THE HYDROGEN MAGAZINE

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Break-through or lock in?

Before going on vacation, there is always an especially large amount to do. The desk and the inbox should be as empty as possible, so that one can truly relax and really hit the ground running in the fall. There are certain parallels to the hydrogen economy.

A whole batch of funded projects is in the middle of implementation or nearing completion. Thyssenkrupp has ordered its first large-scale delivery of hydrogen for green steel production, though only for the next seven years. In a Bavarian town, ten homes are now using hydrogen for heating, delivered by truck.

These projects show what is moving forward, namely pilot projects, and what is still missing, namely the overall long-term concept and the infrastructure. The problem is well known. Anyone who wants to solve it must set a clear framework and, in several places at once, both support and require action. Examples include the rollout of filling stations and the procurement of H2 trucks, as is now happening in Germany. The approach is so obvious that one wonders: why not do it this way from the start?

Merely requiring the use of hydrogen, on the other hand, is an excellent method for letting the technology starve at arm's length. German law, for example, now requires that power plants operate climate-neutrally from 2045 onward and therefore must already be built H2-ready today. Sounds good. It can work, but only if hydrogen production or imports are pushed forward with similar intensity. However, the majority of hydrogen production projects in Germany have so far been awaiting a final investment decision due to unclear prospects. Investors in the MENA region criticize Europe for its lack of commitment to jump-starting green hydrogen and for its complicated regulations.

Germany's federal government is setting the course for austerity. Writing into law that power plants should run on hydrogen somewhere down the road does not cost much. If it then turns out, strangely enough, that there is not enough hydrogen and that the specific cost of transporting and storing it is prohibitively high, especially for the turbines, we will simply have to stick with natural gas. What a shame – but who could have known?

But we are not there yet. Projects that were kicked off years ago are now moving forward. Their momentum carries energy, and they show what is feasible. It is high time to put this energy to political use.

Otherwise, the current tasks will be completed soon, and the vacation may last longer than we would like.

Eva Augsten
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Quiet power for rough waters

Two new hydrogen-powered ferries will carry visitors to the Lofoten Islands off the coast of northern Norway.

© Natascha Plankermann

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Title photo: © Toyota . Photo left: © GreenH (background extended using generative AI)

What's up, Hyfindr?

THE SWARM TAKES FLIGHT

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

At this year's World Hydrogen Summit in Rotterdam, one thing was palpable:

The mood has shifted.

After a phase of high expectations, followed by noticeable disillusionment last year, the conversations today are different. Less loud, less visionary in tone, but at the same time clearer, more concrete and, above all, more confident. This may seem trivial at first glance. But it is not.

Because industries do not develop on the basis of data, business cases or regulatory frameworks alone. They develop on the basis of trust.

A helpful analogy is a flock of birds in the sky. Not every bird analyzes the situation anew. It only takes a few to change direction. A small group follows. And suddenly the entire flock is on the move. In business, momentum works in a similar way. A few market leaders make bold decisions. Early followers validate these steps. The broad mass gains confidence, and follows suit.

That is why the mood among decision-makers is of particular importance. When one company invests, viewed in isolation it seems risky. When several companies invest in similar directions at the same time, the perception changes: the risk becomes a calculable step. The swarm begins to move.

Rotterdam has shown that we could be standing at exactly such a point. The hydrogen economy will not be decided by a single breakthrough. No project, no company, no technology will tip the scales on its own. It will develop when many players simultaneously find the courage to take the next step.

Then we are like birds, and the hydrogen industry moves like a swarm.

Let's get to work, and take flight. ○

Thyssenkrupp nucera pushes into Indian hydrogen market

Thyssenkrupp nucera and Bharat Heavy Electricals Limited (BHEL) have signed a Strategic Collaboration Agreement at BHEL's headquarters in New Delhi for the manufacture of alkaline water electrolyzers. The electrolyzers are intended for the production of green hydrogen in India. According to the agreement, the companies want to work together to gradually establish local manufacturing of electrolysis modules in India. This includes building up local production capacities, jointly participating in tender procedures, and providing support in the realization of projects.

BHEL is one of India's leading state-owned engineering and manufacturing companies. For decades, it has been active in power generation, transmission, renewable energies, oil and gas, transportation, aerospace, and defense. Among other things, it owns more than half of the conventional power plant capacities in India.

Thyssenkrupp nucera targets the Indian hydrogen market "India is one of the most important growth markets for thyssenkrupp nucera," says Kiran Joseph, CEO of thyssenkrupp nucera India. The agreement with BHEL is not thyssenkrupp nucera's first step into the new market. Since the beginning of the year, the electrolysis specialist has also been cooperating with the German Corporation for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit, GIZ) to create a market for green hydrogen and power-to-X in India. Also this year, Indian project developer Juno Joule commissioned thyssenkrupp nucera to carry out a FEED study for a 260 MW green hydrogen production project. ○

Daimler Truck cooperates with Keyou on hydrogen combustion technology. © Daimler Truck

Daimler Truck: Now adding a hydrogen engine

As early as the end of 2027, Daimler Truck plans to bring a truck with a hydrogen engine to market together with Keyou. Daimler Truck and Keyou have agreed to develop the truck jointly. To this end, Daimler Truck will supply Keyou with vehicles of the Mercedes-Benz Actros L 1848 type as tractor units, along with engines manufactured in Mannheim based on the existing 12.8-liter platform. The Munich-based company is responsible for the technological adaptation for hydrogen operation. External service providers will handle the technical conversion of the trucks and the integration of the engine.

The first vehicle from the cooperation is to be the Keyou HICE.40 tractor unit. It is designed for a gross vehicle weight of 40 metric tons. According to Keyou, thanks to 350-bar compressed hydrogen technology, it is expected to achieve a range of up to 650 kilometers. The company states the output at up to 350 kW. A port fuel injection system (PFI) is used. In the future, the technology can also be transferred to further vehicle series. Daimler Truck would then offer the entire spectrum of zero-emission trucks: battery-electric, with fuel cell drive and with hydrogen engine. ○

Floating electrolyzers: up to 1.5 GW per year feasible

Meeting in the wind tunnel: In the center Christoph Ploß, BMWE, surrounded by researchers. To his right, Jens Cruse.
© TU Hamburg

On June 3, 2026, the German Federal Government's coordinator for the Maritime Economy and Tourism, Christoph Ploß, visited Hamburg University of Technology (TUHH) to learn about the results of a project on the production of hydrogen at sea.

Together with industry and research partners, TUHH has developed a floating, self-sufficient offshore electrolysis plant in the ProHyGen project. The hydrogen produced is to be stored without pressure in a liquid organic hydrogen carrier medium (LOHC). The German Federal Ministry for Economic Affairs is funding ProHyGen with around 1.5 million euros (see H2international 2026-2).

The project partners include Cruse Offshore GmbH, the Chair of Chemical Reaction Engineering at Friedrich-Alexander University Erlangen-Nürnberg (FAU), Renk GmbH, and H&R GmbH & Co. KGaA. The plant is intended for sea areas outside the sites of conventional offshore wind farms.

Since the plant produces and consumes its own energy, there is no need for a grid connection, transformer platforms, or subsea cables. The hydrogen is stored temporarily in the "liquid battery storage" LOHC and transported by shuttle tanker via the existing oil infrastructure to the off-taker. According to the calculations, the current purchase price for industry there would be around 5.50 euros/kg H2 (IRR 17.9%).

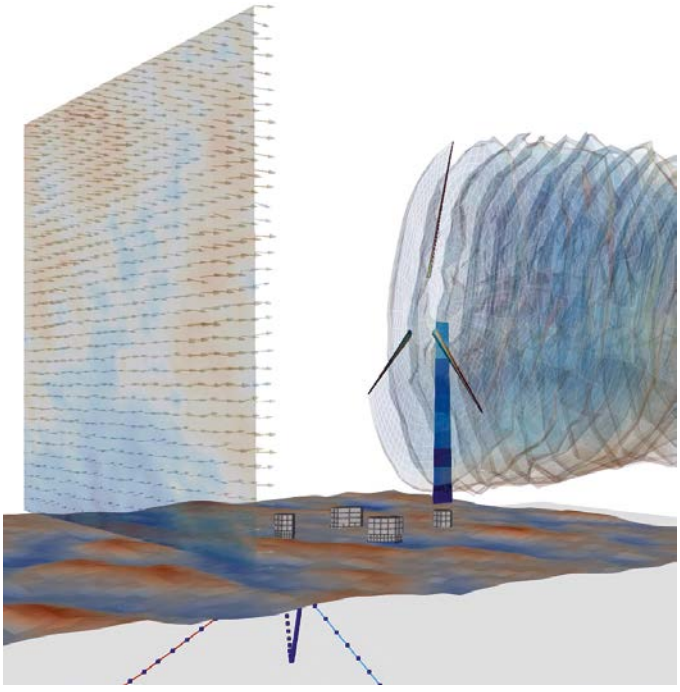
These characteristics apparently impressed the Maritime coordinator. The concept not only significantly reduces the effort for planning and construction, but also lowers investment costs. "At the Dogger Bank offshore wind farm, for example, around 50 percent of the investment costs (CapEx) are attributable to the power grid connection. In our concept, this cost block is completely eliminated," explains project manager Jens Cruse. "In the sea areas we have selected, wind power can be generated almost around the clock, so that the electrolyzer will be utilized accordingly." This, together with the absence of a grid connection, would also "drastically reduce" operating costs (OpEx).

The floating wind-power-to-hydrogen factory is anchored using conventional mooring lines. "The concept is scalable and does not compete for space with other wind or solar installations," Cruse emphasizes. "We also don't need an H2 core network, because transport is to take place via the well-developed inland waterway network in Germany and Europe." This network links H2 hubs such as Hamburg, Rotterdam, Duisburg, Ludwigshafen, and Antwerp-Bruges. In addition, potential off-takers such as the steel and chemical industries as well as refineries are already located there.

Off-takers can be supplied via a "deposit-bottle system for hydrogen," as Andreas Bösmann of FAU explained. "The LOHC carrier liquid can be loaded and unloaded with hydrogen for around 3,000 cycles before it has to be replaced." And: "The heat released during hydrogenation is sufficient to desalinate the seawater so that it can be used for electrolysis."

Thorsten Ronner of the Heinrich Rönner Group said that once central components such as turbines, electrolyzers, and prefabricated steel parts are delivered, a consortium of German shipyards would be able to assemble around 50 to 100 units per year in series production. With an output of 15 MW per plant, this would correspond to an installed capacity of up to 1.5 GW per year.

In the project, which runs until the end of 2026, the Hamburg researchers and their partners have completed the planning of a 5 MW prototype as well as its scaling to 15 MW. Preliminary planning and a feasibility study for a hydrogen park in European sea areas are also available. As a next step, the participants aim to build a first prototype. They discussed possible implementation paths at the expert meeting with Christoph Ploß and industry representatives. Investors are welcome. ○ **Monika Rößiger**



Simulation in the wind tunnel at TU Hamburg
© Cruse-Offshore

Verde Hydrogen supplies electrolyser for off-grid project in China

The US company Verde Hydrogen has received an order from China Coal Energy Group to supply equipment for the first phase of an off-grid green hydrogen production project. According to Verde Hydrogen, it is a flagship project for off-grid hydrogen production in China's heavy industry. The company says that leading Chinese electrolyser manufacturers participated in the public tender. Verde Hydrogen also says that its Chinese subsidiary prevailed thanks to a technical proposal based on its electrolysis core technology, plant performance, and system design.

The contract includes four alkaline electrolysers, each with a hydrogen production capacity of 1,200 Nm^3/h. It also includes an integrated gas-liquid separation and hydrogen purification system with a total capacity of 4,800 Nm^3/h. Verde Hydrogen describes it as a "4-in-1 system". The plant will be operated exclusively with electricity from directly coupled renewable energy sources and will supply high-purity hydrogen for the decarbonisation of heavy industrial processes.

Hydrogen valley in southern Italy to start production in September

Italian engineering company Techfem has completed construction of the "Hydrogen Valley" in the southern Italian city of Lamezia Terme. The term "Hydrogen Valley" refers to an ecosystem in which green hydrogen is produced, stored, and supplied to local industrial and mobility users. In this case, the facility combines on-site renewable power generation, electrolysis, compression, storage, and a loading bay for tube trailers within a single installation on a former industrial site.

Techfem carried out the engineering design and EPC execution on behalf of the client and future plant operator, Teca Gas. According to the company, it is the first project of its kind in the Calabria region and the only one developed by a private beneficiary under Italy's National Recovery and Resilience Plan (NRRP). The project received funding of €6.85 million.

The Hydrogen Valley is centred around a 2 MW PEM electrolyser supplied by IMI. The plant includes storage and compression systems operating at pressures of up to 220 barg, a 480 kW photovoltaic array consisting of 750 modules, and a loading bay for filling tube trailers used to transport hydrogen to off-site users.

According to Techfem, the configuration enables green hydrogen to be produced directly at pressure using renewable electricity. Energy consumption is stated at 55 kWh per kilogram of H_2 at full capacity, below the 58 kWh/kg threshold set by the NRRP. The first offtakers will be the local metalworking industry as well as existing and future transport operators. Teca Gas also plans to produce hydromethane at the site, with an expected annual output of 85 tonnes for use by public transport operators.

The plant will now undergo testing and regulatory inspections carried out by Techfem. Once the authorisation process has been completed, operations are scheduled to begin in September 2026.

©Techfem

Lhyfe ramps up trailer fleet to 84

Lhyfe has taken delivery of ten new Type IV hydrogen containers from supplier Hexagon Purus. According to the company, its fleet now comprises 84 tube trailers dedicated to hydrogen transport – one of the largest and most modern in Europe. Lhyfe and Hexagon Purus share a strategic industrial shareholder, the Japanese trading and investment company Mitsui & Co.

The new Type IV containers are available in four sizes and two compression levels. According to Lhyfe, they are lighter, more durable, and comply with RFNBO certification requirements, allowing larger volumes of hydrogen to be transported per trip.

The company states that its logistics network currently serves around 60 industrial and mobility customers across nine European countries. In 2025, Lhyfe surpassed a total of 1,000 deliveries. According to the company, more than 850 of these deliveries took place in Europe during 2025, representing an increase of more than 80 percent compared with 2024. Customers include BMW Group, TEAL Mobility, H2 Mobility, Karp Kneip, and energy supplier Essent.

According to Matthieu Guesné, Founder and CEO of Lhyfe, delivering hydrogen by truck is only the first step in building a supply chain. "The bulk market is the first to scale up – it is already enabling pioneering players to initiate their energy transition. To support them, we have been committed since 2021 to building a comprehensive, efficient, reliable, and flexible supply chain," he says. He adds that the sector will require multiple distribution formats – including on-site production and pipeline networks – to meet diverse use cases.

Fast projects, slow politics

Text: Eva Augsten

Project developers in the MENA region are ready to scale up green hydrogen. Cornelius Matthes (DII Desert Energy) and Laurent Antony (IPHE) agree that EU regulations are now the main challenge – but disagree on most details.

The Neom Green Hydrogen Project in Saudi Arabia, with its 2.2 GW electrolyser capacity, is currently the largest and best-known project in the MENA region. On the podcast The Hydrogen Elevator, recorded at The Smarter E Europe exhibition in Munich and hosted by Jürgen Pfeiffer, Cornelius Matthes said the project is now 95% complete and is "due to be commissioned in the next few quarters."

It could supply low-cost hydrogen and be a step towards greater energy security for Europe, Matthes pointed out. He noted that most hydrogen projects in the MENA region are located on the Red Sea – like Neom – or in North Africa, meaning they do not depend on passage through the Strait of Hormuz. Matthes argued that, at large scale, cost was no longer the main issue. "We can go below three euros per kilogram today," he said.

MENA developers losing patience with Europe Matthes sees the main obstacle in Europe's regulatory framework. According to him, prospective producers in the MENA region are "extremely annoyed, extremely frustrated by a lack of speed, a lack of clarity" on Europe's part. Without reliable long-term offtake commitments, investors are increasingly looking towards Asia, where projects move faster and regulatory frameworks are more predictable. Referring to offtake agreements, he said: "Ten years is not so good. Twenty years is super. If you have 30 years, it's even much better." He added: "A solid offtake, a solid long-term agreement is simply a prerequisite to make any of these projects bankable." He also called for competitive export credit agency (ECA) support to facilitate the delivery of European technology to the region.

A milestone in comparing apples with apples Laurent Antony, Executive Director of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), also stressed the importance of regulation. IPHE develops international foundations for the hydrogen economy on which governments and standards organisations can build. The field is complex. The organisation has identified 21 hydrogen certification schemes and seven support mechanisms worldwide. Antony considers a single global certification scheme unrealistic. "That's just a dream," he said.

But he pointed out that a milestone had been achieved. At the end of April, a new ISO standard for quantifying greenhouse gas emissions from hydrogen was published. The methodology is based on work initiated by IPHE, involving more than 15 countries and over 70 meetings. The new standard provides a common methodology "to compare apples with apples."

Like Matthes, Antony called for long-term, stable, and predictable rules and pointed to an example that has already proven successful. He cited Japan's Hydrogen Society Promotion Act. The legislation combines 15-year contracts for difference (CfDs) with a further ten years of planning certainty and covers the entire supply chain, from producers to logistics providers.

