis process together with industry partners, with which it will be possible in the future to convert plastic waste into high-quality carbon materials that can be used, for example, in the production of lithium-ion or sodium-ion batteries. Jörissen: "In this way, import dependencies, for example on graphite from China, can also be reduced." That would at least mean one less Achilles' heel. ○



PEM Circle kick-off: project partners pool competencies for circular PEM electrolysis stacks. © PEM Circle

Raw material demand for electrolysis and stationary fuel cells could exceed global production of individual metals many times over by 2045. This is shown by an updated study of the German Mineral Resources Agency (DERA). Particularly affected: iridium, scandium and platinum.

Stuttgart pushes ahead

Text: Leonhard Fromm



Despite tight municipal finances and rising costs, Stuttgart is sticking with its Green Hydrogen Hub. Starting in 2028, three electrolyzers are set to deliver 900 metric tons of hydrogen per year.

The Green Hydrogen Hub in Stuttgart is set to be ready for deliveries starting in 2028, according to Peter Drausnigg, technical managing director of the municipal utility (Stadtwerke) of Baden-Württemberg's state capital, founded in 2011. He apparently felt compelled to make this commitment in mid-September because investments in the project have more than doubled to 75 million euros since planning began, while the City of Stuttgart has been fighting for every cent since trade tax revenues collapsed dramatically.

From 2022 to 2026, the municipal utility, which is responsible for roughly a quarter of Stuttgart's planned CO2 emission reductions, is to invest around one billion euros in climate protection projects. The city originally wanted to contribute 300 million from its budget as additional equity. 100 million flowed in right in 2022. As recently as 2024, the city reaffirmed its willingness to contribute the remaining 200 million. "Partnerships are important now in or-

der to maintain momentum," Drausnigg says. There are also subsidies from the federal and state governments, although their amount is not yet clear.

Behind the Stuttgart H2 project, in which green hydrogen is produced and distributed via a four-kilometer pipeline, stand the federal and state governments as well as the EU, the Stuttgart Regional Association (Verband Region Stuttgart) and additional consortium partners from science and research.

Drausnigg attributes the eighteen-month delay in implementation to a change in legislation. In addition, the project has grown with a third electrolyzer to nine megawatts of installed capacity and an annual capacity of 900 metric tons of H2, and has thus been scaled up at greater cost. The plant is scheduled to enter trial operation at the end of 2027. The technical managing director: "We are building this plant, delivering green hydrogen from 2028, and developing a customer base for it."

LEFT: Installation of a low-pressure storage tank at the hydrogen hub in Stuttgart.

© Stadtwerke Stuttgart

BELOW: Laying of the hydrogen pipeline at the Stuttgart port.

© Stadtwerke Stuttgart

More hydrogen buses planned Specifically, this customer base is above all the Stuttgarter Straßenbahnen AG (SSB), which operates the majority of local public transport in Stuttgart and most of the bus lines. It currently has 15 hydrogen buses in operation. This fleet is being systematically expanded, Drausnigg says. For comparison: in Cologne, 160 buses already run on H₂ in regional passenger transport. “And with the pipeline, we have the option of also supplying industry and the Neckar port with green hydrogen,” says the head of the municipal utility. What he needs now, he says, are clear framework conditions and fewer bureaucratic obstacles. That applies within the city administration, but also at the higher levels.

For competitive reasons, he does not name prices and says nothing about the pricing calculation. Since 2011, the city has invested 447 million euros in its municipal utility, which exclusively sells green electricity, for which its own generation facilities are gradually being built. The SWS also sells natural gas and, through “Stuttgart Netze,” jointly with EnBW operates the inner-city electricity and gas network. The municipal subsidiary is also setting up more and more charging stations for e-mobility in public spaces, has recently been organizing twelve heating networks, and is building up the H₂ infrastructure.

Flagship Daimler Truck Companies in and around Stuttgart are also continuing to bank on hydrogen. Daimler Truck, headquartered in Leinfelden-Echterdingen near Stuttgart, recently announced that it will invest several hundred million euros in hydrogen trucks by the end of the decade. Karin Radström, CEO of the DAX-listed group: “We have invested a lot in battery-electric vehicles, but now in the next step we are putting a great deal of money into helping hydrogen succeed.”

While several competitors are withdrawing from H₂ drivetrains and focusing solely on battery-electric drives, Daimler Truck is deliberately pursuing a dual strategy in order to actually achieve decarbonization in logis-

tics. Radström: “Hydrogen is definitely part of the solution in truck transport across Europe.” This applies to high payloads and ranges, shorter refueling times, and a long-term limited electricity infrastructure. To this end, Daimler Truck is working together with corporations from the logistics sector.

Stuttgart’s small and medium-sized enterprises (Mittelstand) are also showing motivation to participate in building up the H₂ infrastructure. In nearby Ebersbach/Fils, the waste management company ETG from Göppingen has been working for nearly two years with the Augsburg-based start-up Green Hydrogen Technology (GHT). In a pilot plant, different types of waste that cannot be recycled as materials are converted into H₂ and liquid CO₂. Until now, these have been “thermally utilized,” that is, incinerated in waste-to-energy plants or in the cement industry in order to at least make use of the released energy.

The central point of the process: the material, ranging from contaminated wood residues and plastic shreds to sewage sludge, is not incinerated but gasified at 1,200 degrees under oxygen deficiency. In the process, the substances break down into smaller molecules, which are then separated. GHT managing director Robert Nave previously gained experience at two similar plants in Germany, one of which is twenty times larger than the one in Stuttgart.

The owner-operated Göppingen recycling company DU, which includes ETG and is always on the lookout for new business models, immediately showed interest in the process, GHT managing director Robert Nave reports. The district and the Stuttgart Regional Association (Verband Region Stuttgart) also came on board and took a risk with their funding. Currently, the Stuttgart plant, which has already proven itself, is being optimized to simplify the workflow, says Nave.

The plant is designed for 1,000 metric tons of residual waste per year. Oxygen and steam are fed into the process. In the end, around 100 metric tons of H₂ and 1,200 metric tons of CO₂ are produced. Cooperation partners for the offtake of the hydrogen are the H₂ fleet operator Hylane and the fueling station operator GP Joule. Nave puts the production costs at 1.50 euros per kilogram of hydrogen.

The liquid CO₂ is partly used by industry, according to GHT. It can be carbonated in mineral recyclate, as the company Feess in nearby Kirchheim/Teck has been doing for a good two years. In this way, the construction waste recycler produces tradable CO₂ certificates with which money can be earned. From the residual waste in Ebersbach, depending on the fraction processed, one to five percent of the original volume remains as ash. Problem materials are turned into valuable materials that flow back into industrial processes. ○



Shipping navigates climate targets, crises and new fuels

Text: Monika Rößiger

The industry has to reduce its emissions, safeguard supply chains and infrastructure against disruptions and at the same time withstand growing competition from Asian shipyards. The role that hydrogen can play in this was shown at the leading international trade fair for the shipping industry in Hamburg, SMM 2026.

In the new “Naval Hall B8,” naval officers from all over the world are on the move. Several rows of colored ribbon bars adorn their uniforms, and the rank insignia allow even laypeople to sense that there are high-ranking officers among them. They view exhibits on sensor technology and unmanned systems or models of submarines with fuel cell propulsion. Here, hydrogen is not only a vision of the future, but already a reality.

A few halls further on, the question is whether hydrogen is also suitable for ships that have to remain at sea for days on end. As part of the European project NavHyS, work is being carried out on a concept for Service Operation Vessels (SOV) that supply offshore wind farms. Their fuel is to be liquid hydrogen, stored in tanks below deck.

This is still a development project. But it shows how concrete the search for climate-friendly propulsion systems has now become, and which technical and safety-related questions have to be solved in the process.

“Decarbonization, digitalization, safety and resilience” would have to be considered together, summed up Claus Ulrich Selbach, Vice President Exhibitions Maritime & Energy at Hamburg Messe und Congress, who was pleased with this year’s “record attendance.” More than 50,000 visitors from 134 countries attended the SMM, which takes place every two years in Hamburg, and around 2,300 exhibitors were represented.



A large ship's propeller as the landmark of SMM 2026 flanks the entrance to the Hamburg exhibition halls. © Monika Rößiger



Lively exchange and international interest are characteristic of the leading international trade fair of the maritime industry. © Monika Rößiger

With today's propulsion systems, decarbonization begins with a reduction in energy consumption. Because every fuel that is not needed does not have to be produced, stored on board or bunkered.

Efficiency plus hydrogen The technology is ready, says Uwe Lauber, CEO of engine manufacturer Everllence. "What we need now is a credible IMO framework for net-zero emissions, which creates investment security and rewards decarbonization. Every delay favors fossil fuels over climate-neutral alternatives. The gap is no longer technological, but political", says Uwe Lauber.

The "Energy Efficiency Hub" in Hall A2 and the "Energy Efficiency Stage" in Hall A4 focused on alternative propulsion systems, green fuels, hybrid solutions, onboard carbon capture and digital optimization of energy consumption. Under the motto "Efficiency First: Powering the Future of Shipping," manufacturers presented technologies with which emissions can be reduced.

But although there is hardly any way around energy efficiency in the short term, the message of the trade fair is clear: in the medium and long term, shipping needs climate-neutral fuels in order to ensure operation also in the high performance range.

Rocket science for ships This is where liquid hydrogen comes into play, as does the NavHyS (Naval Hydrogen Systems) project, which was also presented in Hall A2. While gaseous hydrogen is considered a practicable option for short distances and inland shipping, for longer ranges the higher volumetric energy density of liquid hydrogen (LH2) is needed, for example in Service Operation Vessels. These are

ships that supply offshore wind farms in operating cycles of up to ten days.

Since liquid hydrogen has to be stored in special tank systems at minus 253 degrees Celsius, one of NavHyS's goals is to develop such systems for shipping. These are below-deck tanks with a capacity of 200 to 300 cubic meters and a storage capacity of 12 to 18 tons of liquid hydrogen. The fuel is to be bunkered in less than two hours.