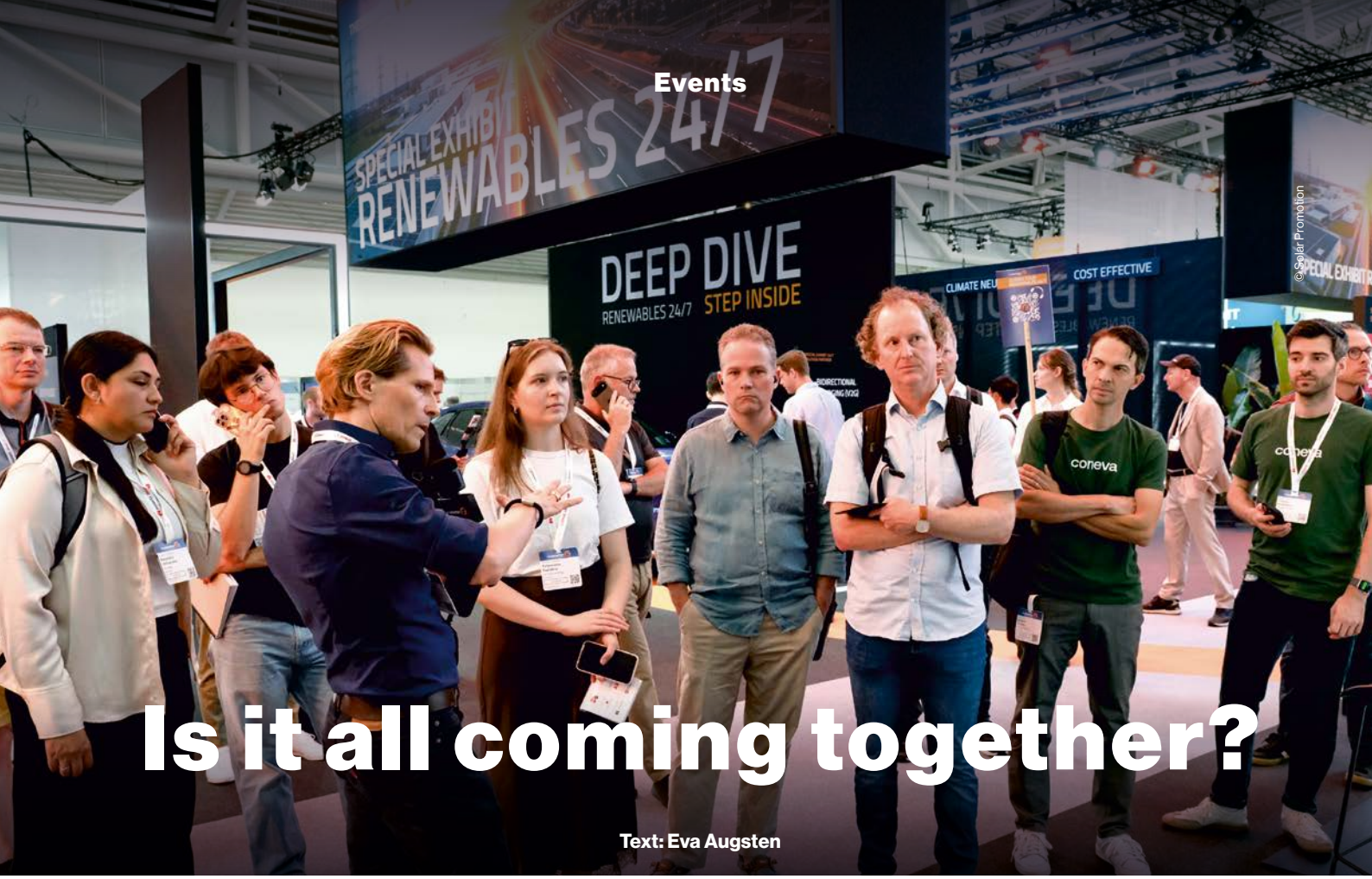
Virtual certificates are controversial The two experts disagreed strongly over certificate trading. Matthes argued in favour of virtual trading of green hydrogen. This would essentially mean trading certificates without transporting the physical hydrogen.

Antony rejected a pure book-and-claim model, at least for now. Before virtual trading can become credible, he argued, the industry must establish trust through physical traceability using a mass-balance approach that links the hydrogen produced with the hydrogen ultimately consumed.

To secure long-term international hydrogen partnerships, Matthes called for more "simplicity" and "a bold commitment by Europe." Antony argued that Europe should regard exporting countries as co-owners rather than merely suppliers. "Let's understand each other and work together," he concluded. ○

© Hydrogen Elevator

The full podcast is available at
www.hzwei.info/podcast



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Is it all coming together?

Text: Eva Augsten

This year, for the first time, the Hydrogen Dialogue, with its conference and forum on the trade fair floor, was part of The Smarter E, the energy transition trade fair. Are electricity and hydrogen now coming together?

It is hot, it is crowded, and loudspeakers are urging visitors to keep the hall doors closed so that the air conditioning can work properly. The trade fair has 2,800 exhibitors, and by the time this issue goes to press, 2,800 visitors are expected.

Renewables 24/7 The trade fair, which started out as Intersolar, has long ceased to be a pure solar event. Storage technologies, e-mobility and grid integration have been an integral part of it for years. The Smarter E is thus also a platform where sectors converge technically and where overall solutions are repeatedly discussed.

An idea of what a fully renewable energy system could look like is showcased this time in a special exhibit titled Renewables 24/7. There is also an application example from the hydrogen sector to be seen there, a 54 MW PEM electrolyzer at BASF in Ludwigshafen.

Strong interest For several years now, providers of hydrogen technologies have been appearing among the battery storage exhibitors. This year, the Munich trade fair is hosting the Hydrogen Dialogue for the first time, a format that previously took place in Nuremberg. It consists of a conference at the congress center and an open forum on the trade fair floor.

This is an opportunity for hydrogen and green electricity to come closer together, as the organizers explained the idea. Around the forum, the concept seems to be working. “The questions from the audience are open-minded and interested,” is the impression of Olivier Bucheli, who advised the trade fair on the technical orientation of the hydrogen forum in the exhibition halls. Silke Frank of Hydrogen Moves, whose booth is located right next to the forum, also praised the good exchange.

Molecules versus electrons? At the opening of the Hydrogen Dialogue Summit at the conference center, however, one gets a different impression. Bavaria’s Minister of Economic Affairs Hubert Aiwanger complained that in his state they were struggling to “desperately prevent brownouts,” since too much solar power keeps flooding the grids. In general, one sometimes gets the impression that hydrogen and green electricity are not partners in the energy transition, but bitter enemies. “Electrons are on the left, molecules are on the right,” said Professor Michael Sterner of the OTH Regensburg (Ostbayerische Technische Hochschule Regensburg). And Jorgo Chatzimarkakis of Hydrogen Europe, known for his punchy statements, spoke of “electro-Taliban.”

If hydrogen and renewable electricity are actually to become a resilient energy supply for Europe, there are still some bridges to be built. Perhaps Munich is the place for it. ○

“There’s no way forward without green molecules.”

Text: Monika Rößiger

After years of high expectations for hydrogen, experts at the Hamburg congress “EnergieZukunftWasserstoff” (Energy future hydrogen) called for a reassessment of the technology. Specialists from engineering, industry, politics and law agreed that hydrogen remains indispensable for a climate-neutral energy system.

In his welcoming address, climate physicist Mojib Latif, president of the Academy of Sciences and Humanities in Hamburg, recalled the first oil crisis in 1973. “By then at the latest, it should have become clear to us that fossil energy sources do not provide secure supplies. Denmark recognized this. We, on the other hand, are standing still.”

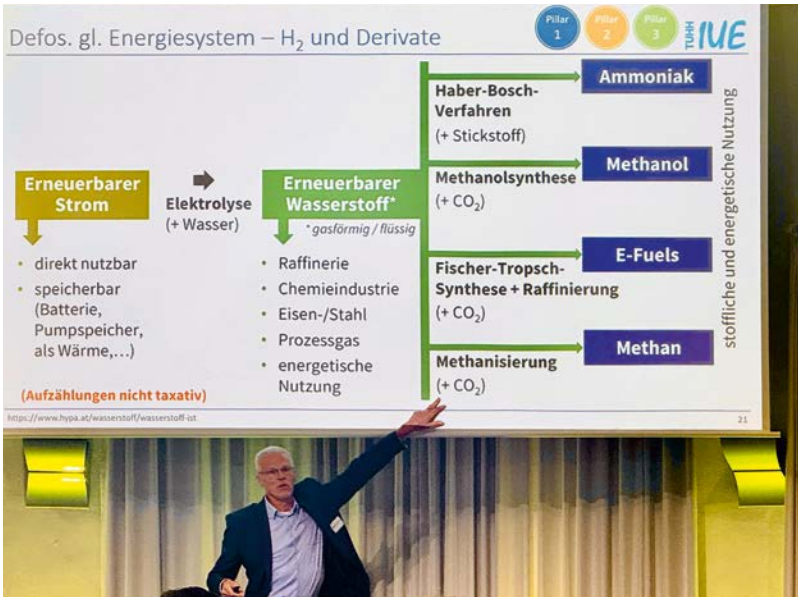
Despite the climate and energy crisis, despite wars and repeatedly flaring conflicts in the Middle East, there is still a lack of insight into how urgently a change of course in energy supply is needed.

The euphoria of the early hydrogen years has faded. The market ramp-up is proceeding more slowly than hoped, but no one at the congress doubted the fundamental necessity of green hydrogen.

The real problems lie less on the technical than on the economic level. “We now have to build a new energy system within 15 years,” said management consultant Marius Buchmann of EERA consulting in Oldenburg. “We need not only CO2 reductions, but a complete transformation.”

As project manager at what was then Jacobs University Bremen, he contributed, among other things, to the dena lead study “Aufbruch Klimaneutralität” (Towards climate neutrality). Dena is the abbreviation for “Deutsche Energie-Agentur” – the German Energy Agency. He admitted that numerous hydrogen scenarios of recent years had been too optimistic in terms of costs. The price for green hydrogen today is around ten euros per kilogram.

“If electrolyzers are no longer exempt from grid fees in the future, the price could even rise to 12 to 15 euros per kilogram,” said Buchmann. That is far from competitive with fossil alternatives. The situation is particularly critical in energy-intensive industries. Even a price of four euros per kilogram is currently considered barely economically viable by parts of the chemical industry.



Bankability as a key issue The term “bankability” came up repeatedly at the congress and has now become decisive for many projects. That is why companies want nothing more than a high CO2 price, according to Buchmann.

In addition, the hydrogen market so far lacks a functioning middle layer of trading players, such as has long been established in the fossil industry.

This could also be built up with the help of the H2Global Foundation, whose basic concept is the so-called double-auction model. Under this scheme, state compensation payments

LEFT: With great commitment, scientist Martin Kaltschmitt conveys his findings to the audience.
© Monika Rößiger

BELOW: Climate researcher Mojib Latif, president of the Academy of Sciences, welcomes his guests at the opening of the congress.
© Monika Rößiger

bridge the difference between import and sales prices until the market for green hydrogen sustains itself.

Hermann Held, professor of Sustainability and Global Change at the University of Hamburg, warned of enormous costs that, according to the Intergovernmental Panel on Climate Change (IPCC), would arise from climate damage if we do not act.

For this reason alone, hydrogen is a "no-regret technology" for industrial applications. "In 2050, the abatement costs with the help of H2 technologies could be 15 to 22 percent lower." In China, the abatement costs are even higher, at around one third of gross domestic product.

The physicist, however, expressly advised against so-called blue hydrogen. An interesting side note: he described himself as "the Chernobyl generation, which walked through the radioactive rain."

Regulation becomes an obstacle Participants discussed the EU requirements for renewable hydrogen (RFNBO) particularly critically. Detlef Schulz of Helmut Schmidt University and spokesperson for the hydrogen working group of the Academy cited the criteria of "additionality" as well as the temporal and geographical correlation between renewable electricity and electrolyzer operation.

These rules are intended to ensure that hydrogen production is based on additional renewable energies and does not compete with direct electrification.

Meanwhile, many market participants see these requirements as an obstacle to the market ramp-up. Professor Schulz described them as one of the main factors slowing the expansion of electrolysis capacities.

Yet we quickly need much more: "Germany currently has around 185 MW of installed electrolysis capacity," says Schulz. "That corresponds to only 1.8 percent of the planned final expansion in 2030." The 10 GW target of the update to Germany's National Hydrogen Strategy is therefore hardly achievable.

Battery storage as new competition Schulz's assessment of the role of battery storage also sparked discussion. While in the public debate these are usually regarded only as an important pillar of the energy transition, he pointed out possible conflicts of interest.

Battery storage systems are increasingly competing with electrolyzers for grid connections and grid capacities. They are indeed market-serving and can stabilize electricity prices, "but they contribute neither to system-serving nor to grid-serving functions."

Often, they even place additional strain on the grid. There is already competition for scarce resources in the area of infrastructure. In order to make better use of flexibility options in the future, correspondingly adapted legislation is required.

Hydrogen without regret Martin Kaltschmitt, head of the Institute of Environmental Technology and Energy Economics at the Hamburg University of Technology, sees the most important fields of application for hydrogen in the chemical industry, steel production, international shipping and aviation, as well as in selected areas of long-term storage. For other applications, direct electrification will remain economically more attractive.

He refers to an estimate by the Berlin Institute for Innovation and Technology (iit), according to which H2 demand in all sectors could rise by 2035 to around ten percent of Germany's current primary energy demand. In any case, "the supply and delivery chains for cost-effective 'green molecules' must also be developed," said the professor. Otherwise, the goal of defossilization by 2045 cannot be achieved. So for him, too, waiting is not an option.

CCS, competition or complement? Another topic was the relationship between hydrogen and carbon capture and storage (CCS). Professor Michael Fehling of Bucerius Law School warned against placing both technologies side by side as politically equivalent.

In his view, both hydrogen and CCS infrastructures require long-term state planning. A permanent coexistence of different technology paths could complicate investment decisions and generate additional uncertainty. His appeal to policymakers was therefore to set clearer priorities and to define the intended fields of application of the respective technologies more precisely.

At the end of the congress, the experts agreed: it is now a matter of removing the existing political and regulatory hurdles. Because, as Martin Kaltschmitt said: "There's no way forward without green molecules." ○

Hamburg Offshore Wind Conference

Windpower and hydrogen: “It takes two to tango”

Text: Monika Rößiger

Europe’s wind industry stands at a crossroads, with direct consequences for the hydrogen ramp-up. Investors in North Sea wind farms want to pull out. At the Hamburg Offshore Wind Conference, representatives of the steel and wind industries are already warning of the gap between expansion targets and reality.

Many of the 115 participants at the Hamburg Offshore Wind Conference (HOW 2026), decision-makers from the areas of production, grid infrastructure, industry and regulation, agree: high costs, supply chain problems and continuously rising interest rates are placing too many risks on companies.

HOW 2026, which traditionally takes place in spring at the Hamburg Coffee Exchange (Kaffeebörse), is jointly organized by the industry network Renewable Energies Hamburg (Erneuerbare Energien Hamburg, EEHH) and the international consulting and certification company DNV.

The success of the European hydrogen economy depends significantly on the expansion of offshore wind energy. From the industry’s perspective, the failed offshore tender in Germany in August 2025 and the postponement of this year’s auction appear all the more alarming.

This development is also a warning signal for the ramp-up of the hydrogen economy: if reliable and scalable green electricity is lacking, the business models of the H2 economy start to falter.

A reduced offshore expansion could also worsen the economic and infrastructural conditions for projects such as AquaVentus (see

H2international No. 5-2025) or ProHyGen (see H2int. No. 2-2026). These aim to produce green hydrogen using wind power directly at sea. The current auction regime is evidently no longer working. The offshore wind industry had already pointed this out last year.

"Now it is up to policymakers," says Peter Frohböse, segment director wind at DNV. The importance of reliable framework conditions is also emphasized by Jan Rispens, managing director of EEHH: "In order for offshore wind in Europe [...] to remain a growth engine, investments along the entire value chain must be plannable." It is precisely this plannability that is lacking, with direct effects on the hydrogen ramp-up.

Missing lead markets = systemic risk The close connection between hydrogen, offshore wind and steel becomes particularly clear at HOW 2026 during the panel discussion on "Green Lead Markets." "Both today's primary steel production and secondary steel production must be decarbonized," explains Yannik Sparrer of the German Steel Federation (Wirtschaftsvereinigung Stahl), where he is responsible for lead markets as head of industry policy and circular economy. "This requires new plants, affordable renewable electricity sources and, in the long term, corresponding hydrogen."

The conversion of primary steel production alone will massively increase the electricity demand of the steel industry, and with it the necessity for a rapid expansion of offshore wind installations. "The steel industry's electricity demand from the grid is already around 12 TWh per year and will rise significantly further through the operation of direct reduction plants and electric arc furnaces."

Group photo at the end of the event.
© Monika Rößiger

However, offshore wind installations themselves are considered one of the most important sources of this additional demand. This is because they consist largely of steel. "A 1 GW offshore project requires around 100,000 tons of steel," explains Korbinian Ott, commercial managing director at Steelwind Nordenham. Like others, he points to the unfair competition from cheap imports from Asia while at the same time emphasizing the role of his industry as a potential lead market for climate-neutral base materials.

Public investment important Through the decarbonization of towers for wind energy installations, the sector could specifically create demand for green steel. However, the prerequisite is reliable political framework conditions and stable expansion pathways. Korbinian Ott warns against watering down the European Union Emissions Trading System (EU-ETS) as an important market-based instrument.

He too confirms the importance of public investments in infrastructure for the demand for green steel. This is decisive for the hydrogen ramp-up: without this market, a key demand anchor is missing.

The mutual dependency is obvious: offshore wind needs green steel; the steel industry needs green electricity and hydrogen at affordable prices. The automotive industry also needs green steel, as does the renewal of infrastructure. However, without functioning markets for low-CO2 steel, the willingness to pay is missing.

"The entire manufacturing sector is currently in a difficult economic situation," says Yannik Sparrer. "That is why there is currently little willingness among the customer industries to pay more for low-emission steel." Policymakers could provide support by creating lead markets and stimulating demand for low-emission steel, both in public procurement and in the private sector. The EU at least plans to count low-emission steel towards fleet emission limits in the automotive sector.

Against the background of necessary investments in public infrastructure such as bridges, railway tracks and H2 pipelines, Sparrer appeals to legislators: "Let us create cross-sectoral win-win situations."

The switch to low-emission steel could reduce the CO2 footprint in the manufacture of offshore wind turbines by up to 80 percent. "Steel is not just a necessary base material here; it also contributes to the reduction of Scope 3 emissions."

Industry for green lead markets Offshore wind energy could become a leading market for low-emission steel made in the EU, according to Sparrer, if policymakers create the right incentives. For example, with the ▷

help of instruments that bring advantages for both sectors and the targeted use of the German "Special Fund for Infrastructure and Climate Protection".