Behind the project is a European consortium of 13 partners, including ArianeGroup, North Star Shipping, Vard Design, Engie, Bureau Veritas and the Maritime Cluster Northern Germany (Maritime Cluster Norddeutschland, MCN). Their common goal is to develop an approvable design concept for the use of liquid hydrogen (LH2) as ship propulsion. The aim is to obtain approval by a classification society by the end of 2027.

The technology of NavHyS Key components of the NavHyS concept include specialized liquid hydrogen pressure pumps and a coaxial coupling for connecting and disconnecting during bunkering. Such a connecting element for transferring cryogenic hydrogen was originally developed for the FIA World Endurance Championship. Now it is to be adapted for maritime applications.

With the help of the tube-in-tube principle of the coaxial coupling, two separate flow paths can be combined in a single interface of the connecting element. The cryogenic hydrogen flows into the tank via the inner channel, while the evaporating gas (boil-off) that is produced is returned via the outer channel. This keeps the pressure in the tank stable during refueling. In addition, it is ensured that no hydrogen escapes into the environment. ▶



Mobility

Space industry expertise Unsurprisingly, the greatest expertise in handling liquid hydrogen lies with the space industry. It is therefore no coincidence that the French-German ArianeGroup, a joint venture between Airbus and the French engine manufacturer Safran, is involved in this project.

“For liquid hydrogen handling and management, ArianeGroup’s experience is of great benefit,” said Elisabeth Loeffelholz, program manager for hydrogen at ArianeGroup. “ArianeGroup has decades of experience in hydrogen mobility and is a pioneer in the application of liquid hydrogen in Europe.”

The project connects European companies and research institutions along the entire value chain, from tank and ship design through safety issues to classification. It is funded with five million euros by the European Commission; the project executing agency is the Clean Hydrogen Partnership. It started in January 2025 and runs for 36 months.

Maritime industry as part of the energy transition The “Offshore Dialogue” additionally focused on renewable energies at sea and the future use of the oceans. The maritime industry thus sees itself not only as a consumer of new energy sources, but also as part of the infrastructure of the energy transition, for example in the construction and operation of offshore wind farms and converter platforms.

This priority was underlined by DNV, the classification society and main sponsor of SMM 2026, in its “Maritime Forecast to 2050” published at the trade fair. According to this, in all conceivable regulatory scenarios, energy efficiency remains the decisive lever for immediately reducing fuel consumption and emissions.

According to DNV, with stricter global rules on energy efficiency, the fleet’s energy demand could be up to 25 percent lower by 2050 than with regulation primarily managed on a regional basis. Fleet renewal, hydrodynamic retrofits, optimized routes and digital operational management can thus buy time and limit the costs of the green fuels needed later.

At the same time, the demand for low-greenhouse-gas fuels depends significantly on the political course. For the year 2030, DNV calculates, depending on the scenario, a demand of between four and 22 million tons of oil equivalent (Mtoe). By the year 2050, the range extends from 33 to 185 Mtoe. (According to IEA conversion, 1 Mtoe corresponds to 11.63 terawatt hours.)

These figures illustrate the challenge: the market for climate-friendly fuels does not emerge solely through technical feasibility, but also through binding demand, production facilities, transport chains and bunkering infrastructure.



ABOVE: Bustling activity at SMM 2026, this time with record attendance. © Monika Röbiger

BELOW: On the last day of the trade fair, one more farewell photo at the ship's propeller at the exit. © Monika Röbiger



For this reason, LNG is likely to play a role for ocean-going vessels for a long time to come, Nils Merkens told H2international. He is technical director at the engineering and consulting company Marine Service in Hamburg, which has specialized in alternative fuels such as hydrogen, LNG (including bio-LNG), methanol, ammonia and synthetic methane.

“LNG is already available as a fossil energy source, as are applications of bio-LNG and synthetic LNG, which, with the already existing infrastructure, enables the transition to green LNG.”

Transition to dual fuel But a transition to further H2 derivatives such as ammonia or methanol is, according to Merkens, also already taking place in new builds: “However, less frequently and always as part of dual-fuel solutions in combination with distillate fuels (diesel), as is also the case with most LNG propulsion systems.”

In new builds, there are also increasingly ships with LNG systems that are prepared for later (partial) use with H2 derivatives as a dual-fuel solution. One example of this are LNG systems whose tanks and transfer systems are designed for later operation with methanol (“methanol-ready”). Combinations with ammonia are also in preparation.

With a service life of 20 to 30 years, before making an investment decision, shipowners have to consider carefully “which energy source will even be available at what cost in their future operating area – costs that ultimately have to be borne by the cargo market,” according to Merkens.

“A consistent step would be ‘all-electric ships’ that dispense with combustion engines,” says Merkens. “Then hydrogen or H2 derivatives would be used in fuel cells for electricity generation and direct current motors would propel the ships. In this way, a more efficient conversion of energy for propulsion and onboard supply would be possible, which could also be used in hybrid solutions together with batteries.”

However, such systems are not yet available to a sufficient extent for larger ships, since correspondingly high-performance fuel cell systems with maritime certification are not yet ready for the market.

Safety first However, hydrogen is not only a question of propulsion systems and fuels. The safe handling of hydrogen in daily operations must also be learned. In May 2026, DNV published a guideline on competency requirements for the use of hydrogen as a ship fuel with the “Recommended Practice DNV-RP-0703.” The recommendation is aimed at crews, inspectors and technical personnel, both on board and on land.

The background is the specific risks: possible leaks, the low ignition energy of hy-

drogen, and the requirements for high-pressure or cryogenic storage systems. According to DNV, this requires not only technical barriers and safe ship concepts, but also training, emergency procedures and a strong safety culture. The guideline supplements existing DNV regulations for LNG, ammonia and methanol.

Flexibility as a strategic imperative For shipping companies, it will therefore be crucial to develop fleet strategies that take several future paths into account. “Ships that are commissioned today will be in service well beyond the year 2050.”

This is how Cristina Saenz de Santa Maria, CEO Maritime at DNV, described the dilemma in which shipowners currently find themselves. A quite comparable situation to that in the aviation industry. “The regulatory requirements are developing faster than the fuels, infrastructures and technological systems required for them.”

Shipping companies therefore need strategies that offer advantages already today and at the same time remain flexible with regard to a variety of regulatory and market-related developments. Without hydrogen, ammonia or methanol, the maritime energy transition will hardly succeed. This also became clear at SMM 2026, because these energy sources are already the subject of concrete ship designs, safety standards and investment decisions.

There was at least some progress in regulation soon after the trade fair: the cross-border initiative Rhine Hydrogen Integration Network of Excellence (RH2INE) received an in principle approval from Lloyd’s Register for the standardized design of exchangeable 380 bar hydrogen containers. ○

NEW PROPULSION SYSTEMS, MISSING FILLING STATIONS

Worldwide, 973 seagoing vessels are currently operated with LNG as an energy source, with 629 further units under construction. These are almost always dual-fuel ships that can also use distillate fuels. 134 seagoing vessels are currently operated with methanol, with 134 further units under construction. 13 seagoing vessels currently have the capability to be operated with ammonia, and six further ones are under construction.

By comparison: in 73 ports worldwide, LNG can be obtained directly for the energy supply of ships. For methanol, there are currently only five ports that offer direct supply of methanol in the port. Direct supply with ammonia as a ship fuel is currently not available in any port in the world.

Source: “Society for Gas as a Marine Fuel” (SGMF), as of August 2026.

Trust is good, control is better

Text: Dr. Jens Peter Meyer

Numerous parameters must be continuously monitored in electrolyzers. Sensor manufacturers have to adapt to many specific customer requirements. But one concern is common to all of them: the sensor technology should not cost too much.

Manufacturers of electrolyzers are still working to optimize their systems for hydrogen production. Efficiencies are to go up, costs down. This also changes the operating parameters and creates new challenges for the sensor technology used to monitor electrolysis.

An important process parameter is the fill level in the liquid circuit. Monitoring it prevents the system from running dry. "Fill levels that are too low can promote gas intermixing, which represents a safety risk," says Nils Springmann, sales engineer at the sensor manufacturer Vega. "Fill levels that are too high can cause electrolyte to enter the gas lines and damage downstream components."

Vega offers sensors for fill level measurement in a wide variety of electrolysis processes, including PEM, alkaline, AEM and SOEC electrolysis. For fill level measurement, the company relies on the physical principle of radar. This can be implemented in two different ways. In guided radar measurement, the microwave generated by the radar sensor is guided along a cable or rod to the medium. There it is reflected and received again by the sensor. The distance to the medium surface, and thus the fill level, can be determined from the signal's transit time.

PFA coating protects against potassium hydroxide solution In aggressive media such as potassium hydroxide solution (KOH), measuring



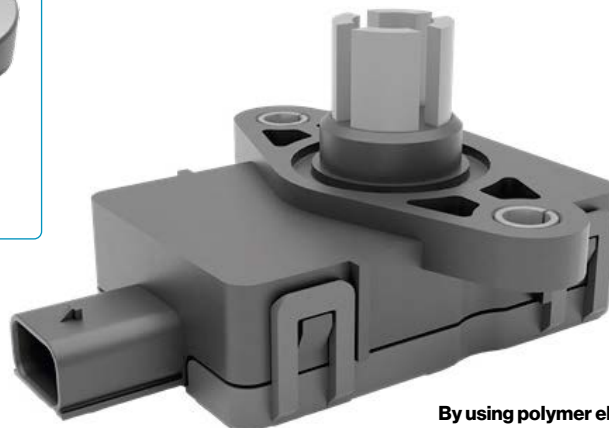
The VEGADIF 85 sensor measures the differential pressure between the oxygen and hydrogen sides in the electrolyzer. © Vega

rods with a PFA coating are used. This chemically extremely stable protective layer prevents corrosion of the base material. However, the coating reaches its limits at higher pressures. KOH can then penetrate through microdamage or stress in the coating down to the underlying stainless steel and cause corrosion. More resistant materials are therefore used in such applications.

Alternatively, the fill level can also be detected with a free-radiating radar. A higher-frequency radar wave is used for this. With this measurement method, the sensor does not come into contact with the medium. The measurement is non-contact. Both methods work continuously and can be used in various electrolysis processes.



The leak sensor detects hydrogen concentrations up to 4 percent with high accuracy. © Marquardt



By using polymer electrodes, the Marquardt conductivity sensor can be manufactured in a single injection molding step.

© Marquardt

Pressure and differential pressure measurement

Another important parameter is pressure. In alkaline electrolysis, the spectrum ranges from systems at atmospheric pressure to pressurized processes with about 30 bar. The pressure must be continuously monitored to comply with the permissible operating limits and to protect the system from damage caused by overpressure. For pressure measurement, Vega offers sensors with ceramic measuring cells. These are also resistant to KOH electrolyte solutions. The portfolio comprises a Basic and a Pro series. Particularly in auxiliary circuits in PEM electrolysis, the more cost-effective Basic series is frequently used. However, if functional safety requirements such as SIL must be met, the Pro series is required.

The differential pressure between the anode and cathode compartment is also one of the process variables that are monitored in an electrolyzer. It serves both to monitor the membrane condition and to detect contamination. In addition, an excessively high pressure difference between the oxygen and hydrogen side must be avoided to prevent the gases from crossing over to the other side.

For differential pressure measurement, Vega uses diaphragm seal systems consisting of a metallic separating diaphragm and a transmission fluid. Vega also offers variants with a gold coating that prevents hydrogen diffusion into the diaphragm seal oil. ➤

PRESSURE MEASUREMENT FOR HYDROGEN APPLICATIONS



- + NOMINAL PRESSURE
0 ... 16 BAR UP TO 0 ... 1,000 BAR
- + OUTPUT SIGNAL:
ANALOG OR DIGITAL
- + IS / SIL2 VERSION
- + GOLD-PLATED PROCESS
CONNECTION



HYDROGEN
HAMBURG
Hall B6 - E64

BD SENSORS
pressure measurement

>> www.bdsensors.de

MONITORING ANODE RECIRCULATION IN FUEL CELLS

In fuel cell systems, anode recirculation ensures that excess hydrogen flows back into the fuel cell. To prevent nitrogen and moisture from accumulating, these must be regularly released via the purge valve. To avoid unnecessarily large amounts of hydrogen escaping in the process, sensors can monitor the hydrogen concentration and enable the optimal timing of the purge. For this purpose, Allengra uses a hydrogen flow sensor based on the ultrasonic measurement principle. It can measure the volume flow and the composition of the gas mixture and is also equipped with pressure and temperature sensors. Allengra uses a stainless steel construction for this. Marquardt is also currently developing an ultrasonic sensor for anode recirculation that determines the hydrogen concentration. The company relies on glass-fiber-reinforced plastic and expects cost advantages compared to a metal version at high volumes. An additional advantage is that the non-contact ultrasonic measurement does not interfere with the flow and therefore does not cause any additional pressure loss.



The Allengra hydrogen flow sensor measures the speed of sound in the medium using ultrasound. © Allengra

The differential pressure sensor can also be used for fill level determination in applications with overpressure in the vessel. On the positive side, the pressure of the liquid column and the gas space are recorded together, while on the negative side only the gas pressure is measured. The difference yields the hydrostatic pressure of the liquid column, from which the fill level is calculated.

Temperature monitoring with Ex approval Explosion protection also plays an important role in monitoring an electrolyzer. The sensor specialist Jumo manufactures pressure and temperature sensors specifically tested for use with hydrogen in order to enable safe operation in the electrolyzer periphery. Jumo supplies products ranging from the sensor to the automation level to evaluation via the cloud. In the area of temperature sensors, Jumo manufactures resistance thermometers with SIL and Ex approval. They consist of a protective fitting according to DIN 43772 with various process connections, a connection head and a replaceable measuring insert.

Jumo also offers a compact, freely configurable safety temperature limiter according to DIN EN 14597, which likewise has SIL and Ex approval. It is intended to detect hazard potentials in the Ex area early and safely. Together with a resistance thermometer or thermocouples, the setup achieves SIL 3 certification.

Ultrasound can determine concentrations The company Allengra focuses on sensor technology using ultrasound. For alkaline electrolysis, the company offers ultrasonic sensors to de-

tect the concentration of potassium hydroxide solution. "The KOH concentration influences the electrical conductivity, the efficiency and the material load," says Jan Wessels, product and portfolio manager at Allengra. "If there is too little KOH in the electrolyte, the H₂ production rate decreases due to the higher electrical resistance. If the KOH concentration is too high, however, you get a problem with corrosion." There is thus an optimal operating range that can be monitored with ultrasound.

To determine the KOH concentration, the sensor is equipped with two ultrasonic transducers that can emit and receive sound waves. This allows them to measure the speed of sound in the medium, which in turn depends on the KOH concentration, because the speed of sound in KOH is higher than in water. This measurement principle is also used in the anode recirculation of fuel cells (see sidebar).

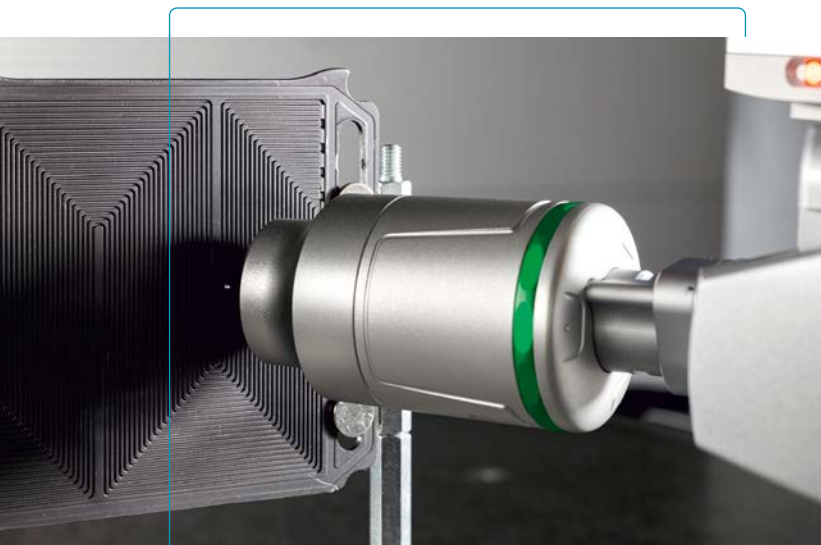
Detecting hydrogen leaks The automotive supplier Marquardt is currently expanding its sensor portfolio for electrolysis applications. A flow sensor and a high-voltage sensor are already available. Both products originally come from heat pump and battery technology, respectively, and are also suitable for hydrogen applications. In addition, the company offers a CVM system for monitoring the cell voltages in electrolysis cells (see H₂international 3/2026, page 46).

New to the portfolio is a production-ready hydrogen leak sensor developed specifically for use in electrolyzers and fuel cells. The sensor detects hydrogen concentrations up to 4 percent with high accuracy, that is, up to the lower explosion limit of hydrogen.



The Jumo safety temperature limiter responds to temperatures outside the specified limits.

© Jumo



The white-light sensor captures the flow field structure of the bipolar plate with a small spot of light. © Hexagon

MEASUREMENT TECHNOLOGY FOR FUEL CELL STACK PRODUCTION

A fuel cell stack can contain up to 400 bipolar plates. Each of them is only 0.05 to 0.1 millimeters thick and has a complex and intricate flow field structure, through which the reaction gases are later distributed. Even the smallest deviations in this structure or in the position of the plate relative to the other stacking elements have a direct impact on the performance and service life of the entire stack.

The company Hexagon offers measurement technology to monitor the production of bipolar plates. When a production line is being commissioned, a high-precision coordinate measuring machine (CMM) with sub-micrometer accuracy is used. The focus here is on the flow field structure itself. From a measurement perspective, the geometry must be inspected at defined profile sections. Since the components must not be damaged or deformed in the process, an optical, non-contact measurement method is used. A high-resolution white-light sensor, in conjunction with a rotary-tilt unit, scans a profile line.

To enable fast and accurate stacking of the fuel cell components in the stacking process, the measurement system is extended with a tactile probe system. In combination with the optical white-light sensor, it ensures the precise metrological alignment of the bipolar plate. Once the line is up and running, the measurement approach changes: in the ongoing, stable production process, the measurement system is only used for spot-check measurements.

Marquardt does not fundamentally commit to a specific measurement principle, but instead develops application-specific sensor solutions for high volumes. The focus is on compact, lightweight sensors with injection-molded plastic components that can be cost-effectively manufactured in-house.

The leak sensor works on the principle of thermal conductivity. "Our sensor exhibits only low cross-sensitivity to other gases," says Martin Götz, systems engineer at Marquardt. At the same time, it covers a wide temperature range. In addition to thermal conductivity, the device also records temperature, humidity and pressure, since these parameters are required for precise concentration determination. With a response time of less than three seconds, hydrogen leaks can be quickly detected. The sensor is currently available with a digital interface. An analog variant is in planning. The goal is to deploy the cost-effective leak sensor at several critical points in the electrolyzer and thus continuously monitor the tightness of the hydrogen lines.

Cost-effective sensor for low electrical conductivities of liquids Another sensor for electrolysis applications is currently under development at Marquardt. It is a sensor for measuring the electrical conductivity of liquids, an important process parameter of electrolysis. It is intended to monitor the water supply of electrolyzers and can also be used in cooling circuits of fuel cells. The sensor is designed for very low conductivities in the range of 0 to 5 $\mu\text{S}/\text{cm}$. For this purpose, Marquardt uses plastic electrodes mixed with carbon fibers and conductive particles. Compared to metal electrodes, they do have a higher internal resistance; however, this plays only a subordinate role when measuring such low conductivities.