Like the European hydrogen association "Hydrogen Europe," Sparrer argues against relying on 100 percent green hydrogen from the outset, because this is "unrealistic." With the gradual use of so-called blue or turquoise hydrogen, CO2 emissions could already be significantly reduced while at the same time incentivizing the hydrogen ramp-up. Environmental associations and parts of the EU Commission are, as is well known, critical of this or fundamentally reject blue hydrogen as a bridging solution.

Fossil dependence is expensive In view of geopolitical crises, Ditlev Engel, CEO Energy Systems at DNV and member of the DNV executive committee, points to sharply increased costs for fossil energy imports: "44 days ago, the conflict in the Strait of Hormuz began. And since then, we in the EU have lost 22 billion euros, in additional costs for fossil fuels such as oil and gas."

The importance of energy independence can hardly be illustrated more aptly. And that is merely the monetary side of the equation. Germany currently covers around 30 percent of its energy demand from its own production, Engel continues. The largest portion must therefore be imported, which is correspondingly susceptible to crisis. "I do not understand why this aspect is not a top priority in politics."

Energy security of utmost importance A DNV survey among more than 1,000 leading representatives of the energy industry at the beginning of 2026 shows that 72 percent of respondents view energy security as the most important goal. This was, it should be noted, before the Iran war. Engel advocates an accelerated expansion of renewable energies, which is "the cheapest and fastest method to produce energy."

At the same time, he calls for simpler and more strongly harmonized framework conditions in Europe, because differing national standards slow down expansion. Furthermore, Engel recalls that Germany is a decisive player in achieving the targeted expansion goal of around 15 gigawatts of offshore wind capacity per year across Europe.

With industrial scaling combined with long-term, binding political commitments, as most recently at the North Sea Summit in Hamburg, this is certainly realistic.

Recycling in focus The panel discussion also reveals potential for closed material cycles. The steel from dismantled offshore installations can definitely be recycled and reused. Admittedly, this too is initially associated with higher costs. Nevertheless, concrete approaches and pilot projects should be considered here, argues Yannik Sparrer. "The question is: how much more money are we as a society, industry and European states willing to pay for resilience, sustainability and stability?" he concludes at the end of the event. Nobody can expect to get all this for free. And policymakers are slowly grasping that a price tag has to be attached to it. ○

LEFT: Panel discussion on green lead markets: Stefan Thimm (BWO), Korbinian Ott (Steelwind Nordenham), in the middle the two moderators Peter Frohböse (DNV) and Jan Rispens (EEHH), Yannik Sparrer (Wirtschaftsvereinigung Stahl) and Frank Spee (Vestas).
© Monika Rößiger

RIGHT: Ditlev Engel, CEO Energy Systems at DNV.
© Monika Rößiger

Inside the hydrogen power house

Text: Dr. Björn Lüssow

A delegation with guests from five countries traveled through China for a good week with Hyfindr, gaining firsthand insights into a hydrogen market that is developing rapidly.

Experiencing one of the world's most dynamic hydrogen markets up close, deepening contacts and initiating new collaborations – that was the goal of our trip. In addition to the Hyfindr team, the delegation included guests from Croatia, Spain, Switzerland, France and Germany, as well as Hyfindr's Chinese partner.

Daxing: An industrial ecosystem in full operation The travel group's first stop was the Daxing International Hydrogen Energy Demonstration Zone near Beijing. The industrial area, which was only established in 2020, has grown into one of the most significant hydrogen clusters in China. More than 200 companies there cover nearly the entire value chain – from research and development through component manufacturing to concrete applications. The difference from many European initiatives lies in the level of maturity: production halls and development centers have been built and are in use – here, things are not merely planned but tested and scaled.

The same applies to the infrastructure: the hydrogen refueling station in Daxing reaches a refueling capacity of approximately five tons per day. At its inauguration in 2021, it was considered the largest in the world; in Europe, it was only in 2025 that the H2Mobility ▷

Building of Great Wall Motors.
© Hyfindr / Background enhanced with generative AI

station reached a similar capacity. In China, this station supplies a fleet of buses and commercial vehicles. Hydrogen vehicles are part of the street scene in the industrial park.

Applications with pace: Hybot and Nowogen Also in Daxing, Hybot, a manufacturer of hydrogen-powered heavy-duty trucks, made the jump from concept to production within a short time. The company works with a 300 kW fuel cell system and, prior to the delegation's visit, announced a significant scale-up of its production capacities in the fourth quarter of this year; the plan is to manufacture 100 trucks per month.

And the company Nowogen develops fuel cell stacks and systems in Daxing. The development speed is impressive here as well: projects that were announced as a concept a year ago are in the testing phase today – for example, a fuel cell stack with a maximum output of 1 MW that we were able to see on the test stand. This stack is used in a modular system for maritime applications. Later this year, it is intended to power inland vessels of 3,000–10,000 tons on the Beijing–Hangzhou Canal and the Yangtze River. These short innovation cycles are typical of the Chinese market.

150 kilometers to the southwest, in Baoding, is the headquarters of the automotive corporation Great Wall Motors. Through its subsidiary FTXT Energy Technology, the company bundles central components of the hydrogen value chain: fuel cell stacks, complete systems, power electronics and hydrogen storage. Development, integration and application are closely interlinked – an approach that significantly shortens development times and accelerates industrialization, and which is rarely seen in Europe with this level of consistency.

The visit to the neighboring testing facilities was also revealing. The company TestHy has operated for several years as an independent testing and validation center. The laboratories operated by TestHy cover an area of more than 20,000 m2 and, according to the company, can perform over 300 test procedures. TestHy supports companies – particularly international partners as well – in accessing Chinese standards and testing processes.

Beijing: Trade fair as a mirror of industrialization Back in Beijing, we visited the China International Hydrogen Congress & Expo (CIHC) and the Beijing International Hydrogen Technology & Equipment Exhibition (HEIE).

The HEIE is a hydrogen trade fair embedded within a large industry and energy fair. The CIHC congress fair is entirely focused on hydrogen and fuel cell technologies – electrolyzers, fuel cells and stacks dominate the picture. With around 20,000 visitors, 500 exhibitors and 1,000 products on display, it is one of China's leading H2 trade fairs; in terms of presentation quality, it is comparable to Europe's leading hydrogen trade fairs.

At the CIHC, the sheer scale of the exhibited products was particularly impressive: electrolyzers in the megawatt range are part of the fair scene, and even larger ones are being installed by companies in practice in China. This gives rise to projects in the range of 100 to 600 MW, which are either under construction or already in operation.

Competition, innovation pressure and rapid technological progress can be experienced firsthand at the trade fair: new generations of fuel cell stacks in the range of up to 300 kW were presented specifically for commercial vehicles – not by just one company, but by several at once.

And the state-owned enterprise Shanghai Hydrogen Propulsion Technology (SHPT), a

LEFT: The Hyfindr delegation in Daxing Hydrogen Park. © Hyfindr

RIGHT: Steven Oji and Dr. Björn Lüssow in front of the PV plant in Rudong. © Hyfindr

BELOW: Test setup in the TestHy laboratory in Baoding. © Hyfindr

subsidiary of the likewise state-owned automotive corporation SAIC, illustrates how closely industry, government structures and real-world applications are interconnected: SHPT develops the fuel cell stacks, SAIC integrates them into its buses and trucks, which then reach the roads with the help of state subsidy programs. In addition, however, SHPT is also advancing its third-party business internationally, which by European standards is somewhat surprising for a state-owned enterprise.

Rudong: An integrated energy system in practice A good distance to the south, in the coastal region of Rudong, there is a large-scale energy project that combines renewable power generation and hydrogen production.

With 400 MW of installed photovoltaic capacity and around 468 million kWh of annual production, the facility supplies, on a balance-sheet basis, roughly 700,000 households. The facility has its own connection to the high-voltage grid (220 kV), a battery storage system of 60 MW/120 MWh, an electrolysis plant with a production capacity of 1,500 Nm3/h (135 kg/h) for the production of green hydrogen (corresponding to approximately 7 to 8 MW of electrolysis capacity), and its own hydrogen refueling station for up to 500 kg of H2 per day.

Rudong follows the principle of "generation – storage – use – reserve," thereby showing an integrated energy system – and at the same time is only a tiny snapshot of China's fully industrialized energy transition. In 2024, China had approximately 70 percent of the world's electrolysis capacity with 3.5 GW, has led the rankings of new PV and wind energy installations for years, and in 2024 broke through the 1,400 GW mark of installed wind and solar energy that had been targeted for 2030.

Understanding through travel where the journey is heading In total, the delegation visited eight cities. In addition, we visited the Jiading Hydrogen Park, a demonstration center for integrated system solutions near Shanghai, and four additional companies, including the safety equipment manufacturer MSA Safety (see video link).

International delegation trips are of great importance in China: for local companies, cities and industrial clusters, they are a platform for initiating international collaborations. Interest in international cooperation is high – not least because competitive pressure in the domestic market is enormous.

Everywhere, our group was received with great openness and hospitality. Direct exchange opens up possibilities that scarcely arise from a distance. Trusting conversations often emerged after the actual business appointments during shared meals – this, too, is part of the business culture.

The speed at which the hydrogen industry is being developed, built and scaled in China can hardly be grasped from a distance. You have to have seen it yourself to truly understand it. Therefore, in 2027, Hyfindr will once again organize a delegation trip to China together with its Chinese partner. ○

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Hyfindr-Video of MSA Safety

Green ammonia from the desert's edge

Text: Natascha Plankermann

Indian tech company ACME is racing to become Oman's green ammonia pioneer, with Chinese electrolyzers, US technology, and a port safely outside the Strait of Hormuz. Is Europe missing the boat?

A landscape like a promise about to be fulfilled. We are driving by car through a stony expanse; it looks as if one were traveling across the moon. Shortly before the coast, a construction-site fence comes into view, and on the horizon the outlines of one of the most ambitious energy projects in the world take shape: a "one-stop" factory that produces green ammonia from sunlight, wind, water and air – as a transportable energy carrier or as a fertilizer feedstock for the world market. It is being built by a company that hardly anyone in Europe knows, while in India it is established as a pioneer of the energy transition: ACME.

The construction site sits like a balcony above the Indian Ocean. Below, the Arabian Sea roars; above, the excavators roll. A broad cut runs down toward the sea through the terraced sandstone cliffs: this is where the pipeline that will connect the project with Europe by ship is to run. Seawater is pumped up for desalination, liquefied ammonia flows down to the tanker. A simple image for a complex transformation in full swing: "We built the road to the coast in one and a half years, now the terminal without a jetty will follow," explains project supervisor Naveen Sharma, who is accompanying me. He is the coordinator for project partners. We meet some of the more than 800 workers deployed here around the clock in rotating shifts. Pride shines from their eyes; respectfully, they speak the name of their company's founder.

Earthworks in Duqm. The coastal desert resembles a lunar landscape. In the background, the Arabian Sea can be seen, which lies outside the Strait of Hormuz.

From solar developer to molecule pioneer ACME – more precisely: ACME Cleantech Solutions Pvt. Ltd., whose name is said to derive from the Greek akmē for "summit" – was founded in 2003 by Manoj K. Upadhyay in Gurugram, not far from New Delhi. Upadhyay, entrepreneur and engineer, started out as a technology supplier for the telecom industry before discovering renewable energies for himself in 2008. By 2015, ACME was already India's largest private solar developer, with a portfolio of over 1,500 MW. Two years later, ACME secured the contract to build a 200 MW solar plant in the Bhadla Solar Park in the Indian Federal State of Rajasthan. The electricity generated there was sold for 2.44 rupees per kilowatt-hour (at the time about 33 euros per megawatt-hour) – according to the company, the lowest price ever negotiated for solar electricity in India at that point.

Further steps followed: in September 2021, ACME commissioned in Rajasthan one of the world's first integrated pilot plants for green hydrogen and green ammonia. It began with around 5 MW of solar capacity and a 2.5 MW electrolyzer. Initially, a modest 5 metric tons of ammonia per day were produced; the signal, however, was what mattered: the project showed how renewable energy can be converted into a transportable feedstock. Upadhyay said at the time: "Green ammonia is the most viable way for India to become a global exporter of clean energy."

At the same time, ACME was looking for the right location for its first major international project. It was found on the coast of Oman.

Billions for Duqm In March 2021, ACME signed a Memorandum of Understanding with the Special Economic Zone at Duqm (SEZAD) – becoming one of the first companies to act in line with Oman's national hydrogen strategy. In August 2021, a binding lease for 92 square kilometers in Duqm followed. The investment volume was put at US$3.5 billion. Today, according to the company, the total investment volume for the expansion stands at around US$6 billion. ▷

Several reasons spoke in favor of Oman, as ACME's Executive Vice President Arnava Sinha explained at the Green Hydrogen Summit in December 2025 in Muscat: a large potential for generating renewable energy, a structured permitting pathway, and a location where several parties can jointly use a shared infrastructure. Above all, however, a stable, supportive government structure. Duqm also lies outside the geopolitically sensitive Strait of Hormuz and has an industrial port. And from ACME's perspective, perhaps the most important factor was something less tangible: confidence in the country's long-term commitment. For projects that require billion-dollar upfront investments and decades of operation, the company sees political stability and reliable legal frameworks as just as decisive as sunshine and wind.

Oman, for its part, has a strategic interest: Duqm is being purposefully developed as a hydrogen and ammonia hub, with the national agency Hydrom as coordinator.

Key project data The project is divided into three phases; the first is already under construction. A production facility for 100,000 metric tons of green ammonia per year is being built, for which around 240 MW of electrolysis capacity and around 650 MW of solar capacity are envisaged. The electrolyzers are being supplied by Chinese specialists: Shuangliang Group and Sungrow Hydrogen.

The technology for producing ammonia comes from the American company KBR, which also supplies specially developed plant components. In order to generate as much electricity as possible, the solar panels on site are equipped with an automatic rotating mechanism – they follow the position of the sun and thereby capture more light. This technology is supplied by the companies Game Change Solar and Arctech.

In addition, the facility has a seawater desalination unit that can process around seven million liters of drinking water per day, as well as a storage unit in which up to 60 metric tons of hydrogen can be stored.

Phases 2 and 3 are in planning. In the next expansion stages, production is to rise to a total of 900,000 to 1.2 million metric tons of ammonia per year. For this, around 2 GW of electrolysis capacity and about 4 GW of solar capacity are envisaged.

The project was initially certified by TÜV Rheinland as a green production facility. It has since become one of the first worldwide to be pre-certified by CertifHy – a European certification system that evaluates sustainably produced hydrogen and related fuels according to uniform standards, thereby creating transparency for buyers and markets. The pre-certification confirms that the plant meets the EU requirements for Renewable Fuels of Non-Biological Origin (RFNBO) under the EU Directive RED III – that is, for fuels produced exclusively from renewable energy sources such as sun or wind.

Deliveries to start in 2027 The original timelines have been postponed several times; in 2023, the parties involved reached a milestone with the financial close: a US$488 million loan from India's state-owned green infrastructure financier REC Limited. Meanwhile, in view of the rapid progress visible on the site, it now appears realistic, as Oman's Energy Minister Salim Al Aufi announced at the World Hydrogen Summit in May 2026 in Rotterdam, that the delivery of green ammonia to Europe is to begin in one year. ACME itself plans to start with its offtaker Yara in early 2027.

Offtaker Yara: the first major agreement The course has been set: ACME and Yara International – the Norwegian fertilizer and ammonia group – signed a long-term offtake agreement in 2024 for 100,000 metric tons of green ammonia per year, one of the first worldwide on this scale. "The green hydrogen market has been slow to move for a long time – all the more reason why everyone, in Oman or beyond, is eager to see the ACME-Yara project!" explains Dr. Dawud Al Ansari, head of the Muscat-based Shaheen Institute for Strategy and Development and professor of hydrogen economics. The deal was made possible after 18 months of negotiations because the regulatory framework in Europe had stabilized.

ABOVE: The workers of the Indian project developer ACME are happy to pose for a photo. © Natascha Plankermann

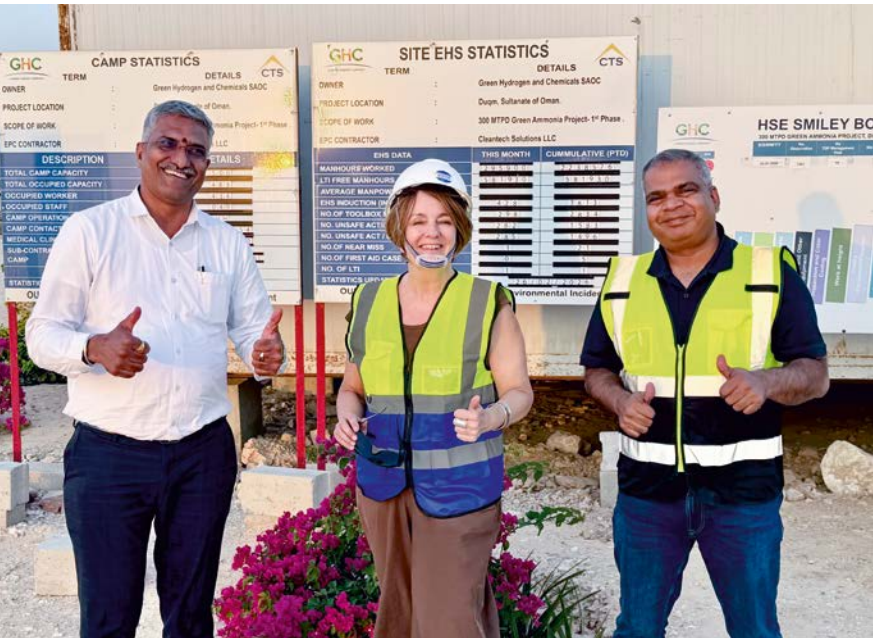
RIGHT: Journalist Natascha Plankermann with her travel companions. © Natascha Plankermann

Yara President Magnus Ankarstrand viewed this as programmatic and announced: "The agreement demonstrates the power of partnerships in developing value chains that reduce emissions." The ammonia produced in Duqm is intended to meet the European RFNBO requirements – thus qualifying as fully renewable and electricity-based. It is to be fed into Yara's global distribution network, with a focus on Europe. Over the entire life cycle of the project, the business partners expect that nearly 45 million metric tons of CO2 equivalents will be saved – which corresponds to about seven percent of Germany's total annual greenhouse gas emissions, which according to the Statista portal most recently stood at around 649 million metric tons.