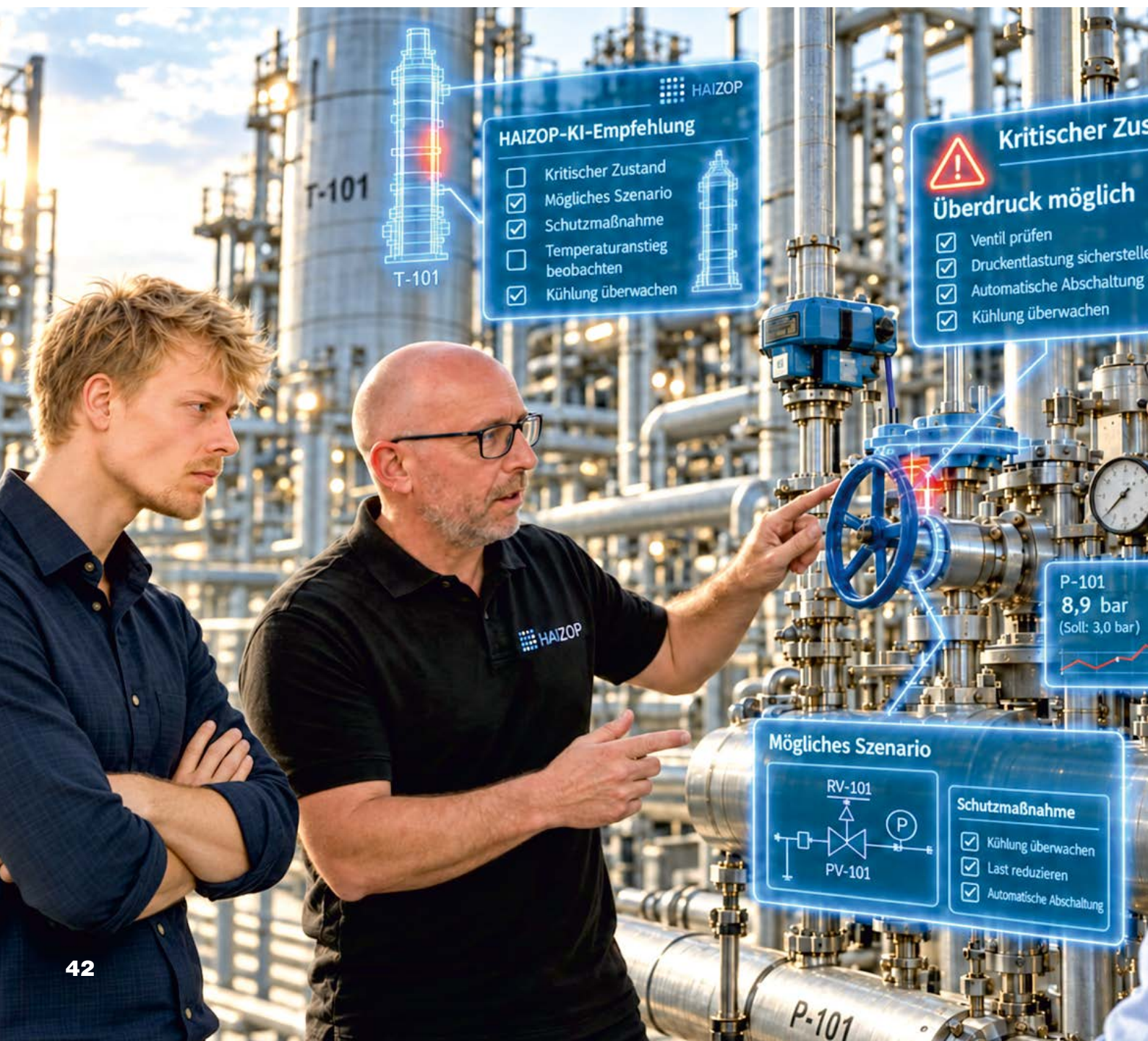
By using plastic electrodes, the entire sensor can be manufactured in a single injection molding step. In addition, the thermal expansion coefficients of plastic electrodes and housing differ only slightly, which supports a permanently stable seal. In contrast, with metal electrodes, which are usually sealed via sealing rings, cracks can develop in the sealing material over time. Another advantage is the high integrated insulation strength. It prevents fault voltages from reaching the higher-level control electronics. However, further development steps are still needed before series production readiness. "We are currently working in particular on reproducibility and on the housing," Götz explains.

Cost-effective sensor technology can improve the monitoring of electrolysis, increase efficiency and extend the service life of the systems. For this, the sensor manufacturers already offer a broad product portfolio and are working on new developments. ○

Spot the hazard, stop the hazard

Text: Eva Augsten

Planning hydrogen plants safely requires not only a high degree of experience, but also a systematic approach. The AI-based software HAZOP is designed to help with this and to speed up the lengthy analyses.



Based on HAIZOP's AI analyses and visualizations, experts can arrive at results more quickly and in a more structured manner during hazard analysis. This photo-montage virtually brings together the team of Karl Friedrich Klahn, Christian Machens and Daniel Schindowski.

© HAIZOP / KI-generiert



Picture the following scene: the final preparations for the commissioning of the gigawatt electrolyzer are underway. A technician connects a nitrogen cylinder in order to inert the compressor system. But the small cylinder is not enough: air remains in one of the lines, and no one notices. The next day, partner companies, the press and political dignitaries gather around the plant. The minister presses the symbolic button and the electrolyzer begins its work. By the time the hydrogen reaches the unpurged spot in the compressor and forms an ignitable mixture with the residual air, the guests have already moved on to coffee. Then an employee at the compressor skid touches a provisional pressure gauge; at the ungrounded measurement line, an electrostatic spark jumps across. A hard bang tears apart the coffee gathering, followed by a scream.

In this scenario, several safety-relevant errors occur in succession. The basis for this chain comes from an exemplary hazard and operability study. An AI thought it up, a safety engineer reviewed it and the author of this text added a few narrative details.

Developing, and avoiding, hazard scenarios A hazard and operability study, usually referred to by the English abbreviation HAZOP, is a structured method for thoroughly scrutinizing a technical plant before it is built, with the help of many different scenarios. The goal is to avoid dangerous situations wherever possible and, where that is not possible, to at least make them manageable. In the example scenario above, the proposed countermeasures consist of two pressure indicators, one for the cylinder pressure and one with a signal to the plant control system, as well as the calculation of the exact purge volume. In addition, the HAZOP record refers to specific sections of the German operational safety ordinance

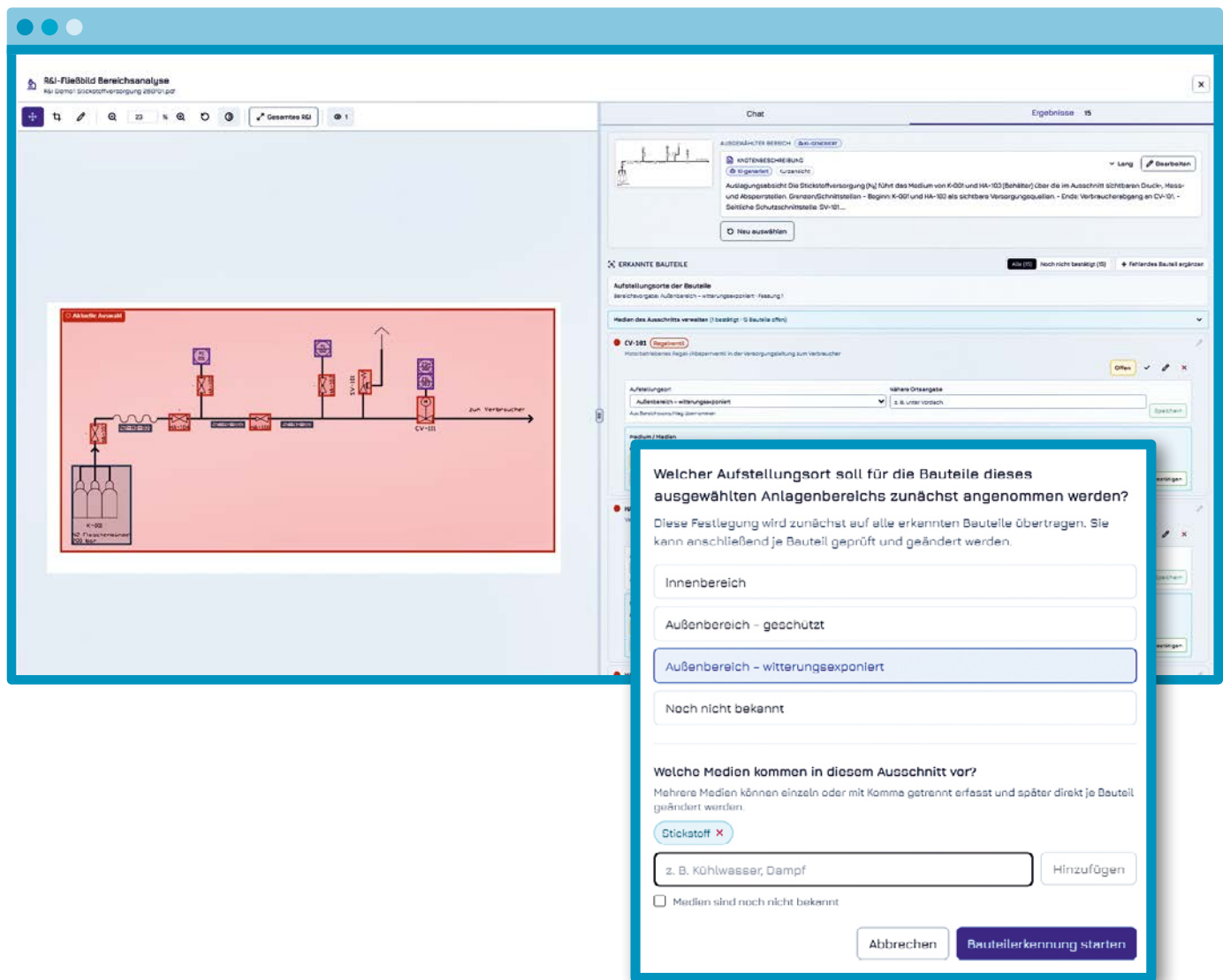
(Betriebssicherheitsverordnung) and the German hazardous substances ordinance (Gefahrstoffverordnung).