Europe debates, Asia moves ahead Green ammonia is no longer a niche topic: it is being traded as a climate-friendly shipping fuel, as a building block for the steel industry, and at the same time remains a central feedstock for fertilizers. In Europe, the political framework is taking shape – but slowly. The new EU Directive RED III obliges industry and fertilizer manufacturers to source a growing share of their hydrogen from renewable, electricity-based sources. By 2030, it must be 42 percent; by 2035, 60 percent. In practice, this means: Europe will have to import large quantities of green hydrogen – and thus green ammonia – because domestic production is not sufficient. The Carbon Border Adjustment Mechanism (CBAM) reinforces this development, because it makes the import of fossil ammonia and fertilizer more expensive. "The economies of the Arabian Gulf see CBAM above all as an opportunity, since they are in a position to provide green energy and clean industrial goods at favorable prices," explains Dr. Al Ansari. According to the Dutch agricultural bank Rabobank, prices will rise by 10 to 20 percent in 2026 as a result, and by 2030 it could be up to 50 percent.

Nevertheless, price remains a problem even for green ammonia. Jorgo Chatzimarkakis, President of the Hydrogen Europe association, sums up the dilemma: "Europe is steering demand with rules, quotas and verification systems. But the instruments that trigger investment are missing." What is meant are, for example, binding offtake guarantees and clear price commitments. There are positive signals – such as possible funding for lead markets, or integration into EU programs such as the ETS Innovation Fund or the Hydrogen Bank. But: none of this is binding so far.

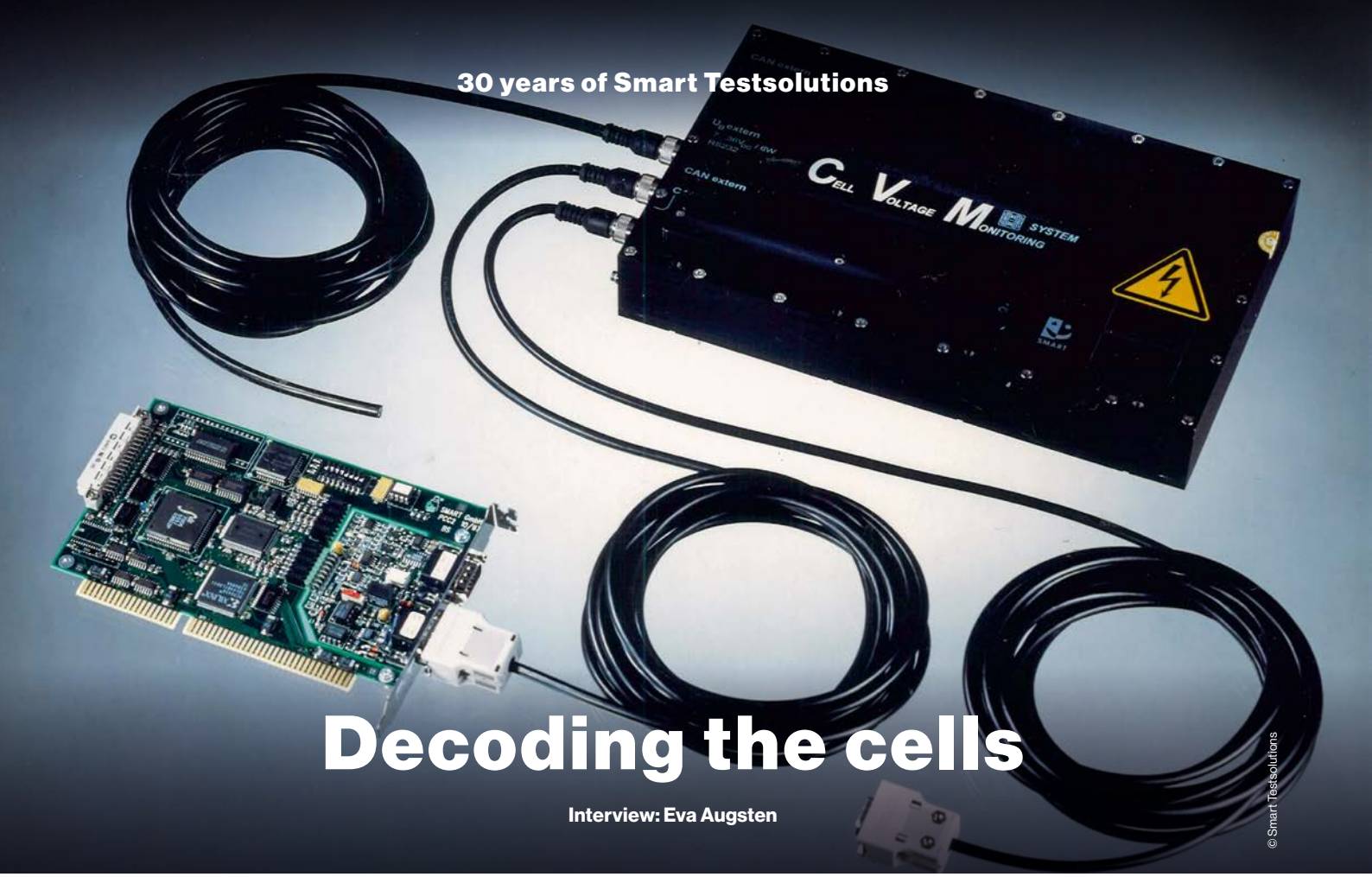
Asia is further along – there, the focus is increasingly shifting from regulation to concrete procurement: Japan and South Korea have created import pathways, state funding and long-term contracts. While the large project in Duqm (Oman) is aimed at the European market, ACME has in parallel concluded a supply agreement with the Japanese industrial group IHI – though for a separate ammonia project in the Indian Federal State of Odisha.



Duqm as a testing ground At present, it looks as though Duqm is developing into a testing ground for whether the green molecule economy is industrially scalable – under real conditions, beyond pilot projects.

For Germany this means: if the steel industry – Thyssenkrupp, HKM, Salzgitter – switches to direct reduction with hydrogen from the late 2020s onwards, green molecules will have to be imported. The ammonia from Oman could come via Rotterdam, Antwerp or Duisburg. All three ports are currently expanding corresponding terminals.

Oman's Energy Minister Al Aufi already said it at the Green Hydrogen Summit 2025 in Muscat: the ACME complex could in the long term be expanded to 1.2 million metric tons of ammonia per year. So far, however, the question remains open as to whether Europe will act quickly enough to secure the volumes to be produced in phases 2 and 3 – or whether Asia will take up the production volumes. That will not be decided in Duqm, where ACME's excavators are building the future. It will be decided in Brussels, Berlin, in the corporate headquarters of the investors, and at the next Oman Climate Week from September 14 to 16, 2026. ○



Decoding the cells

Interview: Eva Augsten

A lot can be derived from the voltage of electrolysis or fuel cells, if measured correctly and continuously. That has been the expertise of Smart Testsolutions for 30 years.

H2international: Mr. Neu, 30 years is a long time when things go up and down constantly, as they do with hydrogen. How did Smart Testsolutions manage to grow so old in such a volatile industry?

Wolfgang Neu: You have to have had a bad experience and learned from it. For us, it was the development of inverters for photovoltaics. Back then, as a young company, we developed an inverter to the point of functional maturity that had a better efficiency than all the others, and at that time we even installed the devices ourselves on rooftops. That was shortly before the 1,000 Roofs Program ended in 1992. After that, there was no market anymore. So we put our development on ice and focused on electronics for automotive applications, our core business. When the 100,000 Roofs Program was launched in 1999, we didn't have a series-ready product, and we watched competitors like SMA grow rapidly. We didn't want to repeat this mistake with hydrogen.

And what did that mean when applied to the hydrogen industry?

In 1996, we developed our first cell voltage monitoring system for the Daimler research department in Ulm. The first application was then in the NEBUS by Daimler-Benz, together with Ballard and later also Ford. Ten stacks were installed in it, each with its own electronics, interconnected using the master-slave principle in order to reach the required total voltage. That was very successful, led to an initial small series, and even to good revenues. There was a real hydrogen hype back then. But then Daimler, because of the political situation in the USA, saw no chance that the vehicles would be approved there, and the European market alone was too small. So a lean period followed. But after our experience with PV, we assumed that the topic would come back, so we had to hold out.

> "In photovoltaics, we didn't have a series-ready product when the 100,000 Roofs Program was launched. We didn't want to repeat this mistake with hydrogen."

That means you lived off the automotive business in the meantime?

Correct, off measurement and test systems and engineering contracts. Cell voltage monitoring was initially nothing more than a voltage measurement assembly.

In parallel, there were research institutions and, from time to time, pilot projects, from VW, Ford, GM. We also developed systems for submarines, which were the first series applications, on average six to eight submarines per year. These

were very special systems that we have continuously developed further.

In the automotive industry, Daimler then approached us again. At the time, however, it was still thought that cell voltage monitoring was only needed in the development phase, until the processes ran stably. Actually, today it is also firmly planned into series production. However, we no longer measure every cell, but for example the first and the last and then a few selected ones in the middle.

> "Initially, it was thought that cell voltage monitoring was only needed in the development phase. Actually, today it is also planned into series production."

What is so complicated about the cell voltage anyway? Every multimeter from the hardware store measures voltage.
We have to deliver reliable data over years, at temperatures between −40 and +105 degrees Celsius, and also when the system is freezing or thawing. It can happen that so much moisture forms that the electronics are practically bathing in the fuel cell system. There are temperature shocks, there are vibrations, all of which we have to take into account.

What about space? In the automotive industry, everything is integrated into minimal space.
The very first stack from 1996 had 127 cells and was almost 50 cm long. Today you have 400 cells at half the length. Nevertheless, the measurement is faster and has more functions. In the beginning, the electronics still consisted of individual parts, then it became more and more integrated. Contacting is also an issue, you have to somehow get to the 1 mm thin cells in such a way that it holds even under vibration. In the beginning, they were still attached individually with tweezers...

But compactness has its limits. We're talking about high-voltage systems with 400 or even up to 800 volts. That means we always have to maintain clearances and very high safety requirements so that the galvanic isolation of the supply and bus connection is absolutely safe.

With the electronics, we are now in the sixth generation. The cycles are becoming ever shorter.

Can one now speak of CVM as a series product?
The systems are intended for series applications, however, the applications are mostly in a prototype phase. The real series applications still fail because hydrogen and infrastructure are missing.

Speaking of which: What about electrolyzers? Do they also need cell monitoring, and is it easier? There is plenty of space.
We thought so too. But in contrast to earlier, today the electronics are usually wanted directly on the stack. So you're operating in an environment with explosion protection requirements. And there are different bus technologies, more likely Profinet or Profibus instead of CAN bus like in automotive.

How is AI changing measurement technology?
For us, it doesn't play a big role yet, but rather at the higher level, in data analysis. But there are approaches to integrate more intelligence into the cell voltage monitoring, and to also sample other sensors. We have already implemented something like this for a submarine. Now we are working on it for a customer in a significantly more integrated version.

And what about the competition from China?
So far, our Chinese competitors have hardly operated beyond their national borders. They are extending their feelers toward Japan, but the Japanese are very cautious, also because of political tensions. We also keep hearing that the Chinese products cannot keep up with ours in terms of stability and reliability. But in two or three years I expect competitive products from there.

So what are your plans to stay in the game?zu bleiben?
We are keeping our core business in measurement and test technology.

In hydrogen, there was a real slump starting in 2024. Now, in 2026, we are feeling a tentative revival, more projects are coming again for which we are developing series products. One is a funded project at a well-known supplier. In addition, we are in a B-sample phase with a major OEM, and in the offer phase for a customer from Japan. We are working on applications in aerospace, for example a prototype for a space organization, and for an aircraft manufacturer we are currently preparing fuel cells for flight operations. And with submarines, we now have three different manufacturers as customers. There are applications in practically every industry in which hydrogen is to be used. ○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ABOUT WOLFGANG NEU AND SMART TESTSOLUTIONS

Wolfgang Neu is founder and managing director of SMART Testsolutions GmbH, headquartered in Stuttgart. His professional roots lie in automotive electronics development at Bosch, where he worked in advanced development on functional prototypes for the first direct injection. In 1988, together with two other colleagues, he founded an engineering office from which SMART Testsolutions emerged. Since then, he has shaped the company technologically and strategically with a clear focus on measurement and test technology for demanding electronics and automotive applications.

How policymakers can mobilize private capital

Text: Klaus Ulrich Hachmeier

Without government kick-start support, the ramp-up of the hydrogen economy will not succeed. CfDs could serve as a bridge to competitiveness, argues our guest author from CIP, a global fund manager and leading investor in renewable energy infrastructure.

In Germany, the low-carbon hydrogen economy is still in its infancy. Without steady and strong policy support, this will not change. The gap between the market prices expected for the coming years and the price level acceptable to internationally competitive industry is simply too wide. The latter lies between two and three euros per kilogram of hydrogen, depending on the sector and purpose.

That is far removed from the market prices of five to twelve euros per kilogram forecast in the German Federal Government's monitoring report. The ramp-up must therefore be driven by public policy and reliably designed so that the financing of concrete projects by private investors gains momentum.

The Hydrogen Acceleration Act (Wasserstoffbeschleunigungsgesetz, WasserstoffBG), which entered into force in April of this year, is at least an important boost for the sector. Since then, hydrogen infrastructure facilities and pipelines have been classified as being "of overriding public interest," which underscores the political determination to develop this energy carrier and the associated technologies.

The tightening of the greenhouse gas reduction target adopted by the Bundestag, the Federal Parliament of Germany, also points in the right direction: for several years now, fuel suppliers have been obligated under the German Federal Immission Control Act (Bundes-Immissionsschutzgesetz, BImSchG) to progressively reduce the CO2 intensity of their fuels.

Alongside the blending of biofuels and the provision of electricity for electric vehicles, the use of green hydrogen in refineries is the most important option for this purpose. The Bundestag's decision provides even more momentum than the Federal Government had planned. Specifically, the greenhouse gas reduction mandate (THG-Quote) will be extended through 2040, rising incrementally from the current 10.6 percent to 65 percent, six percentage points more than the draft adopted by the cabinet had envisaged.

Decisive for the hydrogen ramp-up is the so-called "RFNBO sub-quota," which specifies a minimum blending of green hydrogen (RFNBO stands for renewable fuels of non-biological origin). It stands at 1.5 percent for 2030, three percent for 2032, and is intended to rise to ten percent by 2040. To meet these sub-quotas, however, electrolysis capacities of an estimated more than three gigawatts (GW) would be necessary for 2030 alone.

Slowed down by the cabinet Unfortunately, the Federal Government is slowing progress elsewhere: according to the recently published draft of the Electricity Supply Security and Capacity Act (Strom-Versorgungssicherheits- und Kapazitätsgesetz, StromVKG), the hydrogen-capable gas reserve power plants once envisaged as important anchor customers are initially only to be implemented in a weakened form. They merely need to be "H2-ready" so they can later be upgraded for operation with hydrogen.

That means additional investments for retrofitting down the road. And the originally ambitious expansion targets for electrolyzers of ten gigawatts by 2030 are to be replaced by "flexible" targets that, due to their vagueness, hardly convey any political or economic signaling effect.

In short: the signals from the political sphere are currently not very coherent and thus not well suited to supporting the hydrogen ramp-up. A robust foundation for a dynamic increase in positive investment decisions has so far not been established. For this to change, several conditions must be met:

1. Predictable revenue streams and viable financing structures Long-term offtake contracts with creditworthy counterparties are a central prerequisite for the economic viability of hydrogen projects. Without industrial customers, energy suppliers, or the state as long-term offtakers or guarantors, raising debt capital will hardly be possible.

After all, the funds raised must later be serviced from the reliable cash flows of the project. Since the current market prices for green hydrogen do not yet meet the competitiveness required by industrial customers, an active government is indispensable to temporarily bridge this gap.

To attract private capital, sound project structuring is also required. Hydrogen projects must be clearly delineated and have robust project rights, all required permits in place, and transparent and reliable governance structures.

2. Regulation and support Regulatory risks are often the most difficult risks for project developers to hedge. This is precisely why coherent regulation that follows a comprehensible logic is so important. The legislator's strategy here is to stimulate ▷

the market ramp-up through incentives on both the supply and demand sides. The largely averted weakening of the European Emissions Trading System (EU ETS), the almost completed implementation of the RED III Directive in the transport sector, and the strengthened THG quota will have a positive effect on demand for green hydrogen.

In addition to these instruments, Carbon Contracts for Difference (CfDs) are also a proven means of increasing the investment security of hydrogen projects. They reduce price risk by hedging the difference between the still too-high production costs for green hydrogen and the market prices of fossil energy.

"With the 2027 federal budget, the Federal Government could set a decisive impulse for the hydrogen ramp-up by creating the foundation for hydrogen CfDs and further guarantee instruments."

Such state-backed contracts would offer green hydrogen producers long-term planning security by guaranteeing the offtake of defined volumes over several years. An alliance of the energy industry, industry, SMEs, and municipalities has proposed a model to the Federal Government showing what this could look like in concrete terms, one that would reduce the cost gap and secure demand.

Specifically, by combining CfDs with guarantee instruments in such a way that they bundle generation and demand on the one hand and incentivize cost efficiency through market-based action on the other.

Through the competitive award of CfD contracts in an auction procedure, this financial predictability would provide financial certainty for all actors in the supply chain, a genuine launching point for the ramp-up of the hydrogen economy.

Outlook: Innovative future fields Despite the currently stalling hydrogen ramp-up, there is so far no doubt that green or low-carbon hydrogen remains an essential building block of decarbonization. It will foreseeably have to be deployed in large quantities. Already now, the focus is on new application fields and technological innovations, not least to advance cost declines for green hydrogen.

One possible building block is artificial energy islands to produce green hydrogen from offshore wind power in the North Sea. With the help of this future technology, wind power could be used that would otherwise have to be curtailed due to grid bottlenecks. And it would save billions in the transformation of the energy system, because the very expensive electricity transmission lines from offshore wind farms to the mainland could be built with significantly lower capacity.

Instead, the wind power generated at sea would be used directly offshore for hydrogen production, and the hydrogen would then be transported cost-efficiently to shore via pipelines. Offshore hydrogen production in the framework of demonstration projects in the North Sea should therefore be realized as quickly as possible.

As a further possible building block, "white" hydrogen, which occurs naturally in the earth, should also be considered. Admittedly, the data situation regarding deposits and economic feasibility is still unclear. All the more reason that the Federal Government has taken initial steps with the Hydrogen Acceleration Act that enable exploration and potential development.

Overall, the hydrogen ramp-up in Germany stands at a crossroads. With the consistent further development of existing support programs, in particular through a national program for hydrogen CfDs, the Federal Government could underscore its commitment to the technology.

From an investor's perspective, well-structured projects with clear revenue streams are needed. If the Federal Government succeeds in reliably establishing a policy mix with the elements described, sufficient private capital can in any case be mobilized for a successful ramp-up. ○

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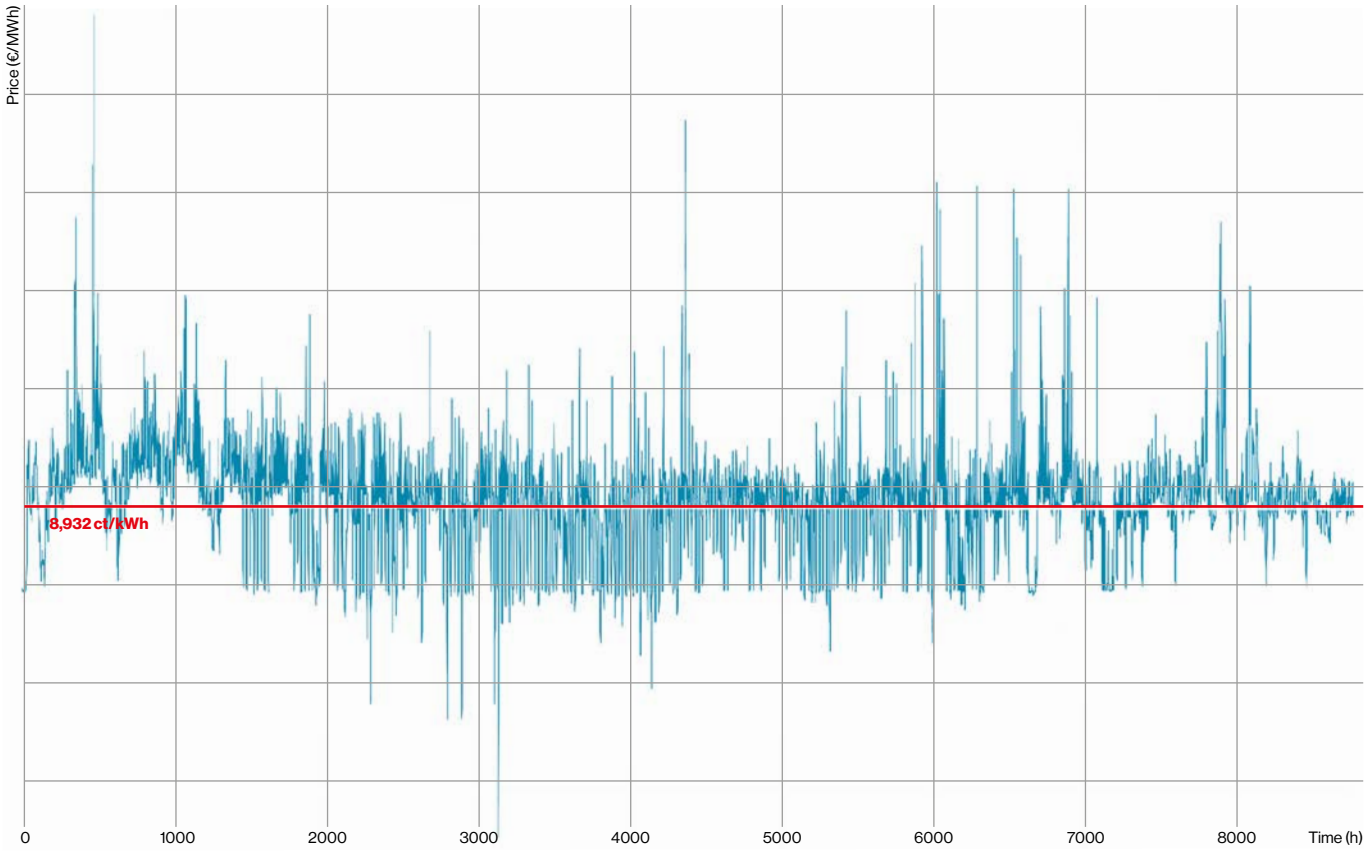
Economically attractive and ready for immediate implementation

Text: Marcel Corneille

Green hydrogen in the natural gas grid already bridges the gap between producers and consumers today. This potential should be leveraged more strongly to accelerate the German market ramp-up, argues our guest author from the engineering firm Emcel. No technical adjustments are required while simultaneously providing climate benefits.

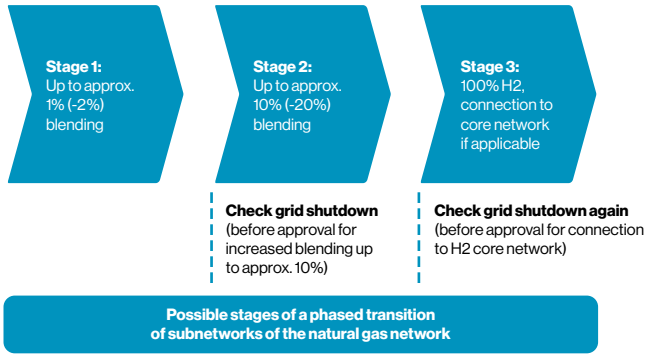


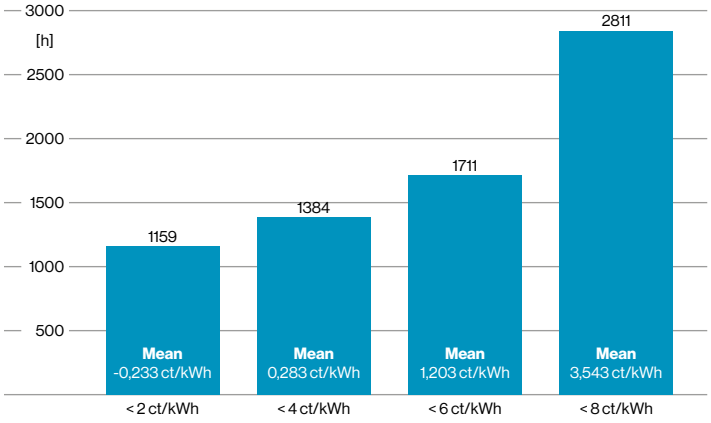
Blending hydrogen into the natural gas grid could play an important role in the market ramp-up of the hydrogen economy. Large industrial consumers and parts of the transport sector are only gradually developing their hydrogen demand, and many projects are still waiting for viable sales markets. Blending can already create additional marketing opportunities today and support the build-up of electrolysis capacities.

Numerous demonstration and pilot projects over the past years have proven that ▷

Trend of exchange electricity prices in Germany 2025: The average electricity price was below 9 ct/kWh.

Data source: SMARD market data





this is technically feasible and safe. Eon demonstrated this as early as 2013 with its 2 MW power-to-gas facility in Falkenhagen, in the federal state of Brandenburg. Further examples can be found in Haßfurt, a small town in Bavaria, and in the grid area of Eon subsidiary Avacon, among others.

Marketing via existing gas grids has proven successful in practice. In Falkenhagen and Haßfurt, utilities offered the blended hydrogen to their customers as "wind gas" under a green energy tariff. At the same time, electrolysis capacities can be built up that can later serve additional fields of application. In Haßfurt, for example, the green hydrogen produced is additionally used in a hydrogen combined heat and power plant.

Often ten percent feed-in possible A great deal has changed in the regulatory framework in recent years. The feed-in of hydrogen into gas grids is now generally regulated by law and takes place within a framework similar to the feed-in of biogas. Technical requirements are defined in particular by the code of practice of the German Technical and Scientific Association for Gas and Water (Deutscher Verein des Gas- und Wasserfaches, DVGW).

Currently, hydrogen shares of up to ten percent by volume are possible in many grid areas in Germany. Beyond that, practical tests with higher shares have already proven successful, for example a 20 percent blending in the Jerichower Land region in the federal state of Saxony-Anhalt, also carried out by Avacon in 2022. Further adjustments to the limit values are therefore to be expected.

What is decisive here is not only the hydrogen in the gas mixture. The blended hydrogen can additionally be combined with bio-methane, thereby further increasing the share of green gas in the gas grid.

Decarbonization included The aim of blending is to provide climate protection today. Depending on the operating mode and utilization, a 1 MW electrolyzer can avoid several hundred tons of CO2 per year. Blending thus represents a way to put renewably produced hydrogen to effective use immediately in principle, while simultaneously gaining experience for the further expansion of the hydrogen economy.

One of the greatest challenges of the hydrogen economy at present is not the production of hydrogen but its marketing. While demand in many future target markets, such as industry, aviation, or heavy-duty transport, still lags behind expectations, blending hydrogen into the existing gas grid can be an interesting and attractive business model for operators of decentralized electrolysis plants.

The underlying principle has been known from the electricity market for many years. With the help of guarantees of origin and a balance sheet allocation between generation and consumption, customers can specifically choose a green electricity tariff. A comparable model can be transferred to the gas market. Customers who consciously opt for a more climate-friendly gas product take out a corresponding green gas tariff and receive proof of the balance sheet share of renewable gases. Such offers already exist on the market, but only in very limited quantities.

Without technical effort The decisive advantage of this approach is that the moderate blending of one to two percent requires practically no adjustments to the existing infrastructure. At the same time, a marketable product emerges that addresses different customer groups. In addition to private households, particularly municipal utilities, commercial customers, and companies with their own sustainability and decarbonization targets come into question as consumers.

Experience from the green electricity market shows that a notable share of customers is willing to pay a premium for climate-friendly energy sources. From a business perspective, it is precisely this premium that is the key to economic viability. Hydrogen is

The analysis of exchange electricity prices in 2025 shows that there were around 1,200 hours in which electricity was available for an average of 0 ct/kWh. This makes the operation of electrolyzers and H2 blending economically interesting.

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Data source: SMARD market data

Parameter	Symbol	Value
Natural gas price	$€_{CH4}$	10 ct/kWh
Green gas surcharge	$€_{Öko}$	1 ct/kWh
Hydrogen price	$€_{H2}$	39 ct/kWh = 13 €/kg
H2 share	**x**	**10 % vol***

* Hydrogen has approximately 1/3 of the volumetric energy density of natural gas.

$$> \quad \chi = \frac{€_{Öko}}{€_{H2} - €_{CH4}}$$

$$> \quad \chi = \frac{1\,\frac{ct}{kWh}}{39\,\frac{ct}{kWh} - 10\,\frac{ct}{kWh}} = 0{,}035 \rightarrow \textbf{10 Vol. \%}$$

The table and calculation show that with a natural gas base price of 10 ct/kWh, a green gas surcharge of 1 ct/kWh, and an assumed hydrogen price of 13 €/kg, a hydrogen blending share of ten percent by volume results.

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currently still more expensive than natural gas. The decisive factor is therefore not the energy price alone but the willingness to pay for a climate-friendly product. Even a comparatively small surcharge on a green gas tariff can be sufficient to generate economically interesting revenues for hydrogen fed into the grid.

Sample calculations show that at suitable locations, with a blending of ten percent hydrogen by volume, sales revenues on the order of around 13 euros per kilogram of hydrogen are achievable, a value that is already economically attractive for many projects today.

In addition, the framework conditions for the operation of electrolyzers have improved significantly in recent years. Various levies and grid fees are waived under certain conditions for hydrogen production from renewable energies.

Already economically viable As a result, electricity costs, which account for a large share of hydrogen production costs, are reduced. Furthermore, there are additional revenue potentials for by-products of electrolysis, such as the use of waste heat, the marketing of oxygen, or revenues from grid-serving operating modes.

Blending hydrogen enables a gradual transformation of existing gas grids without immediately requiring extensive infrastructure measures or complete grid conversions. Instead of an abrupt change, development should take place in three essential stages (see corresponding figure).

First, small hydrogen shares of one to two percent by volume are fed in. Practically all sub-grids are already capable of this today. In a second phase, the shares can be increased, depending on the technical prerequisites of the respective sub-grid, to ten to twenty percent.

In the long term, a fully hydrogen-capable grid can emerge from this, or a connection to the hydrogen core grid being built up in parallel can be made.

Between these steps, there is always the critical examination of whether the decommissioning of the respective sub-grid is advisable or whether the sub-grid will no longer be utilized in the future because former users have, for example, switched to heat pumps. A key advantage of this approach lies in its flexibility.

As the hydrogen economy expands, the quantities produced can later also be made available to other sectors, for example industry, mobility, or directly to the hydrogen core grid.

> “Investments in electrolyzers are thus already creating production capacities today for the future hydrogen supply.”

Local value creation This approach is particularly interesting for decentralized projects. While large electrolysis plants with capacities of several hundred megawatts will often be built in the immediate vicinity of the hydrogen core grid, plants of one to ten megawatts of capacity can specifically tap regional potentials.

They use existing renewable energy sources on site, reduce transport requirements, and create local value. At the same time, they can contribute to gaining experience with the operation of hydrogen plants and gradually building up regional markets for hydrogen.

Hydrogen blending should therefore not be understood as competition to the hydrogen core grid or other green gases. All approaches fulfill different tasks on the path to complete decarbonization. ○

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To the Lofoten Islands with green hydrogen

Text: Holger Matthiesen

The 20 MW hydrogen electrolysis plant in Langstranda near Bodø is a joint project between the European infrastructure investor Luxcara and the Norwegian developer GreenH. Their goal: zero-emission shipping for regional and coastal transport.

The view from the ferry terminal in Bodø stretches far across the Vestfjord, which opens up in front of the harbor. On windless days, the crossing to the Lofoten Islands feels almost peaceful, while on others it demonstrates impressively just how rough the sea can be north of the Arctic Circle. The connection between the Norwegian mainland and the Lofoten Islands is the longest regular ferry route in the country. In the small town of Bodø, one of Norway's largest hydrogen projects is currently being developed. In the future, hydrogen is set to become an integral part of daily life here, both for the people living in the region and for its visitors.

Secured demand enables the launch. The backbone of the first expansion stage, with a capacity of 20 MW, is a long-term offtake agreement with the ferry operator Torghatten Nord. It was crucial for solving the well-known chicken-and-egg problem between hydrogen production and use. The guaranteed offtake creates reliable revenues and significantly reduces the risks associated with project financing. Publicly regulated or concessioned transport services are therefore particularly well suited as anchor customers for building a regional hydrogen infrastructure.

After commissioning and test operations have been completed, regular operations are scheduled to begin in the course of 2027. Then, two ferries, each 117 meters long and the largest hydrogen-powered ferries in the world to date, will transport up to 120 vehicles and nearly 600 passengers per crossing to Moskenes in the Lofoten Islands. Through the use of five to six metric tons of green hydrogen per day, an estimated 26,500 metric tons of CO2 emissions can be avoided per year. This makes the route an important example of how climate-friendly technologies can also be established under demanding maritime conditions.

The hydrogen project is deliberately designed to be modular and can be expanded in the future. In a possible phase 2, another 10 MW could be added. Planning and engineering of the current phase are already complete, and the central components are being delivered. Construction and installation at the port site are already underway.

The maritime sector in particular clearly demonstrates the conditions under which hydrogen mobility outperforms purely battery-electric drives. This also applies to ships operating near the coast, such as ferries with longer crossings, as well as offshore, oil, and gas supply vessels.

The substantial weight and high volume of the onboard batteries required for longer ranges prove to be limiting factors in several respects: in the design of the ships, in the permissible cargo weight, and also in operational flexibility.

For this, hydrogen-based solutions already exist today as a practical, emission-free option. The Bodø-Moskenes route

Photo: © Einar Aslaksen / Graphic: © NEONBOLD / Freepik.com

is exemplary of a regulated, reliable transport demand, and thus of precisely the planning certainty that enables investments in new infrastructure.

Short distances in the port. A key feature of the project is spatial integration. The hydrogen plant is being built directly at the port, with storage and compression solutions part of the overall concept from the outset. In addition, the project includes a directly connected bunkering system, through which the hydrogen produced in the plant can be delivered to ships using the cascade principle. The short distances not only increase efficiency but also simplify safety, permitting, and operational concepts.

The port thus becomes a system space in which production, logistics, and utilization are brought together. For port operators and municipalities, this approach is particularly relevant. It reduces complexity because interfaces are minimized and responsibilities can be clearly assigned. Instead of many isolated individual measures, a consistent system is created that can be expanded step by step, for example through additional offtakers, higher production volumes, or new ship types. This configuration makes the approach relevant beyond the individual case.

Many European port and coastal regions have similar preconditions. These include access to a reliable electricity supply based on renewable energy, as is typical for many sites in northern Norway.

The combination of predictable availability of green electricity and spatial proximity between production and offtake creates favorable conditions for continuous operation, a factor not to be underestimated for economic viability in the early market phase.

Looking ahead, the integrated plant concept also opens up the possibility of using by-products such as waste heat or oxygen from the electrolysis process onsite. Such efficiency gains increase the attractiveness of the site without requiring additional infrastructure. ▷

Reliability as an investment factor. The ramp-up of maritime hydrogen applications depends on a reliable regulatory environment. In Norway, clear climate policy targets in the transport sector meet a comprehensive funding landscape.

The targeted support for the market ramp-up of hydrogen-based shipping, including through funding programs by the state-owned company Enova, covers both the construction of ships and the development of the necessary hydrogen infrastructure.

Funding can cover up to 80 percent of the additional costs incurred when replacing a diesel-powered ship with a hydrogen-based propulsion system.