Days-long group processes A HAZOP is a time-consuming affair. Section by section, an interdisciplinary team works through the plant plans and devises dozens of possible problem cases. From guide words such as “pressure” and “more” or “less”, scenarios emerge: What happens with more pressure? No pressure? Reversed pressure? The experts assess the possible consequences and look for suitable countermeasures.

Such a HAZOP meeting easily lasts a few days; for larger projects it can also be weeks. The costs are correspondingly high, and so is the savings potential. That was what Christian Machens, a safety expert in the hydrogen industry, thought two years ago. In H2international he presented his approach at the time of simplifying the HAZOP with the help of artificial intelligence. This has now become an AI-based software called “HAIZOP”, which also provided the content basis for the opening scene of this text.

A HAZOP is not a review laid down by law or standard with fixed limit values. It is rather a method of structuring the process, similar to how one can use Kanban for project management. The binding values and safety regulations are instead found in the relevant standards, laws and ordinances for the respective industries and plants. This distinction is central, because only in this way is it possible to develop a software like HAIZOP that can in principle cover entirely different types of plants.

The founding and development team consists of three people in three very different locations with different backgrounds: safety engineer Machens in Leipzig, the SAP >



specialist Daniel Schindowski and Karl Friedrich Klahn in Dresden, whose activity as a working student transitioned directly into the role of shareholder. A meeting with all three has never taken place. Connected purely digitally, they have created a cloud-based tool that guides safety professionals through all the steps of the HAZOP and supports them in many tedious tasks.

AI learns to read plans One thing Machens emphasizes again and again: "AI cannot replace people." Nor can it do their thinking for them. It is rather their attentive assistant. When the plant plans are uploaded to HAZOP, the AI creates a list of the existing components: compressors, valves, control devices and much more. Each of these must be actively confirmed by a person. Additional information can also be en-

tered: Is the plant located in a residential area? By the sea? In the desert? In the first step, the HAZOP software is a structured collection point for all kinds of information about the plant. The more precise the input, the better the result later.

In the next step, the plant diagram can be broken down into sections which, similar to a classic HAZOP meeting, are examined individually. Now the AI can play to its strength: it can spit out possible hazard scenarios in a fraction of the time humans would need for it.

Physics tutoring for the AI makes the difference

A focus of the development work lies in these scenarios. The experts have drilled their models to stick strictly to physics instead of producing creative horror movies. "It was not training in the actual sense, but above all a restriction,"

With the help of the AI analysis, selected areas of the plant can be examined (left side of the window). Details for the respective areas can be specified by the user. © HAZOP

Klahn explains. The fact that an AI model can eloquently describe the fundamentals of thermodynamics or the design of a pump by no means implies that it will come up with the idea that any of this might have something to do with its task. It took about two years to drum into the AI what is self-evident to most people: that the laws of nature really do always apply. Now it not only knows which faults can occur with which valve types, but also draws conclusions about how the components influence one another, that a valve closed too suddenly, for example, leads to a pressure surge in the line; or that a pump running without liquid can heat up dangerously.

Here too the following applies: the human remains master of the proceedings. Every procedure must be reviewed and approved, and can be changed or supplemented. And even with the AI-based software, there is no way around a HAZOP meeting. “But you can prepare much more beforehand and work in a more focused way,” Machens explains.

Documentation almost by itself Last but not least, the AI also helps with what most people particularly dislike doing: documentation and writing work. Every step is automatically recorded: not only the scenarios and measures themselves, but also every check mark that is set. Together with plant plans and parts lists, the AI thus already has the most important things on hand to prepare the final documentation. These, of course, still have to be reviewed, revised and approved by people.

Sticking point: data protection Where AI and cloud solutions are involved, it is always also about data protection and data security. Many AI companies are based in the USA and have their servers there, not to mention Chinese providers. Exactly which models are used for which steps is something HAZOP does not reveal. In addition, the models would be swapped out again and again, since now one, now the other is ahead in certain capabilities. The cloud application, however, is said to run on servers that are “at least in Western Europe,” Machens affirms. Further restrictions are also said to be possible at the customer’s request. “Some companies have strict requirements about which data may be transmitted where. We can also run our application on a customer-owned server, if its performance allows for it,” Machens says.

The second topic, alongside possible access by third parties, is: What do the software and the AI itself do with the uploaded information? Machens says: “Our AI does not learn from our customer data.” Plans, projects and also uploaded standards and safety regulations for the databases remain strictly separated from one another, he assures.

AI is no bargain Instead of replacing people, HAZOP is thus intended above all to save expensive engineering hours, since these quickly add up to six-figure amounts. About 25 to 30 percent of this is said to be saveable with the software. But the software costs are also no small change, amounting, depending on the number of user accounts, to several thousand euros per month. The licenses distinguish between the different user roles. Engineers carry out the AI analyses and work on the scenarios and measures. Reviewers can go through the documents and comment, and observers are limited to reading along. To illustrate that this is money well spent, HAZOP has programmed a profitability calculator. There one can enter in detail how many people usually work how many hours per year on the hazard analyses. The ROI calculator then calculates the return the software delivers, using a perfectly normal algorithm without AI.

From launch to scaling Right now, HAZOP is taking its first commercial steps. Licenses have been available for purchase since July. Fine-tuning will certainly still take place in the early phase. Above all, however, the HAZOP team is hoping for a large and rapid rollout. The core of the software is transferable worldwide. It is about substance databases and basic physical principles, and these apply in an electrolysis plant in the Federal State of Brandenburg just as they do in Brazil, in a refinery in Norway just as they do in the Arabian desert. “The customers can then upload the specific standards for the industries and countries themselves,” says Machens. If it is up to the HAZOP team, the international rollout is to start this year. ○

AI helps with project financing

Text: Mert Satici

Artificial intelligence monitors, optimizes and searches for faults in hydrogen projects. But its ability to represent an outside perspective can also help to convince lenders or insurers of a project.

Electrolyzers, sensors and AI models for the control, regulation and monitoring of plants are today highly developed from a technical standpoint. Nevertheless, project developers often have difficulty convincing financiers. What is often missing is the trust of the financial players, who ultimately have to approve a project, in the operation of the electrolysis plant.

To solve this problem, one has to understand what lenders, insurers and offtakers actually need from an AI system. And this differs significantly from what most of today's systems are designed for.

The transparency problem The prevailing paradigm for AI in electrolyzers currently focuses on operational transparency. Sensor data are collected, processed and made available to operating teams in near real time. Voltage curves are tracked, efficiency metrics monitored. If certain limit values are exceeded, the system triggers alerts regarding possible anomalies. These functions help operators to react more quickly, to detect faults earlier and to better understand how a specific plant behaves under certain conditions.

For the financing decision, however, they are not the goal, but the starting point. Lenders, technical advisors and insurers do not evaluate whether an electrolyzer is operating efficiently today. They examine whether it will generate predictable cash flows over a loan term of twelve to fifteen years. Real-time operating data are necessary for this, but not sufficient.

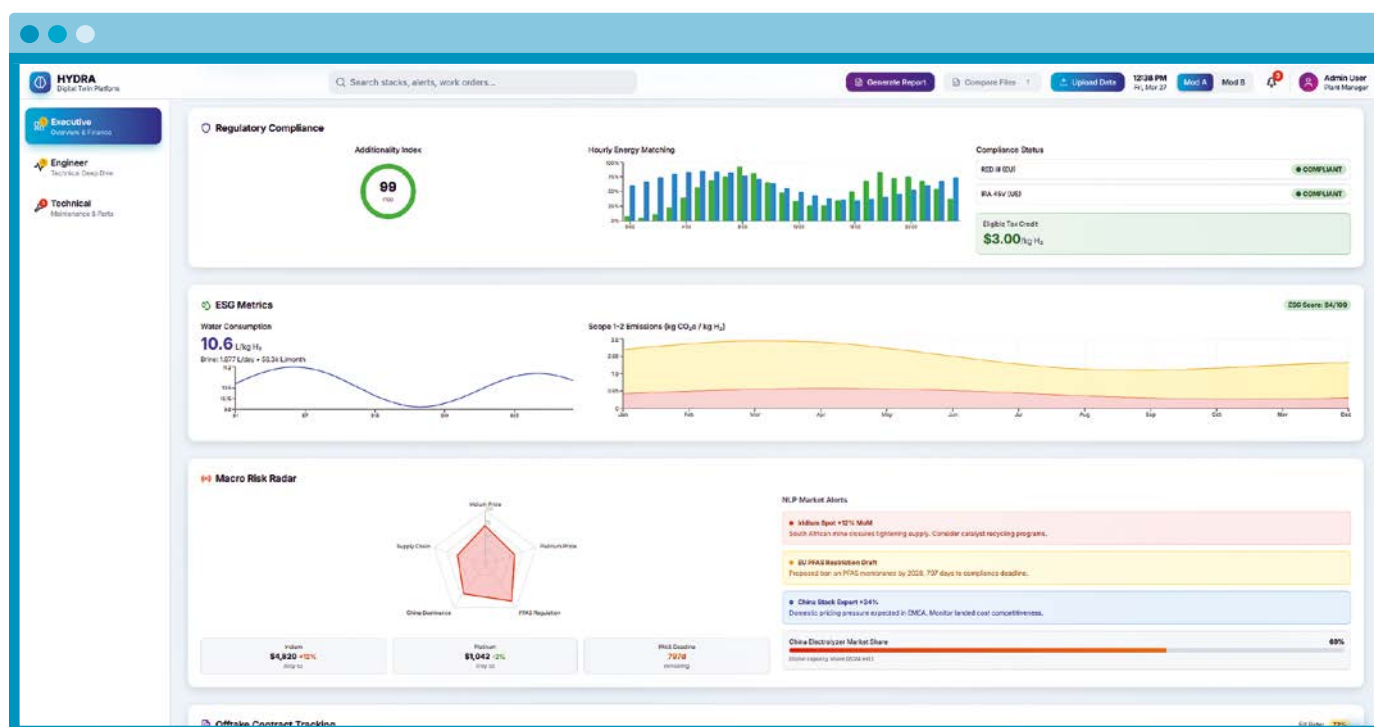
What is required instead is a documented and verifiable history of plant performance: How is the plant aging? What interventions have been carried out? How is its remaining useful life estimated? And on the basis of comprehensible physical relationships, not on the

basis of proprietary correlations that cannot be independently verified.