Not overly detailed regulation. For the market ramp-up, what is decisive is not the absence of regulation, but its concrete design and application. Funding programs such as those of Enova are indeed linked to reporting and compliance requirements that can bring additional challenges during the implementation phase.

At the same time, the Norwegian example shows that a technology-open funding framework, combined with a clear focus on early applications and sectoral priorities, enables the realization of projects without all regulatory details having to be conclusively clarified in advance.

Norway is part of the European single market but not a member of the EU. Nevertheless, the country does not take on a special role but is deliberately advancing the introduction of green hydrogen, in particular by promoting demand, for example in maritime transport, and through reliable political framework conditions.

A model for the EU? The combination of ambitious targets, targeted demand promotion, and pragmatic implementation offers good guidance for other European coastal regions as well as for the EU debate on how the ramp-up of green H2 can be accelerated through less restrictive requirements.

A structural advantage of Norway lies in its electricity system: the almost entirely renewable electricity mix ensures that EU requirements for green hydrogen, especially regarding temporal correlation and geographical proximity, are much less significant than in many EU member states.

For future exports to the EU, this offers favorable conditions for meeting the corresponding requirements. However, the project in Bodø, in its current expansion stage, is primarily geared toward supplying the Norwegian market.

Hydrogen as a question of mentality. The approach from Bodø cannot be transferred one-to-one. What is transferable, however, is the underlying mindset: clear use cases, integrated site concepts, and early contractual security. Where these elements come together, hydrogen can make a pragmatic contribution to the decarbonization of the maritime economy. ○

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LUXCARA
Luxcara is an independent European infrastructure investor headquartered in Hamburg, Germany. The asset manager focuses on long-term investments in energy infrastructure. In addition to wind power and photovoltaic plants, Luxcara's portfolio also includes charging stations for electric vehicles, battery storage systems, and electrolyzers for the production of green hydrogen.

GREENH
GreenH is a Norwegian project developer for green hydrogen solutions headquartered in Oslo. The company develops integrated concepts for the production and use of hydrogen, particularly in the maritime sector and at several locations in Norway.

Test planes cleared for take-off

Text: Steven Oji, Carolin Anger

At the end of April, Aero 2026 took place in Friedrichshafen, one of the leading aviation trade fairs with more than 850 exhibitors. Steven Oji and Carolin Anger of Hyfindr took a look around, and found an industry in the midst of a debate about sustainable propulsion systems.

Between aircraft on the tarmac and well-attended halls, a clear picture emerged: the industry is not looking for the one perfect solution, but for a viable compromise between efficiency, performance, and scalability. The planning horizon of this industry is comparatively long, which is why short-term sentiments are less of a focus. Hydrogen is becoming increasingly relevant, because the energy demand in aviation is enormous, particularly during take-off and on longer routes. This is precisely where purely battery-electric solutions quickly reach physical limits.

Hydrogen as a practical middle ground Several interlocutors therefore described hydrogen as a "practical middle ground." Irwin Kerboriou of Beyond Aero, a French company that intends to build a hydrogen aircraft, put it very aptly: hydrogen enables "a good compromise between efficiency and performance."

At the trade fair, the discussion was no longer only about future scenarios; concrete systems could be seen, ranging from fuel cell solutions to specialized components and even first test aircraft. Companies such as Green GT, EKPO, and Kasaero are driving development forward.

Small aircraft in test operation The company Kasaero, which specializes in engineering services for aircraft, has developed a hydrogen-powered ultralight aircraft whose electric variant is already in flight operation, reports project manager Erick Vianello. The company is currently looking for additional investors for this project.

Research institutions and student teams are meanwhile testing prototypes. Prof. Johannes Markmiller, Professor of Aircraft Engineering at TU Dresden, explained in an interview that his twin-engine Diamond DA62 MPP aircraft is now entering test operation with a hydrogen propulsion system. This is a special version of the aircraft type that, according to media reports, the German Federal Chancellor flies privately.

Commercial applications still take time The projects show that the technology is increasingly gaining traction in practice.

Despite the positive momentum, realism was also tangible. Infrastructure, certification, safety requirements, and the availability of green hydrogen remain major challenges. In particular, larger, commercial applications will still require years, if not decades. The innovation pressure on aviation from the Far East, and especially from China, is already being felt, and this is accelerating projects in the here and now, so that they can hold their own in competition later.

Reducing dependencies Another topic in many conversations was energy sovereignty. Hydrogen is no longer viewed solely as a climate protection solution, but also as a strategic factor. Frédérich Thébault of the company GreenGT, which presented fuel cell systems for the aviation industry at the trade fair, summed it up as follows: hydrogen offers "an energy-politically sovereign alternative to fossil fuels." Particularly in a geopolitically uncertain environment, this is an argument that is gaining importance.

The attitude of a relevant portion of the industry is remarkable: the willingness to pursue new paths is clearly noticeable. Hydrogen in aviation is no longer a distant future topic, but an ecosystem that is beginning to take shape. ○

Steven Oji, Carolin Anger
Hyfindr GmbH

Hyfindr-Video of Aero 2026

Molecules with a quota

Text: Claus Bünnagel

Heavy-duty trucks are actually a perfect use case for the energy carrier hydrogen. But in the logistics industry, cost pressure is particularly harsh. The newly introduced tradable GHG quotas and the new funding program from the German federal government could help make the market entry possible.

With its five-year plans, China has already announced and captured market-leading positions in several key industries, for example in solar, battery, semiconductor, and automation technologies. With the 15th Five-Year Plan (2026–2030) presented in March 2026, the Middle Kingdom is going one step further. The draft submitted to the National People's Congress reads like a catalog of the most important future technologies: artificial intelligence, semiconductors, robotics, quantum technology, biotechnology, nuclear fusion, drones, 6G technology, and brain-computer interfaces. China intends to set the tone in all of these areas in the future.

The most recent five-year plan lists an additional area for this: hydrogen technology. Since 2021, a large-scale trial has been underway in 44 Chinese cities in so-called "China Hydrogen City Clusters" to empirically investigate the benefits of hydrogen in transportation and in other industries. The deployment of buses and other fuel cell vehicles is an important part of the experiment. However, pipelines for transporting hydrogen and refueling stations are also being built. That said, even the Asian superpower cannot work miracles: according to the statistics of the automotive manufacturers' association CAAM, only 23,501 fuel cell vehicles in total were sold in the People's Republic between 2015 and 2024, with a downward trend since then.

But things are slowly picking up in the Middle Kingdom when it comes to H2 vehicle models. In mid-May 2026, Dongfeng presented a 49-ton truck in Wuhan equipped with

LEFT: Five Daimler GenH2 hydrogen trucks have been shuttling for around one and a half years in the regions between the two currently available liquid H2 refueling stations in Duisburg and Wörth am Rhein.

© Daimler Truck AG

BELOW: According to the Chinese manufacturer, the 49-t truck from Dongfeng presented in mid-May 2026 in Wuhan with the 400 kW Hydrogen Core fuel cell system on board achieves a range of up to 1,700 km with a refueling time of 15 minutes.

© Dongfeng

the 400 kW Hydrogen Core fuel cell system on board. According to the Chinese commercial vehicle giant, it is said to have a service life of more than 30,000 hours and to allow a cold start at temperatures as low as -40 °C. The fuel cell platform with metallic bipolar plates has also passed the 10,000-hour endurance test according to the new national standard. According to Dongfeng, the tractor unit weighs only 8.8 tons and, with a refueling time of 15 minutes, achieves a range for the entire truck combination of up to 1,700 km, notably measured according to the less stringent Chinese CLTC test cycle.

European manufacturers are well positioned How worried should Europe, and specifically Germany as the leading European nation in the field of fuel cell technologies, be about being overtaken by China? Technologically, Europe is well positioned, both in terms of fuel cell technology and matching vehicle models. In the logistics sector, this ranges from vehicles such as the Mercedes-Benz NextGenH2 Truck with liquid gas tanks, to the brand new EVA dispenser from H2 Mobility with its short refueling time of on average 6:45 minutes for 20 kg of hydrogen, and the CryoPump station from Bosch Rexroth for hydrogen refueling stations, to the BZA375 fuel cell system from Cellcentric. The latter two were only recently presented at the Hannover Messe in April 2026 in Hanover. With the BZA375, a fully loaded 40-t truck should be able to get by with less than 6 kg of hydrogen per 100 km under real driving conditions, achieve ranges of more than 1,000 km, and reach refueling times comparable to those of diesel.

Vehicle and tank technology is not currently the biggest hurdle. Where things are stalling can be summed up in four words: funding, bureaucracy, customer initiative, hydrogen price. But here too, there is light at the end of the tunnel. In January 2026, the German Federal Ministry of Transport re-entered the funding of H2 mobility in Germany. It is providing 220 million euros for the establishment of a nationwide initial network of hydrogen refueling stations for heavy commercial vehicles in Germany. Up to 40 refueling stations and 400 hydrogen-powered commercial vehicles are being funded. Refueling station operators can be reimbursed for up to 50 percent of the eligible expenditures for building new hydrogen refueling stations. The prerequisite is that the facilities meet the requirements of the European AFIR regulation (Alternative Fuels Infrastructure Regulation). For new hydrogen trucks of vehicle classes N2 and N3, the funding amounts to up to 80 percent of the additional investment expenditures compared to a diesel vehicle. Originally, a deadline of May 31, 2026 had been set for submitting applications. Due to the strong response, however, the submission period was extended to June 30, 2026.

Hopes pinned on GHG quotas Excessive bureaucracy and regulatory frameworks have so far stopped or delayed many projects. For a long time, this also applied to the application of greenhouse gas reduction quotas (GHG quotas). After lengthy bureaucratic processes, this process is now slowly getting underway. Both producers of green hydrogen and the logistics industry are pinning great hopes on it.

The incentive system at the German federal political level works as follows: those who exceed their GHG quota can sell the surplus certificates to a third party who also has to meet reduction quotas. If companies place green, RFNBO-certified (RFNBO = Renewable Fuels of Non-Biological Origin) and thus quota-eligible hydrogen on the market via their refueling stations, they can participate in this certificate trade. This generates additional revenues for fuel traders and lower costs for logistics operators, which in the first market phase mitigates the additional costs for the infrastructure and the vehicles.

For example, Tyczka Hydrogen GmbH, a hydrogen producer and supplier from the Federal State of Bavaria, certified since April 2025, can already offer hydrogen at 350 bar at its refueling station in Augsburg for approximately 9.00 euros/kg net under the GHG quota scheme. And refueling station leader H2 Mobility also announced at the end of May 2026 that as of June 1 it would initially reduce the prices for hydrogen at several high-throughput refueling stations by around 10 percent. This affects the locations in Mannheim, Heidelberg, Frank- ▷

enthal, Ludwigshafen, and Düsseldorf-Höherweg and applies to the 350 and 700 bar pressure levels. Martin Jüngel, managing director and CFO of the company, commented: "With the price reduction at our high-volume locations, we are making the benefits of GHG quota trading tangible for our customers for the first time. Our goal is to make green hydrogen competitive and to actively accelerate the market ramp-up."

However, H2 Mobility also reports to H2international that "at present, tenders for hydrogen refueling stations frequently stall or even fail several times." In one specific case, a tender came to nothing three times and could only be successfully implemented on the fourth attempt, after the approach had been fundamentally redesigned. H2 Mobility itself has recently closed several hydrogen refueling stations, especially for 700 bar passenger car refueling, but also smaller commercial vehicle depot stations. The company is now building new facilities primarily at locations with larger transport companies as anchor customers, which with their city buses form a reliable daily core customer base.

Showcase projects with varying success But it is not only bureaucratic hurdles that prevent customers from getting on board. Many shy away from the risk of the "hydrogen adventure." Lighthouse projects, such as the following two, are intended to show how it works in the best case. Between the two first available liquid hydrogen refueling stations in Duisburg and Wörth and in the region, five Daimler GenH2 hydrogen trucks have been in operation for around one and a half years. And four DAF CF trucks, converted into fuel cell trucks by the Dutch vehicle manufacturer VDL, have been running for a year from Toyota's European central warehouse in Diest, Belgium, to various depots in Amsterdam, Rotterdam, Lille, and Cologne.

Scaling up in reality is often more complex. The Korean passenger car and commercial vehicle manufacturer Hyundai alone has delivered 165 of its Xcient Fuel Cell heavy-duty trucks, which are on the road in Germany, France, the Netherlands, and Austria. All trucks together exceeded the mark of 20 million kilometers in the winter of 2025/26, and did so within a very short time compared to the 10 million km mark, which was only reached in June 2024. But of all things, in the showcase project in Switzerland, where the first vehicles started almost six years ago, only 50 trucks are on the road instead of the 1,500 planned by 2025. Hyundai is planning neither a successor to the Xcient nor a model refresh, and from 2030 a performance-related heavy vehicle charge (LSVA) will also be due in Switzerland for such electrified vehicles. The continuation of the Swiss federal model project is therefore up in the air.

The hydrogen price must come down All projects have one thing in common: the participating hauliers complain about the far too high H2 price per kilogram. In the case of Toyota's parts supply, up to 18 euros/kg sometimes have to be paid, for example in the Netherlands. Even at 9.90 euros/kg, the operation of fuel cell trucks can hardly keep up in the long term given the increasing presence of their battery-electric counterparts, especially as the latter are catching up in terms of range in seven-league boots, according to reports from the ranks of the logistics companies involved.

The cost comparison between pure battery electric vehicles and their fuel cell counterparts paints a clear picture: a heavy-duty electric truck consumes around 110 to 130 kWh per 100 km depending on the field of application and topography, while the H2 counterpart consumes about 6 to 8 kg of hydrogen. At a current commercial electricity price of 27

LEFT: The refueling nozzle on the DAF-VDL from Toyota is located on the left behind the driver's cab. In the future, refueling should be possible via two nozzles simultaneously in order to minimize refueling times. © Toyota

BELOW: Due to the tower arrangement of the hydrogen tanks, no space is lost for the usual dimensions and load on the DAF-VDL-Toyota truck. © Toyota

ct/kWh, the electric truck "refuels" for this distance at its own depot at 29.70 to 35.10 euros, significantly cheaper than the hydrogen truck at kilogram prices currently mostly between 13.85 and 15.80 euros with a price range of 83.10 to 126.40 euros/100 km.

At least: the current energy price crisis as a result of the Iran war has significantly narrowed the gap to classic diesel, still the most important benchmark. At a net price of 1.71 euros per liter in April 2026 and a consumption of around 30 to 35 liters per 100 km, the 40-ton combustion engine truck at currently between 51.30 euros and 59.85 euros/100 km is no longer significantly cheaper than a fuel cell truck. However, the gap could widen again should the conflict at the Strait of Hormuz come to an end.

The hydrogen price is still the biggest hurdle for the rollout of fuel cell technology in logistics. All other problem areas can be resolved in the short to medium term. For hauliers, every cent counts in pricing for their customers, even more so than for municipal transport companies, for example. Approaches such as the GHG quotas and other governmental regulations therefore appear urgently necessary. ○

Claus Bünnagel
Claus Bünnagel is editor-in-chief of the magazine busplaner and writes as a freelance journalist for trade media in the transportation sector. He has personally tested the hydrogen trucks from Toyota.

The Powder that could cut costs

Interview: Eva Augsten

Catalysts made of platinum and iridium are still a cost driver in the hydrogen economy. Christian Mohrdieck took over as head of the catalyst manufacturer Pajarito Powder in April and is convinced that his company's products can reduce the cost of fuel cells by one-fifth.

H2international: Mr. Mohrdieck, you bring 34 years of experience from major automotive corporations such as Daimler and Mercedes to Pajarito Powder, a manufacturer of catalyst materials with around 35 employees. What do you want to change in your new position as CEO?

Dr. Christian Mohrdieck: For me, it's a shift from looking at the system level to the level of the core components. These need to be revisited for the next stage of commercialization. We have good ingredients, now it's about the best recipe.

Pajarito Powder already has good products. But we need to adapt them more to the business and processes of the automotive industry and make them suitable for series production in order to get the optimum out of the core components as well.

And of course it's no secret that networking is important. You have to talk to the right people on the customer side.

How much is there still to gain with the catalysts? Platinum quantities have already been reduced enormously.

A fuel cell system for a passenger car contains 10 to 20 grams of platinum, in a truck it is two to three times as much. Even today, the catalyst can account for more than half the cost of a fuel cell stack. I think that in the ideal case, we can reduce the cost of the stacks by 20 percent by saving 40 percent on the catalyst. This is primarily about using less platinum and better utilization.

"By saving 40 percent on the catalyst, we could reduce stack costs by up to 20 percent."

© Pajarito Powder

The platinum content varies depending on customer requirements. For a truck, one tends to use around 60 percent by weight, but practically no one wants to go below 40 percent by weight. The catalyst degrades over time. This means that high performance can initially be achieved with relatively little platinum, but then the fuel cell doesn't last as long.

How do you reduce the platinum content in such a way that the cell still works well?
We use a mesoporous, i.e. medium-porous, carbon support material. It offers a large internal surface area on which platinum can attach without forming clumps. We also have a whole toolkit of additives and dopants, for example with niobium or cobalt, that can be used to improve activity.

What about iridium?
Iridium is even more expensive than platinum. In fuel cells, it is used when the cells need to be tolerant of cell voltage reversal, for example during a cold start or after longer downtimes. But above all, it is used in electrolyzers and accounts for a large share of the cost there, even more than platinum in fuel cells.

Can such scarce and critical materials as platinum and iridium not be replaced by others?
For platinum, the basic availability is good. Modern fuel cell cars ultimately need similar quantities of platinum as the exhaust catalysts of combustion engines. Iridium is more critical. However, there is no alternative in sight.

> "There is no alternative to iridium in sight, so we have to increase utilization."

So we have to increase utilization. Our activity per mass for iridium is almost twice as high as the published values of our competitors. When transitioning to large-scale production, performance will probably decrease a little, but this will be offset by a boost in cost reduction.

Where do we stand in terms of scaling and industrialization?
With our new line, we can produce batches of up to 20 kilograms, of which up to 60 percent by weight is platinum. The potential customers now want to see how the line runs.