A high model accuracy based on test data may convince a data scientist. It does not necessarily convince a lawyer specializing in project financing or a risk committee tasked with underwriting the future cash flows of a plant worth several hundred million dollars.

What makes AI credible for banks The credibility gap of AI systems for electrolyzers has three central dimensions. All of them must be addressed if AI is actually to make a contribution to financing decisions.

- **Traceability:** Every optimization recommendation, every fault classification and every forecast of the remaining useful life must be traceable to an underlying physical mechanism, for instance to the increase in the area-specific resistance (ASR), the thinning of the membrane or the kinetics of catalyst layer detachment. Lenders regularly commission independent technical advisors to review operational systems. If an AI system cannot explain why it issues a particular recommendation, and in a form that an electrochemistry engineer can verify, then this recommendation has no robust evidentiary value in a formal due diligence process.
- **Physics-based foundations:** There is a fundamental difference between a machine learning model trained exclusively on historical operating data and a model whose solution space is bounded by thermodynamic and electrochemical laws.
A model that relies only on historical data may deliver physically impos- ➤



The dashboard also shows macro risks of electrolysis projects, such as the development of iridium prices. © Polestar Technology

sible results under extreme conditions. This can easily happen when electrolyzers respond dynamically to fluctuating power generation from renewable energies and in doing so reach operating states that lie outside the training data. A model with a physically bounded solution space will not do this, because impossible states are excluded by design. For a lender evaluating a plant that is to be operated for 13 years with variable renewable energy sources, this difference determines whether AI results are reliable even under previously unobserved conditions. For financiers, it is decisive whether AI results can be transferred to new operating states, a question that becomes particularly important in the later years of many hydrogen project financings.

- **Auditability:** A credible AI system must deliver not only insights, but also evidence. This includes:
 - time-stamped performance logs
 - histories of interventions and maintenance measures
 - the documentation of degradation trajectories
 - comparisons between predicted and actual behavior.

Technical due diligence reports are prepared on the basis of this information. If it is missing, there is nothing for technical advisors to review, and in that case even a technically highly deve-

loped system makes no contribution to the financing process.

Analysts and advisors frequently speak, in the context of green hydrogen, of a “bankability gap”: projects are technically sound, but cannot demonstrate the operational predictability that project financing without comprehensive recourse to the project sponsors requires.

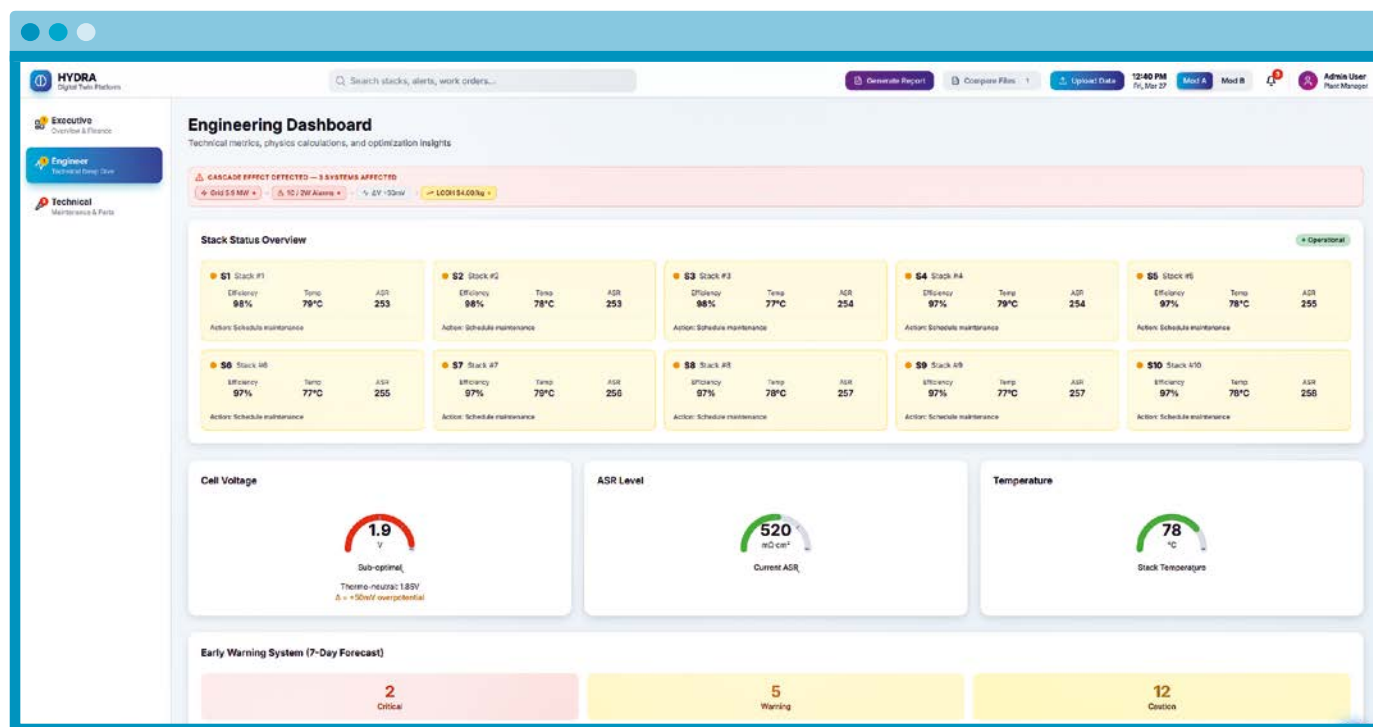
The financing gap: an example This bankability gap primarily does not concern the plants themselves. It concerns the intelligence layer between the physical plant and the financial players who have to evaluate it.

Take an electrolyzer that has been operated for two years with conventional monitoring systems. The technical advisor of a lender receives voltage curves, pressure logs and maintenance records. The advisor can calculate the capacity factor and estimate the remaining useful life on the basis of conservative assumptions.

What the technical advisor cannot do, however:

- quantify the efficiency loss caused by an undetected increase in ASR
- verify whether dynamic load operation has stressed the membrane more than intended
- assess risks that are not visible in the available data set.

So the advisor is literally pricing in a risk that cannot be seen. ▶



The engineering view shows further technical details. © Polestar Technology

Now let us consider the same plant with a physics-based AI system. This continuously monitors degradation processes, creates traceable logs of interventions and delivers forecasts of the remaining useful life on the basis of electrochemical kinetics.

The technical advisor can now:

- review the previous degradation trajectory
- understand the physical basis of the service life forecast
- assess whether the operating decisions of the past two years were geared toward maximum service life.

The risk becomes visible. And what is visible can be assessed and priced. In this way, a project becomes financeable.

A framework for the industry The AI industry in the electrolyzer sector must focus on one central question: Does this system deliver evidence that a lender can rely on?

From this, several concrete requirements follow:

- Physical boundary conditions must bound the solution space of the AI, not as a subsequent add-on feature, but as a fundamental architectural principle.
- Every output must contain a comprehensible explanation in the language of the respective target audience.

- Operating data and degradation trajectories must be continuously documented in formats that enable independent review.
- Performance forecasts must be supplemented by a quantification of uncertainty, based on physical models and not solely through point forecasts.

The best dashboards and visualizations do not help here. This does not mean that real-time functions have to be dispensed with. It merely requires the decision to treat credibility toward lenders as a central requirement already at the system architecture stage, and not only as a downstream problem. ○



Mert Satici

Mert Satici is founder of Polestar Technology, a company for industrial AI solutions with a focus on electrolyzer intelligence and infrastructure for green hydrogen.

From chimney pipe to bipolar plate

Text: Monika Rößiger

Metallic bipolar plates are a core component of hydrogen mobility, and their series production is one of the most demanding tasks in production engineering. A family-owned business in southern Germany has specialized in exactly this and is in the middle of the difficult transformation from the combustion engine to e-mobility.

Müllheim, a small town in the southern Black Forest, not far from the Swiss border. In the bright, spotlessly clean production and assembly halls of Weil Technology, laser welding systems hum and robotic arms join metal parts with surgical precision. Sales assistant Susanne Tegel, who guides visitors through the plant, explains the complexity of all these processes and what is being created here: machines that in turn build machines, for washing machines, air conditioning systems and exhaust systems. And now also for fuel cells.

That sounds almost like a logical further development. But behind it lies a strategic decision that put the company at a crossroads a few years ago: continue to sail in the slipstream of the combustion engine, or change course before the wind shifts.

Roots in the can industry Weil Technology was founded in 1987 by Florian Weil's father – the same year, as it happens, that today's managing director came into the world. "I am employee number 1, even though that's not really true," says Florian Weil with a smile. "Because in fact that's Susanne Tegel." The founding father came from the can industry: roll a piece of sheet metal, weld it, done. This basic artisanal principle has shaped the company to this day.

The first in-house development was a laser welding system for chimney pipes, a genuine innovation at the time. "In the early 1990s, that was not yet widespread," Florian Weil recalls. The fall of the Berlin Wall brought the young company a boom: in eastern Germany, dilapidated houses and factories were being refurbished, and chimney pipes were in short supply. Weil Technology supplied the systems to manufacture them.

Chimney pipes were followed by laser-welded washing machine drums, among others for Miele, and then catalytic converter

housings for exhaust systems. Always the same basic principle: form sheet metal, laser weld. With every emissions standard, from Euro 1 to Euro 6, demand for more sophisticated exhaust gas treatment systems grew, and with it Weil Technology's business. The company grew from an initial 20 to around 270 employees today.