We are on the shortlist for fuel cells with a manufacturer from Asia. We have qualified for the supply chain of one of the world's top-5 electrolyzer manufacturers from North America. In Europe, we are talking with several contacts about smaller quantities.

Especially in the automotive sector, standards such as ISO standards are important. We have just hired an experienced quality manager for this. Particularly important in documentation, for example, is traceability. Basically, these ISO audits can be carried out at any production volume.

As we expand further, capital and networking will be important. We have Hyundai Motor, NV Bekaert SA and Technip Energies NV among our investors and on our supervisory board. That helps. ○

© Pajarito Powder

ABOUT CHRISTIAN MOHRDIECK AND PAJARITO POWDER

Pajarito Powder, headquartered in Albuquerque, New Mexico, specializes in catalysts for electrolyzers and fuel cells. In 2020, the German automotive manager Christian Mohrdieck joined the board, and since April of this year he has been leading the company as CEO.

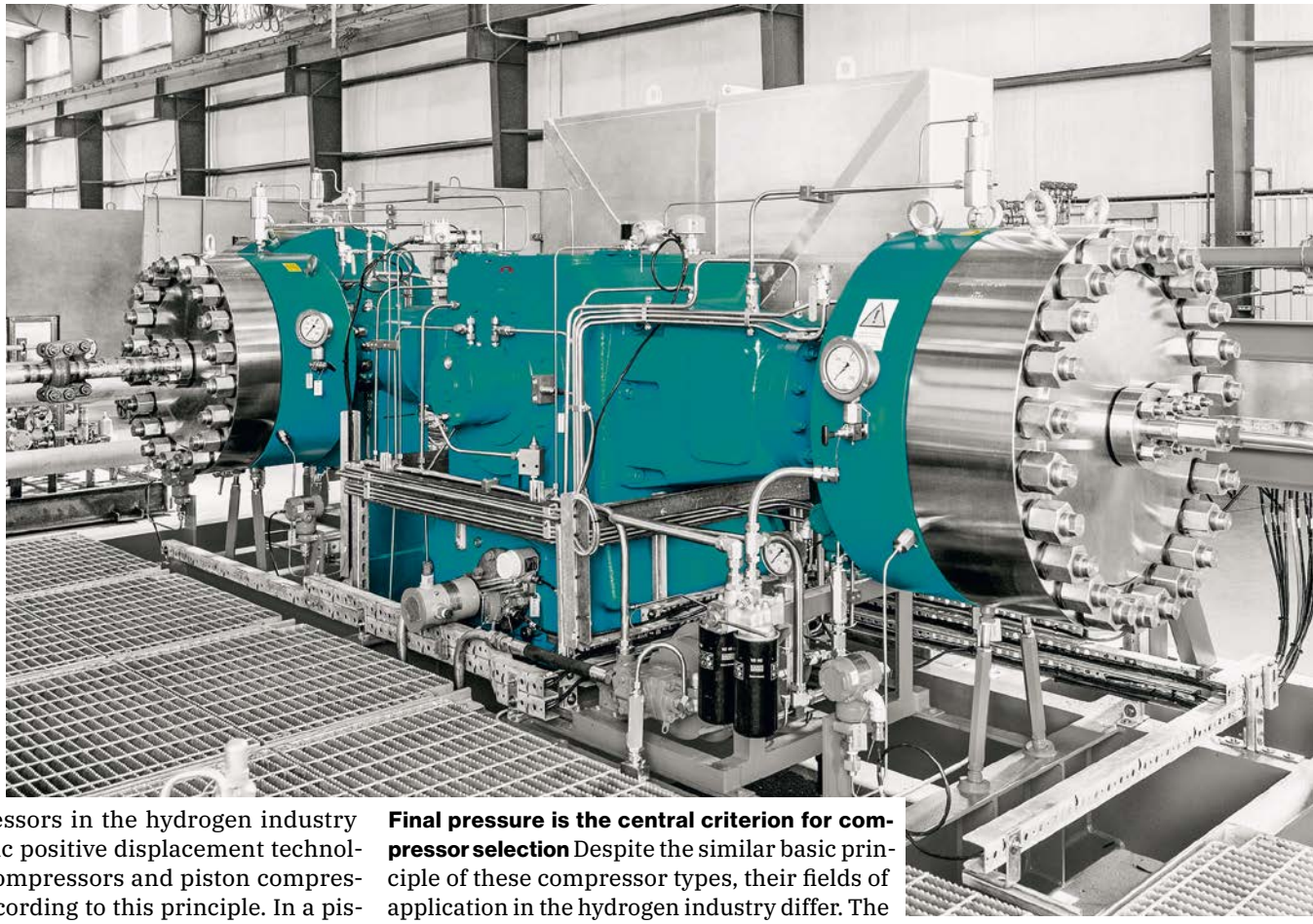
Mohrdieck has served as CTO at Hyzon Motors, as CCO at Cellcentric and as CEO at Mercedes-Benz Fuel Cells, among other positions. He holds a doctorate in physics, studied in Germany and France, and is an honorary professor at the University of Ulm as well as a lecturer at the Vienna University of Technology.

Founded in 2012, Pajarito Powder is quite small with XX employees compared to its customers in the automotive industry, but has major financial backers. These include the Hyundai Motor Company, NV Bekaert, Ecovyst, the Advanced Materials & Catalysts business unit of Technip Energies, the Verge Fund and Omphalos Venture Partners. For the production of its catalysts, Pajarito Powder uses both its own patents and licenses from Los Alamos National Laboratory. Its products include catalysts made from platinum group metals (PGM), Engineered Catalyst Supports (ECS) and Engineered Electrolyzer Catalysts (EEC).

Putting on the pressure

Text: Jens Peter Meyer

The optimal compressor technology for any given electrolysis application depends primarily on the required pressure and the electrolysis capacity. Other factors include the necessary hydrogen purity and the intended operating mode of the compressor. H2international provides an overview of the compressor basics.



Diaphragm compressors can achieve final pressures of up to 3,000 bar.
© Neuman & Esser

Most compressors in the hydrogen industry rely on classic positive displacement technology. Screw compressors and piston compressors work according to this principle. In a piston compressor, hydrogen gas is drawn into a cylinder and compressed by a piston. The piston's movement is generated via a crankshaft driven by an electric motor. Hydraulically driven, dry-running piston compressors also use the movement of a piston to compress gas. A special design of the piston compressor is the diaphragm compressor. In this type, the gas is displaced by a set of at least three metallic diaphragms. These are moved by an oil column that is driven by the piston movement of a classic gear unit.

Final pressure is the central criterion for compressor selection Despite the similar basic principle of these compressor types, their fields of application in the hydrogen industry differ. The most important points are the available suction pressure, the desired final pressure for the hydrogen application and the quantity of hydrogen gas and thus the capacity of the electrolysis. Further factors are the required purity of the hydrogen or the operating mode intended for the compressor.

For pure hydrogen, hydrogen lines and pipelines with a typical operating pressure of between 25 bar and 100 bar are at the lower end. In tanker vehicles, so-called tube trailers, hydrogen is transported at pressures of 200 to

380 bar, and newer developments with TYPE IV CFRP tanks are even moving towards 680 bar. For the storage of large quantities of hydrogen, salt deposits are being developed or tube bundle storage systems are used. Here, according to Neuman & Esser, storage pressures range from 200 bar to 700 bar. The refueling of cars also requires pressures of up to 700 bar.

In derivative production, methanol synthesis in the low-pressure process at 50 bar is quite modest in terms of pressure. If the hydrogen is to be used in ammonia synthesis, the Haber-Bosch process requires pressures of between 250 and 350 bar. In the future, hydrogen will play a major role in the production of sustainable aviation fuels (SAF), according to Jan Gehrmann, product manager at compressor manufacturer Aerzen. Here too, different pressures are required depending on the process.

Screw compressors for large volume flows The starting point of compression is the suction pressure provided by the electrolysis. Low-pressure electrolysis operates in the range of atmospheric pressure up to a slight overpressure. A large electrolysis plant with a capacity of 500 megawatts, for example, generates a volume flow of up to 120,000 m^3 of hydrogen gas per hour. In such a case, one or several parallel screw compressors can be used. According to Gehrmann, screw compressors can easily handle such large volumes. In a typical application, the screw compressor compresses the hydrogen gas from 1 to 6 bar and reduces the volume flow from, for example, 100,000 to around 16,500 m^3 per hour. This volume flow can then be further compressed by a piston compressor in the following stage. “The screw compressor is always only a pre-compressor,” says Gehrmann.

Compressors for higher pressures Piston compressors provide higher pressures. According to Neuman & Esser, oil-free piston compressors in the latest development stage achieve final pressures of 300 to 500 bar. With correspondingly large pistons, high delivery capacities can be achieved. It is also possible to integrate several pressure stages in one machine, so that high final pressures can be achieved even at low suction pressures. Hydraulically driven piston compressors achieve very high final pressures of up to 4,000 bar. Diaphragm compressors can also reach final pressures of up to 3,000 bar. Neuman & Esser manufactures large piston compressors such as those needed for the storage of hydrogen in salt caverns or for feeding hydrogen into pipelines. The company’s portfolio also includes diaphragm compressors and hydraulically driven piston compressors.

Oil-free compression chambers for high-purity hydrogen In the diaphragm compressor, the gas chamber is hermetically separated by the metallic, gas-impermeable diaphragms. This prevents any contamination of the hydrogen in the compressor. In dry-running piston compressors, contamination of the gas by lubricating oil is also ruled out, however, dynamic seals are required, in which a certain amount of abrasion is unavoidable.

Aerzen also produces oil-free compressors for the hydrogen industry. A special feature of this type of compressor is that the compression can be cooled by injecting small quantities of water. This reduces the outlet temperature and benefits the maximum possible pressure increase. According to Gehrmann, the water injection is not a problem, because the hydrogen gas from the electrolysis is already saturated with water vapor anyway and because a drying unit is usually installed downstream.

Compressors for volatile power sources In the production of hydrogen from renewable energy sources, it is important that the compressors can react to the volatility of the energy availability. Smaller sizes of piston compressors and especially the hydraulically driven piston compressors are more suitable for start-stop operation. Large compressors are designed for continuous operation. If the delivered gas volume has to be adjusted for process-related reasons, this can, according to Neuman & Esser, be realized by valve lifting or bypass operation. In diaphragm compressors, the delivery rate can be regulated by frequency converter operation.

To account for planned or unplanned downtimes, compressors are usually designed with redundancy. Typical redundant configurations for piston compressors are, according to the manufacturer Neuman & Esser, 2 × 100 %, 2 × 50 % or also 3 × 50 %. The 2 × 100 % configuration ensures complete redundancy; with 2 × 50 %, a certain redundancy is available in the event of unexpected shutdowns, in order to transport half of the possible gas volume flow. With 3 × 50 %, at least half of the delivery capacity can be maintained during maintenance and a simultaneous failure of another compressor.

With the ramp-up of the hydrogen industry, a strong increase in demand for compressors is to be expected. Many manufacturers are already prepared for this today and offer project-specific customized systems. ○

Compressor case study

25 years on, still compressing

Text: Ronald Spindler

Nearly 25 years ago, Burckhardt Compression delivered two hydrogen compressors for a trailer filling station at Infraserv Höchst. They still run reliably today with service intervals of 8,000 to 9,000 hours.

Compressors used to fill tube trailers naturally have to start and stop frequently. This poses a challenge for reliable operation. In addition, all scheduled downtimes of the compressors must be coordinated with those of other plant components in order to keep operational interruptions to a minimum. A practical example from Burckhardt Compression and Infraserv Höchst demonstrates how this can be achieved. The compressors, delivered in 2001, still achieve excellent availability today and a mean time between overhauls (MTBO) of between 8,000 and 9,000 hours.

Few solutions available 25 years ago

Twenty-five years ago, supplying high-pressure hydrogen still involved enormous difficulties. To handle the smallest molecules in the world and, at the same time, ensure that compressors remained tight at 230 bar gauge pressure (bar (g)), only a few technical solutions were available. Today, similar plants are specified for up to 550 bar (g), thanks in part to the industry solutions from Burckhardt Compression.

For the two type 2CS hydrogen compressors in the Infraserv application, frequent start-stop cycles were to be expected as part of normal operation. This usually has a negative impact on maintenance intervals. The operating costs of the new trailer filling station were naturally to be kept as low as possible and the compressors were to be available to the maximum extent. The target of 8,000 to 9,000 MTBO was set in coordination with the maintenance requirements of other plant components. Burckhardt Compression could also have achieved an MTBO of 12,000 hours if required.

Aerial view of the Höchst Industrial Park from the northwest. The hydrogen filling station is located in the background on the other side of the Main River.

Proprietary materials and components Such service life and efficiency require a combination of design expertise and carefully selected materials. Drawing on decades of experience, Burckhardt Compression has developed its own materials, such as Persisto rings and Redura sealing systems, key components for dry-running high-pressure compressors.

The plant operates with many compressors for various gases, distributed across the entire site. These include numerous Laby compressors (oil-free piston compressors with labyrinth sealing), which are maintained on site by Burckhardt Compression technicians.

Strong presence and communication Another important aspect of the cooperation with Infraserv is communication. Burckhardt Compression appointed a central contact person to ensure an effective exchange of information. This enabled the efficient handling of all aspects of compressor management, from initial commissioning and training through to scheduled maintenance and troubleshooting.

Burckhardt Compression's presence in Germany covers four locations. They offer customers competent support, available around the clock, which helps keep total cost of ownership (TCO) as low as possible.

Optimizing productivity for the future Steffen Enghard, mechanical operations engineering at Infraserv Höchst, said, "In recent years, we have experienced nearly continuous trouble-free operation, hardly any unplanned maintenance work, hardly any unexpected failures. This has enabled us to ensure optimal productivity for our company. The continuous support from Burckhardt Compression has been invaluable and has ensured that our systems function flawlessly. The filling process of the hydrogen trailers is a central element of our facilities, and high availability is essential."

For Infraserv Höchst, the combination of technical solutions and on-site support was the decisive factor for the long-standing business relationship. And with the hydrogen ramp-up, Burckhardt Compression is also expanding its network of experts for 24/7 support. Last year, six new service centers were added worldwide. ○

Ronald Spindler
Burckhardt Compression Product Manager Services

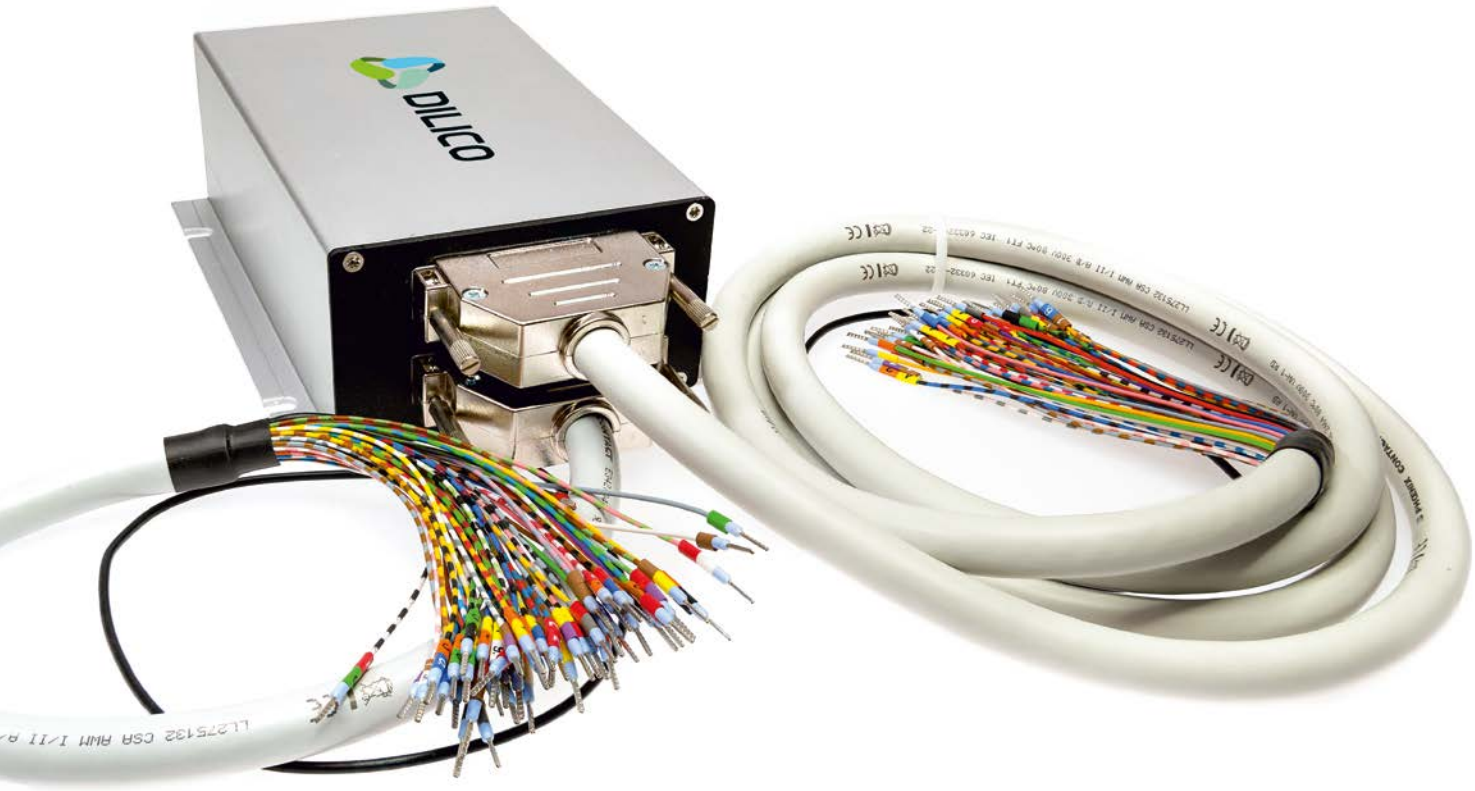
A deep look into the life of the cell

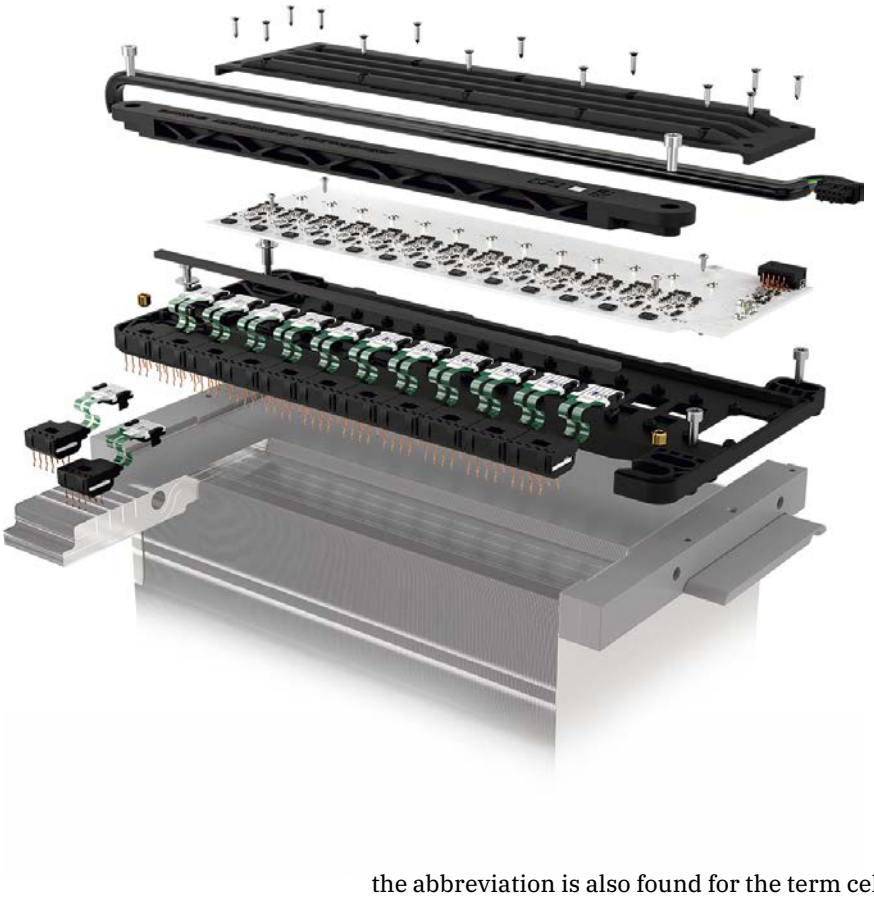
Text: Jens Peter Meyer

The measurement of cell voltage in electrolyzers and fuel cells is currently making the leap from research into series production. In this environment, cost, ease of assembly and reliability of the measurement system are more important than maximum accuracy and a high measurement frequency.