But the growth had a weak point. Around 70 percent of sales came from the exhaust business with the automotive industry, a market that came under structural pressure when the debate about climate protection and reducing emissions in the transport sector began. ➤



CEO Florian Weil and sales assistant Susanne Tegel at their plant in Müllheim. © Monika Rößiger

Technology

The internal mobility transition “From 2017 onwards, as a medium-sized family business, we began thinking about e-mobility,” says Florian Weil. “At a time when it was not yet a major topic in public discussion.”

The question was not whether the combustion engine would eventually be replaced, but how and by what. Purely battery-electric? Fuel cell? Both? And above all: how does a sheet metal processing and laser welding specialist position itself for the future?

Weil and his team found the answer through a sober analysis of their competencies. The company had mastered the joining of thin metal foils by laser, the development of precise clamping technology and the machine building for series production processes.

What was sought was an application that required exactly these capabilities. It was found in the metallic bipolar plate, the most important component in the stack of a fuel cell system.

Formula 1 of laser technology To understand why bipolar plates are such a demanding yet logical application for Weil Technology, it is worth taking a look at the TechCenter. Thomas Frey, industry manager for renewable energies at Weil, stands in the laser welding cell and points to the test rig: two large lenses, a camera and fiber optic cables that guide the laser beam down from the laser source on the roof.

“This is a relatively new technology,” he explains. “Normally, you have to guide the laser head mechanically, with a robotic arm or an axis. Here, we deflect the beam using small mirrors. The head itself stays still.”

Two such scanner systems work simultaneously. The patented dual-field scanner welding module is the heart of Weil’s technology for bipolar plates. The result: a welding speed of one meter per second. 2.7 meters of weld seam, the length required for a single bipolar plate, are drawn in 2.7 seconds.

“A fully welded plate comes out of here every four seconds,” says Frey, explaining why the weld seam is so important. A bipolar plate consists of two embossed metal foils, each just 0.1 millimeters thin.

The anode and cathode are welded together, with the membrane lying on top. Together they form the basic element of the fuel cell stack, in which hydrogen and oxygen react electrochemically to form electricity and water.

Three media flow through the plate: air, hydrogen and cooling water – strictly separated from each other by the weld seam, which seals each individual channel. A leak would be critical: after all, hydrogen must not escape in an uncontrolled manner.

Extreme precision The permissible gap size during welding is a maximum of ten micrometers, one-tenth of the thickness of a human

hair. “This challenged us so much that we grew with it,” says Florian Weil. “For me, this is the Formula 1 of laser technology.”

To ensure that the wafer-thin plates do not warp during welding, Weil developed its own automated clamping technology: with around 800 kilograms of clamping force, the foils are pressed together before the laser is applied. A symmetrical welding sequence, internally called “Butterfly Weld,” distributes the heat input evenly and minimizes distortion and contour deviations.

Corona as a catalyst The development of this technology took place during an unusual time. During the coronavirus pandemic, Weil Technology set up its own development department and began constructing the first prototype systems.

“From a health and economic point of view, corona was a bad time,” Florian Weil admits. “But for innovation and transformation, it was a very good time.”

The reason: suddenly, top managers were available. Those who otherwise had to wait weeks for an appointment now got someone on the phone within hours. Weil Technology seized this opportunity, pitched its ideas, discussed in sprints with potential customers and continuously refined the concept.

These conversations led to the first orders for sample systems, and ultimately also for series production systems. But the road there was not without setbacks. “When we built the first tool, it ended up in the bin,” the managing director recalls. “That was our tuition. Something like that is part of it.”

From prototype to series production system Today, at its in-house TechCenter, Weil Technology has a laboratory system that offers customers the opportunity to validate bipolar plate



Renewable energies manager Thomas Frey explains the machines and processes in the technology center.

© Monika Rößiger

designs before they invest in a fully automated series production line. The company deliberately relies on technological continuity: the tools and processes used in the TechCenter correspond as far as possible to those of the later series production modules. What works in the lab is intended to scale up in production.

For the complete process chain, Weil Technology cooperates with two partners under the umbrella of the German Fuel Cell Cooperation: the Tübingen-based manufacturing specialist Zeltwanger handles the leak testing, and the Dresden-based family business Von Ardenne the coating of the finished plates. Together, the three companies cover the entire chain from joining and testing through to coating.

Stalling hydrogen ramp-up But Florian Weil also speaks openly about the current market situation. Although Weil Technology has already delivered series production systems, the order volume in the fuel cell sector has recently declined. “At the moment, we have no active project for the construction of a system,” he says.

The reason is that the market for fuel cell vehicles is growing more slowly than hoped, partly because the hydrogen supply is not yet sufficient. This in turn is also due to unclear regulations on the part of the European Union.

“We first have to boost hydrogen production before the uptake can increase,” says Thomas Frey. A vehicle needs around 300 bipolar plates in the stack; for a thousand vehicles, that would be 300,000 plates. Demand on this scale, however, is so far lacking.

Electrolyzers and cryogenic tanks Weil Technology is therefore not only thinking about the consumption side of hydrogen, but also about its production. Electrolyzers require bipolar plates similar to those used in fuel cells, but thicker, and they have to withstand higher pressure.

Around five development projects with customers from the electrolyzer sector are currently running in the TechCenter. The laboratory system can be converted for these thicker plates.

In addition, the technical center enables the round bending of thicker sheets and the subsequent laser welding of cylindrical cryogenic tanks, vessels for cryogenic liquid hydrogen that is needed for transport and storage. “We are machine builders,” Frey emphasizes. “A customer comes to us and needs a machine, then we are on board.”

Bipolar plates for aviation A particularly ambitious project connects Weil Technology with the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, DLR) and other industry partners: the collaborative project “Bi-Pro2Scale,” funded by the German Federal Ministry for Economic Affairs and Energy. The aim is to scale up bipolar plates to a surface area corresponding to a power output in the megawatt range, intended for later use in aviation.

For this purpose, a mirror-based laser scanner optic is used in the TechCenter, which deflects the infrared beam extremely quickly via micro-movements, thus welding two adjacent plates simultaneously. The 200-micrometer-thin metal plates are pressed together with around 800 kilograms of clamping force. The project covers the entire value chain, from the development of suitable joining processes through to the validation of the finished components.

Resilience through broad positioning Whether fuel cells, electrolyzers or cryogenic tanks: Weil Technology relies on diversification. That has always been the case. “There are always market fluctuations in mechanical engineering,” says Florian Weil. “That is why you should not be dependent on one market and need at least five irons in the fire.”

In addition to the hydrogen and battery sector, the company remains active in the classical automotive industry, in the heating, air conditioning and ventilation sector, as well as in the household appliance industry. And: “We export all over the world,” says Susanne Tegel.

The transformation away from the combustion engine is real at Weil Technology, but it is not an abrupt break, rather a step-by-step expansion of the competency profile. The micro welding technology for bipolar plates, which a dedicated department within the company now develops independently, technically has hardly anything in common with the classical macro welding for chimney pipes or washing machines. And yet it has grown from the same roots: sheet metal, laser, precision.

“I believe it was the right decision to face up to the change,” says Florian Weil. How far that decision will carry will be decided by the market, as soon as enough green hydrogen is on offer. ○

During the tour with Susanne Tegel through the production halls of Weil Technology.

© Monika Röbiger



Companies

Bipolar Plates

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

Communication & Marketing

HYDROGEN MOVES *contact@hydrogen-moves.de*
Phone +49-1590-6485048
Push the Market! www.hydrogen-moves.de
Hydrogen Universe: Knowledge | Network | Collaboration

Compressors

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

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

Distribution

KUSTEC **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 **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

thyssenkrupp Uhde Chlorine Engineers GmbH,
Vosskuhle 38, 44141 Dortmund, Germany,
Phone +49-231-547-0, Fax -2334,
info-uce@thyssenkrupp.com,
www.thyssenkrupp-uhde-chlorine-engineers.com

Electronics



MACEAS GmbH,
Königstr. 2, 26676 Barßel-Harkebrügge,
Germany, Phone +49-4497-9269-90,
Fax -18, www.maceas.com



Munk GmbH,
Gewerbepark 8+10,
59069 Hamm,
Germany, sales@rectifier.com, www.rectifier.com,
Customized power supply solutions for industrial applications



plating electronic GmbH, DC Power Supplies,
Rheinstr. 4, 79350 Sexau, Germany,
Phone +49-7641-93500-0,
info@plating.de, www.plating.de



Prüfrex Innovative Power Products GmbH, Egersdorfer Str. 36, 90556 Cadolzburg, Germany, Phone +49-(0)9103-7953-0, Fax -55, www.pruefreflex.com



wir bewegen Zukunft

info@vaf-bopfingen.de, www.vaf-bopfingen.de

VAF GmbH, Automation expert
for cell stacking, Bergstr. 13,
73441 Bopfingen, Germany,
Phone +49-7362-96030,

Fittings, Regulators, Valves



Bürkert Werke GmbH & Co. KG,
Solenoid Valves, Mass Flow Controller,
Fluid Power System Solutions,
Christian-Bürkert-Str. 13-17, 74653 Ingelfingen, Germany,
Phone +49-7940-10-0, Fax -91204, www.buerkert.com



Festo SE & Co. KG,
Automation Electrolyser,
HRS, Compressor, Stack & Fuel Cell Production, Rüterstr. 82,
73734 Esslingen, Germany, Phone +49-711-3471185, markus.ott@festo.com, www.festo.com



Nova Werke AG,
H₂ High Pressure
Solenoid Valves, Vogelsangstr. 24, 8307 Effretikon,
Switzerland, Phone +41-52-3541616, www.novaswiss.com



www.imiplc.com/industrial-automation, hydrogen@imi-precision.com

IMI – Buschjost GmbH, Detmolder
Straße 256, 32545 Bad Oeynhausen,
Germany, Phone +49-5731-791-0,

Fuel Cells



SFC Energy AG, EFOY Fuel Cells,
Eugen-Sänger-Ring 7, 85649 Brunnthal,
Germany, Phone +49-89-673592-555,
info@sfc.com, www.sfc.com, www.efoy-pro.com

Gas Diffusion Layers (GDL)



SGL Carbon GmbH,
Werner-von-Siemens-Str. 18,
86405 Meitingen, Germany, Phone +49-(0)8271-83-3360,
Fax -103360, fuelcellcomponents@sglgroup.com, www.sglgroup.com

Integration



**Deutsches Zentrum
für Luft- und Raumfahrt**
German Aerospace Center
Institute of Engineering Thermodynamics

**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



ODONICS Your-Tool GmbH, Strassfeld 10, 3441 Freundorf,
Austria, Phone +43-2274-30601, www.odonics.com

Measurement and Control Technology



BD|SENSORS GmbH,
el. Druckmesstechnik,
BD-SENSORS-Str. 1, 95199 Thierstein, Germany, Phone
+49-(0)9235-98110 www.bdsensors.de, Manufacturer of
electronic pressure and level measurement technology



**Henze-Hauck
Prozessmesstechnik /
Analytik GmbH**,

Wasserstoffanalysatoren, ATEX zertifiziert, Sicherheits-
technik, Dünnhauptstr. 14, 06847 Dessau, Germany, Phone
+49-340 5169363, info@henze-hauck.de, www.processanalytik.de



HYDAC Electronic GmbH, H₂ pressure transmitters with
approvals for hazardous environments as well as EC
79/2009, Hauptstr. 27, 66128 Saarbrücken, Germany,
Phone +49-6897-50901, electronic@hydac.com, www.hydac.com



JUMO GmbH & Co. KG,
Measurement, control and
automation technology for
hydrogen applications,

Moritz-Juchheim-Str. 1, 36039 Fulda, Germany,
Phone +49-661-6003-0, Fax -500, mail@jumo.net,
www.jumo.de, en.jumo.de/web/applications/hydrogen



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

Measurement Data Management and Monitoring



DILICO engineering GmbH,
Lorenzweg 43,
39124 Magdeburg, Germany,
Phone +49-391-620282-70, info@dilico.de, www.dilico.de



Smart Testsolutions GmbH,
Rötestr. 17, 70197 Stuttgart, Germany,
Phone +49-711-25521-46,
www.smart-testsolutions.de

Companies



Weidmüller Group,
Klingenbergstraße 26, 32758 Detmold, Germany,
Phone +49-5231-14-280, www.weidmueller.de/wasserstoff

Membranes and Separators



FUMATECH BWT GmbH,
Carl-Benz-Str. 4, 74321 Bietig-
heim-Bissingen, Germany,
Phone +49-(0)7142-3737-900,
Fax -999, www.fumatech.com

Organizations

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

Organizers (Events)



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



**Messe Stuttgart, hy fcell –
International Expo and Conference
in Stuttgart and worldwide,**
www.hy-fcell.com/worldwide



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

Plant Engineering

Kloekner DESMA Elastomertechnik GmbH,
Injection molding machine manufacturer for the produc-
tion of elastomer articles, An der Baera, 78567 Fridingen,
Germany, Phone +49-7463-8340, www.desma.biz

Reformers



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

Research & Development



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

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



Fraunhofer ISE,
Heidenhofstrasse 2,
ISE 79110 Freiburg, Germany,
Phone +49-(0)761- 4588-5208, Fax -9202, www.h2-ise.de

Fraunhofer-Institut für Windenergiesysteme IWES,
Postkamp 12, 30159 Hannover, Germany,
Phone +49-471-14290-456, www.iwes.fraunhofer.de



HyCentA Research GmbH,
Inffeldgasse 15, 8010 Graz, Austria,
Phone +43 (0)316-873-9501,
office@hycenta.at, www.hycenta.at

Storage

AMBARtec AG, Supplier of compact, efficient and sustaina-
ble H₂-storage systems, Erna-Berger-Str. 17, 01097 Dresden,
Germany, Phone +49-351-30993666, www.ambartec.de



CyTec Mönchengladbach GmbH & Co. KG,
Lehmkuhlenweg 13, 41065 Mönchengladbach, Germany,
Phone +49-(0)2161-65907-0, Fax -68, www.cytec-mg.de

Suppliers

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



Borit NV, Bipolar Plates and
Interconnects, Lammerdries 18e,
2440 Geel, Belgium,
Phone +32-(0)14-25090-0,
contact@borit.be, www.borit.be



HIAT
HYDROGEN AND INFORMATICS
INSTITUTE OF APPLIED TECHNOLOGIES

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

SIEMENS

Siemens, contributes to successful process implementations in H₂ production, conversion, storage, transport and usage as reliable partner with a comprehensive automation and digitalization portfolio. www.siemens.com/h2



Sorst Streckmetall GmbH –

Use in OEMs and electrolyzers made of titanium, stainless steel, nickel, also prefabrication, planning, implementation. Phone +49-511-67675650, info@sorst.de, www.sorst.de



Spir Star AG,

Auf der Rut 7, 64668 Rimbach-Mitlechtern, Germany,

Phone +49-6253-9889-0, info@spirstar.de, www.spirstar.de

Testing



baltic FuelCells GmbH,
PEM- and electrolysis-
single cell testing equip-

ment for R&D and QA, Wilhelm-Hennemann-Str. 18, 19061 Schwerin, Phone +49-385-4893010, www.balticfuelcells.com,



competence in
gastechonlogy

JA-Gastechnology GmbH,

Albrecht-Thaer-Ring 9,
30938 Burgwedel, Germany,

Phone +49-5139-98550, www.jag.de

MAXIMATOR®
maximum pressure

Maximator GmbH,
High Pressure
Hydrogen Technology,

Testing Equipment, Customer Testing Services, Lange Strasse 6, 99734 Nordhausen, Germany, Phone +49-3631-9533-5040, info@maximator.de, www.maximator.de



Sonplas GmbH, H₂ test stand,
Testing of hydrogen-carrying
components with real fuel,

Sachsenring 57, 94315 Straubing, Germany,
Phone +49-9421-9275-0, info@sonplas.de, www.sonplas.com

Test Stands



AIP Automotive GmbH & Co. KG,

Hojen 30, 87490 Haldenwang,
Germany, Phone +49-8374-24090,

info@aip-automotive.de, www.aip-automotive.de

DAS NEUE ENERGIEPORTAL MIT FACHWISSEN ZUR ENERGIE- WENDE

**Gebündeltes Expertenwissen
zu allen relevanten Themen
der Energiewende**



Uneingeschränkter Zugriff auf exklusive Inhalte

- **30 E-Paper** Ausgaben pro Jahr von ERNEUERBARE ENERGIE, Gebäude Energieberater und photovoltaik.
- **Fokus Themenhefte**
- **Marktübersichten** über wichtige Produkte
- Zugriff auf ein umfangreiches **Online-Archiv**
- Exklusive **Webinare**

KONTAKTIEREN SIE UNS!

Einzellizenz



Bestellung: (Mo–Fr 8–16 Uhr)
Tel: 0711-63672-400
service@gentner.de

Firmenlizenz



Eric Le Gall
Tel: 02202-2514244
Mobil: 0172- 2575333
LeGall@gentner.de

WWW.FUTURE-WATT.DE



Future Watt

H2international 1/2027 will be published on February 23, 2027.

NAMIBIA

Hopes and obstacles for the new hydrogen economy.

WHITE HYDROGEN

The arduous search for the treasure underground.

RESEARCH

Which technological leaps can be expected in 2027?



© Martin Egbert



© Made with Google AI



© iStockphoto / Adobe Stock, made with AI

IMPRINT



PUBLISHER AND COMPANY

Gentner Energy Media GmbH
Forststraße 131, 70193 Stuttgart
Postfach 10 17 42,
70015 Stuttgart, Germany

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
Mobil +49 159 062 246 48
Email: nahirna@gentner.de

ORDER MANAGEMENT

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

DESIGN AND LAYOUT

www.neon-bold.de, Berlin

WEBSITE

www.h2-international.com

PUBLICATION DETAILS

Publication Frequency: 4 issues per year
26th Year, 2026
ISSN: 1862-393X

SUBSCRIPTION PRICES

€129.90 per year (including VAT),

New orders are subject to the subscription prices valid at the time of order. The applicable advertising rate list No. 27 from 01.01.2026 applies.

SUBSCRIPTION TERMS

Orders can be placed at any time through the reader service or bookstores domestically and internationally. Subscriptions renew annually unless canceled in writing three months before the subscription year ends.

Subscription fees are invoiced in advance or debited via direct debit. If the magazine cannot be delivered due to reasons beyond the publisher's control, there is no claim for replacement or refund of prepaid fees.

The legal venue for merchants is Stuttgart; for others, it applies if claims are made through a dunning process. Please notify the reader service of any address or recipient changes at least six weeks in advance.

COPYRIGHTS

The structured layout of the magazine and all individual articles and images contained within it are protected by copyright. By accepting an article for publication, the publisher acquires comprehensive usage rights from the author in an unrestricted and exclusive manner, particularly for further reproduction and commercial distribution through mechanical, digital, or other means.

Unless revoked (socialmedia@gentner.de), this also applies to the use of images, graphics, and audiovisual works on all social media channels, including Facebook, Instagram, and YouTube. No part of this magazine may be reproduced or converted into machine-readable language without the publisher's written consent, except within the narrow limits of copyright exceptions.

The automated analysis of the work to extract information, especially patterns, trends, or correlations according to German law § 44b Urheberrechtsgesetz (Text and Data Mining), is prohibited.

The use of product names, trade names, and trademarks in this magazine does not imply that such names may be freely used by anyone; they are often legally protected registered trademarks, even if not explicitly marked as such.

CONTACT OUR READER SERVICE

Postfach 91 61, 97091 Würzburg, Germany
Email: service@gentner.de Phone: +49 711 63 67 24 08
Fax: +49 711 63 67 24 14

TRUSTED HYDROGEN INSIGHTS FOR 20 YEARS

Join our newsletter: quick insights,
expert voices, and must-see events