For a long time, monitoring the cell voltage of electrolysis and fuel cells was a topic for research. But that is now changing. At present, a shift is taking place from research to industrial, practice-oriented questions, says Wolfgang Häußler, responsible for Business Innovation in the hydrogen sector at Marquardt GmbH, a supplier of mechatronic systems. The company offers cell voltage monitoring systems (CVM), which are increasingly being used in practice. Because in operation too, the CVM can provide valuable information and uncover faults and aging processes. Whether it is membrane degradation or membrane defects, cell leakages, insufficient electrolyte supply or the loss of the electrode coating. Critical operating conditions under overvoltage are also detected. If such faults are detected early, the process parameters can be adjusted or maintenance can be carried out. The CVM can even contribute to the prevention of accidents, experts say.

Cell voltage monitoring (CVM) refers to the continuous monitoring of the cell voltages within a stack, that is, a system that comprises the hardware for the measurement and the software for data evaluation. Occasionally,





RIGHT: Cell voltage monitoring from Smart Testsolutions © Smart Testsolutions

LEFT: If the CVM is not located directly on the stack, the paths for the analog data transmission should be as short as possible. © Dilico

the abbreviation is also found for the term cell voltage measurement, whereby this term only describes the actual measurement process of the cell voltage measurement. Cell voltage pick-up (CVP) refers to the hardware directly on the stack, which handles the electrical contacting of the individual cells as well as the connection to the measurement technology.

Systems for all common stack technologies Marquardt's CVM portfolio covers all stack technologies commonly used today. In electrolyzers, the electronics can be used in both PEM and alkaline stacks based on the same architecture. In the fuel cell sector, the applications range from passenger cars and heavy commercial vehicles to stationary use cases such as emergency power supply and combined heat and power. "In Europe, we work closely with several of the leading stack developers, which enables us to maintain a continuous feedback loop between our electronics and the requirements of real series stacks," says Häußler. In doing so, the company uses technology from its business unit for battery management in the automotive sector. "A large part of the know-how comes directly from cell monitoring in high-voltage traction batteries," says Häußler.

The cell voltage measurement of fuel cell stacks and those in electrolysis does not differ significantly. "Differences arise primarily from the respective system requirements," says Carsten Krüger, Strategic Marketing Manager at CVM manufacturer Dilico. "These include temperature ranges, humidity influences, possible media contact, cell voltage ranges as well as safety-related requirements such as ATEX specifications. Installation space, accessibility and maintenance concepts also differ significantly in some cases." Since there are no standardized cell geometries, the company always develops the solutions on a customer-specific basis.

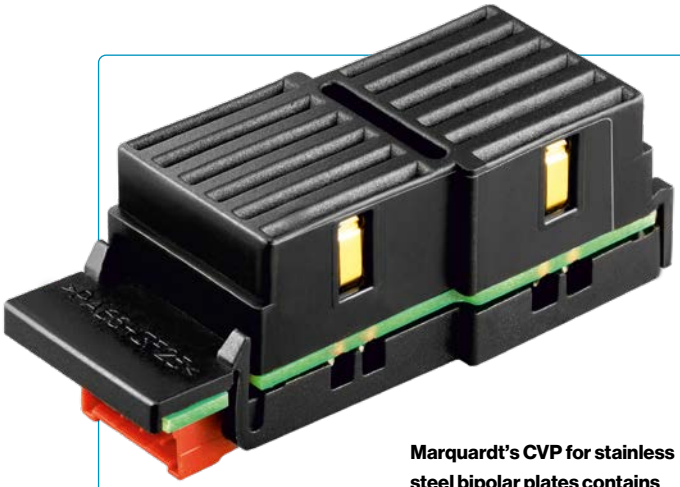
What matters in CVM Currently, Dilico is focusing on stationary applications. However, further development toward automotive applications is conceivable. Differences between stationary and mobile applications arise from the requirements for robustness, integration and standardization. "In the automotive sector, the focus is in particular on vibrations, dynamic load changes, EMC requirements, installation space restrictions and safety-related specifications. Stationary systems, on the other hand, focus more strongly on long-term stability, ease of maintenance and scalable integration," says Krüger. According to him, what is important in a CVM is the reliable, continuous and interference-free monitoring of the individual cell voltages. In addition to measurement accuracy, the integration of the measurement technology directly on the stack plays a central role, according to Dilico.

For Marquardt, the measurement range comes first. "A detail that is often overlooked here is the ability to measure negative cell voltages," says Häußler. "A negative individual cell voltage is one of the clearest indicators of a critical fault: a frozen cell, an under-supplied cell or a cell with strong reversal. A CVM that cuts off at zero loses precisely the information that you need most urgently."

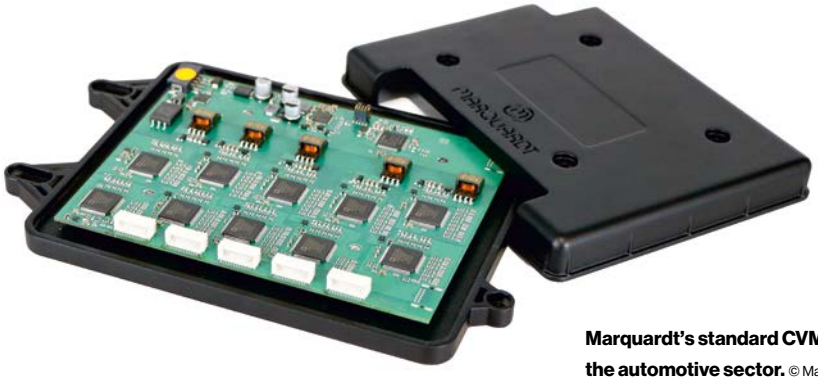
Functional safety is also a central criterion. In the automotive sector, Marquardt offers, according to the ASIL (Automotive Safety Integrity Level) risk classification system of the ISO 26262 standard, safety levels up to ASIL B. In most series projects, however, level QM for standard quality management processes is sufficient.

Weighing accuracy and measurement frequency against costs "The third point, and one that is very close to our hearts, is not to over-dimension," says Häußler. "Beyond a certain threshold, additional accuracy and measurement frequency cause costs without providing the stack controller with significantly better information." Specifying the CVM to the actual diagnostic need and not beyond is an essential part of transferring the system into series production. In research, one wants to measure as much as possible. In practice, on the other hand, what matters is that the technology works reliably and what it costs. "Price is increasingly a topic," says Häußler. ▷

Dilico's cell voltage pickup converts the measurements directly on the stack into digital data. © Dilico



Marquardt's CVP for stainless steel bipolar plates contains three finger contacts with integrated latching.
© Marquardt



Marquardt's standard CVM for the automotive sector. © Marquardt

For the reliability of the measurement, the design must be robust from the CVP through to the evaluation software. In doing so, the software must handle enormous amounts of data. The raw voltage values are only of limited use to the stack controller. Therefore, the CVM condenses them in real time into the relevant variables: minimum, maximum and mean value as well as scatter and gradients per cell. In addition, there are special detection paths for voltage reversal, low-voltage events, drift and line breaks. And speed also matters. "The data must reach the stack controller in time to trigger a protective response," says Häußler. For Marquardt, on the communication side, CAN and CAN-FD are the relevant interfaces for fuel cell systems in the automotive sector. For electrolyzers, the company supports the communication protocols customary in the industry.

And another point is important: the data provided should also feed into the further development of the underlying models. At Marquardt, therefore, data processing is optimized in close cooperation with the model developers. Dilico is currently developing an intelligent software platform for the evaluation of the measurement data. The goal is to analyze cell voltages, temperature profiles and further operating data on a data-based level and to derive concrete condition and action recommendations from them. In the long term, the aim is to create a diagnostic and analysis platform that improves the safety and efficiency of large hydrogen systems and enables predictive maintenance.

Contacts in the tightest space The contacting for capturing the cell voltage must also be reliable. There are different connection technologies for this. These range from classic individual wiring through spring contact elements to other mechanical contacting solutions. "Which technology is suitable depends strongly on the respective requirements," says Krüger. Decisive here too are installation space, ease of assembly, vibration resistance, maintenance concepts as well as process reliability and reproducibility of the contacting. Dilico uses customer-specific contacting concepts and develops them specifically further for the respective stack technology.

Marquardt offers two main families of cell voltage pickup products, which differ in the type of bipolar plate. For mechanically sen-

sitive bipolar plates made of graphite, contactings are required that distribute the load carefully and avoid local stresses. For metallic bipolar plates made of stainless steel, the contact partner is a stamped tab. Here the focus is on corrosion resistance and reliable clip engagement with a very thin geometry. Both product families can be adapted to the stack geometry of the customer and cover a wide range of cell spacings. Thus, Marquardt can contact both compact automotive stacks with spacings in the submillimeter range and stacks with larger spacings, as are typical for industrial systems. The spring, tab or pin contacts used in each case are selected by the company on a project-specific basis according to the stack design.

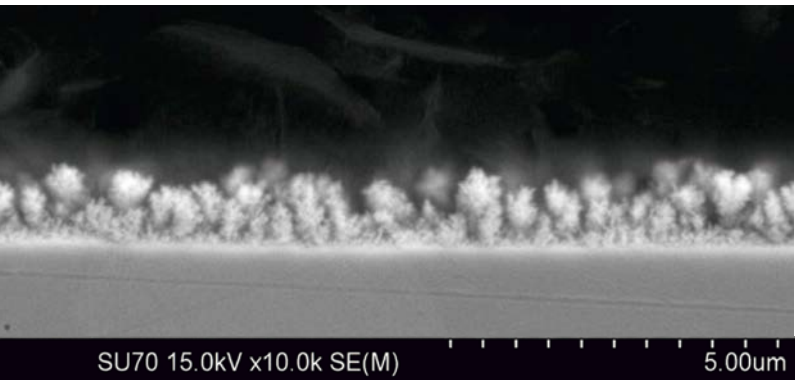
Measurement technology directly on the stack

In the past, cell voltages were often captured via individual wiring, in which each cell was connected separately to external measurement technology. If this is done via long cable paths into a switch cabinet, this means a great deal of effort for the wiring and integration into the plant. “At the same time, high voltage potentials, in some cases up to 1,500 VDC, have to be routed over larger distances within the system,” says Krüger. “Long analog line paths can also impair signal quality and increase susceptibility to electromagnetic interference.”

Therefore, Dilico has developed a CVP that enables stack-near measurement with short analog signal routing and immediate digitization near the cell. This significantly reduces line lengths, interference influences and potential sources of error. At the same time, according to Krüger, signal quality, process reliability and integration capability improve considerably. The stack-near integration also creates the basis for additional functions such as temperature measurement, further sensor signals or a targeted individual cell bleed-down. Dilico's patented bleed-down technology enables the controlled discharge of individual cells and can thereby make an essential contribution to cell health, operating stability and service life of the entire stack, according to Dilico. Marquardt also offers a system with the CVM-compact that integrates the measurement electronics in the CVP and passes on the data via a digital interface.

Measure every cell or a representative subset?

For research purposes, all cells are measured. In series use, this is not always necessary. The manufacturer Smart Testsolutions, for example, measures the first and last cells and then a few selected ones in the middle (see interview with Wolfgang Neu, Managing Director of Smart Testsolutions). Marquardt recommends monitoring every single cell. “Full coverage offers the best possible insight into the cell stack: in this way, the controller can narrow down a fault to a single position,” says Häußler. Some customers, however, decide to monitor only a certain range of cells. For example, the cells that are most susceptible to faults under their operating profile, or a representative subset. This reduces the number of channels and saves costs. The better the customer already knows the behavior of their stack, the better a selection of the cells to be monitored is possible. ○



Membrane permeable from 100 degrees celsius

Tanaka Precious Metal has developed a metallic membrane that is said to already achieve high permeability for hydrogen at around 100 degrees Celsius. The palladium membrane bears the name HPM-L111. It is intended to make it possible to separate high-purity hydrogen quickly and at significantly lower temperatures than before, thereby saving energy.

Metallic membranes are frequently used for the purification of hydrogen, but typically require temperatures of at least 300 degrees in order to become permeable to hydrogen, according to Tanaka. One example from the Tanaka product range is the PdCu40, an alloy of 60 percent palladium and 40 percent copper with particularly high hydrogen permeability – which, however, requires temperatures of around 400 degrees to achieve this.

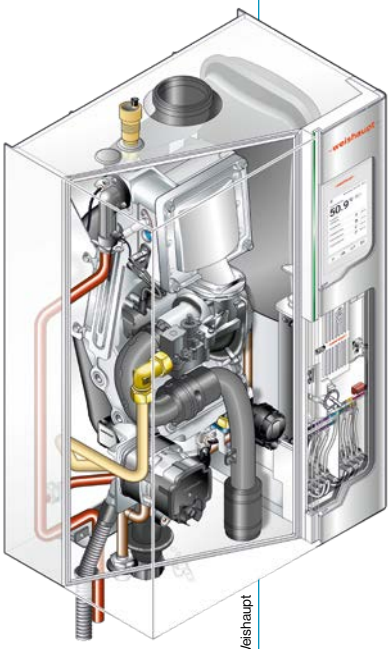
This has now been changed by means of a special surface treatment. Fine microstructures enlarge the surface area. This is said to increase the penetration speed of hydrogen, so that even at low temperatures more H2 molecules can pass through the membrane.

As fields of application, in addition to purification, Tanaka names hydrogen sensors (isolating other interfering gases), fuel cells, and the removal of hydrogen generated inside equipment from vacuum systems. According to the company, production at Tanaka Precious Metals is initially to be limited to around one hundred sample pieces per month, deliveries of which are said to have begun in March. ○

More information: tanaka-preciousmetals.com/de/

What looks like a winter forest is actually the structured surface of Tanaka's new hydrogen separation membrane.

©Tanaka



© Weishaupt

Explosion-proof thermal chamber

Sonplas offers explosion-protected thermal chambers for test benches and stand-alone applications. The modular systems are designed for tests with explosive or toxic media such as hydrogen, methanol, ammonia, LPG and natural gas.

According to the manufacturer, the operating range extends from -60 to 180 °C. The chambers can, according to the company, be adapted to different test media with little effort, for example by changing the flow conditions. They are intended, among other things, for testing injectors, pumps, pressure sensors, fuel systems as well as electronic components such as inverters and control units.

For explosion protection, Sonplas relies on inertization by pressurized enclosure according to IEC 60079-2 with nitrogen. In contrast to many thermal chambers common on the market, monitoring is, according to the manufacturer, not carried out via an oxygen sensor. This is intended to make the solution more robust and require less maintenance. The temperature control is arranged externally; only a heat exchanger sits inside the chamber itself. This creates space for the test setup and is intended to avoid critical surface temperatures.

The equipment includes, among other things, door interlocking, gas monitoring, overpressure protection, a floor pan with level switch, as well as extraction when the door is open. According to the company, the systems are designed for ATEX and IECEx. ○

More information: www.sonplas.com

© Sonplas

Condensing boiler is H2-ready

The Thermo Condens gas condensing boiler from Weishaupt is, in a special version, also approved for operation with pure hydrogen – following a conversion, however.

The hydrogen variant features a new burner surface and combustion control with UV flame monitoring. These are also in use in the H2HoWi hydrogen project in Holzwickede, in the service area of Westnetz, at three test customers, and can be viewed in a Weishaupt showroom.

The standard series has intelligent combustion control for the air-to-gas ratio. This is intended to allow it to switch easily between different fuels – LPG, biomethane and, of course, natural gas, the latter with up to 20 percent hydrogen blended in. ○

More information: www.weishaupt.de/

Bipolar Plates

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