HEROES OF HYDROGEN

Hydrogen Europe 2024

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Content

Prologue

The road to progress is paved by those who walk it first. Pioneers have always driven humanity forward by taking the risks nobody else dared to. To strive for new frontiers for the betterment of our society can be called heroic.

This book is the third instalment of our Heroes of Hydrogen photobook series. As the industry grows, the pool of selection grows ever wider. This is fantastic news for the sector and for the energy transition.

The four heroes chosen in this year's book represent very different parts of the value chain, each of them bringing a leadership mentality and entrepreneurial spirit to the challenge of establishing hydrogen as the crucial decarbonisation enabler it is destined to be.

Their stories are accompanied by stunning photography demonstrating the intricacy and scale of the work being done, from transformative electrolysis technology in Estonia to hydrogen-powered cruise ships in Italy. From the build-up of massive hydrogen infrastructure in the Netherlands to putting zero emission trucks on the road in Germany. All of these heroes are ensuring another piece of the puzzle is laid down.

There is still much work to be done, and many more heroes of hydrogen to highlight. If you are reading this, we hope that this book will enlighten and inspire you to join the energy revolution, no matter your interests or inclinations. Net Zero is within reach – all we need are more heroes.

Jorge Chatzimarkakis
CEO, Hydrogen Europe

Story 1

Driving the future of mobility

One of the world's largest commercial vehicle manufacturers is working to revolutionise zero emissions mobility for heavy-duty vehicles and beyond.

Daimler Truck's Mercedes-Benz GenH2 Truck prototype parked at the company's test and development centre in Wörth am Rhein, Germany.

Stuttgart, Germany - Europe's heavy-duty vehicle manufacturers have until 2040 to reduce CO_2 emissions by 90%. Companies in the sector will naturally have to use every tool at their disposal to decarbonise Europe's fleet of over 6.75 million trucks in time.

While certainly an ambitious timeline, and facing recent opposition from certain member states, many vehicle manufacturers are getting on with the job confident that they have the technology and know-how necessary to achieve this target.

Manfred Schuckert, head of automotive regulatory strategy, commercial vehicles, Daimler Truck AG.

"The long-term view is clear. Strict regulations will enforce, over the next 15 years, a fully decarbonised transport system," says Manfred Schuckert, head of automotive regulatory strategy for commercial vehicles at Daimler Truck AG.

Daimler Truck, one of the world's largest commercial vehicle manufacturer, is not waiting around for the rest of the market to act. In fact, it has set itself the ambition to only sell new vehicles that are CO2-neutral in driving operation in its core markets USA, Europe and Japan as early as 2039. The company's pedigree, including the Mercedes-Benz Truck brand, gives it the ideal blend of engineering mastery and innovative vision to lead its sector on this total transformation.

Commercial vehicles play a huge part in society's everyday functioning. Buses and trucks transport people and goods – by the millions – every single day to ensure their timely arrival. There is no discussion about reducing their number, in fact it is more likely that their number should increase. But going forward these will have to be, like passenger vehicles, emission-free. And Daimler Truck will explore any promising avenue to do so.

"Clearly, we need to go for all zero emission technologies, batteries and hydrogen being the main ones. Hydrogen will play a big role in that game, whether it's 30/70, or 40/60 with batteries depends on economic conditions, over which we do not have full control," explains Manfred.

Daimler Truck's Mercedes-Benz GenH2 Truck, which is currently being tested by a selection of major customers.

In the beginning

Manfred has been involved with hydrogen fuel cells since before the technology was a glint in the European Commission's eye. 25 years ago, working at Daimler Truck's subsidiary EvoBus, he was asked to design a project that became one of the world's largest cell bus trial at that time. Fuel Cell Citaro for Europe involved the commissioning of 30 fuel cell buses across 10 European cities.

"We learnt how much customers appreciated the reduced noise level of fuel cell vehicles and how smooth they drove. You could say this was the beginning of my hydrogen career," Manfred recalls. The project was then expanded to China and Australia with equally high levels of success.

"So, what were we to do next? Well, we made a more efficient bus, halving its hydrogen consumption, which was tremendous," he adds.

Indeed, those new buses went from 20kg of hydrogen per 100km travelled to 7.5kg per 100km. The last of these models drove until 2018, displaying the room for market maturity in the fuel cell space.

By 2015, discussions were on-going in Daimler on applying these successes to trucks, resulting in the formation of the GenH2 Truck project in 2018. Studies were drawn up and management concluded that it made sense to pursue hydrogen trucking on the basis that the price of hydrogen would decrease and more storage space would be made available on board. Of course, these decisions were less than unanimous.

"You can imagine that in 2015, with passenger cars moving towards batteries, it being not the best economic situation, that proposing fuel cell mobility as a solution was definitely not a home run. But through intensive discussions with suppliers, and realising the potential of the technology, we decided to go for hydrogen," Manfred explains.

"We did this all step by step, and now we're in really good shape and ready to develop."

The connection of the GenH2 Truck's tractor to its trailer. Zero emission vehicles may take more tractor space to fit their propulsion systems.

Test driving the
GenH2 Truck.

Refilling the GenH2 Truck
with sLH2 liquid hydrogen.

Trucks parked at the Mercedez-Benz test and development centre. Daimler Truck is committed to decarbonising its range with battery and hydrogen technology.

The fuel cell trucks by Daimler Truck are now being tested firsthand by its customer base, some of which have already signed on to participate in these trials. Earlier this year, five of these trucks were provided to Amazon, Air Products, INEOS, Holcim and Wiedmann & Winz to test their suitability and viability for long distance transport.

The truck is built in a typical layout for heavy-duty freight transport, though slightly longer than regular combustion engine trucks as the EU, under its Weights & Dimensions directive, has allowed trucks more space to accomodate the hydrogen fuel cell propulsion systems. In a sector where every cubic milli-meter of space is important, this is hugely beneficial and allows them to maintain the normal trailer size, which would have otherwise needed to be sacrificed to accommodate the fuel cell system.

The truck carries two 40-kilogram storage tanks of hydrogen which carry a potential range of more than 1,000 kilometres – but more on that impressive number later. These storage tanks are filled with subcooled liquid hydrogen at -253°C and a pressure level of 16 bar. While this may sound contrary to the conventional approach in Europe of gaseous hydrogen, Daimler Truck took this decision because the liquid model offers numerous advantages from a technical point of view. The most important of these is its higher energy density, enabling the truck to store more energy and achieve higher ranges. And, from a customer's point of view, would ensure the truck's condition would be well preserved even after weeks of inactivity.

Daimler Truck and Linde Engineering presented in February 2024 "sLH2", a jointly developed refuelling technology for subcooled liquid hydrogen. Compared to gaseous hydrogen, the companies said, subcooled liquid hydrogen (sLH2) allows for refuelling as safe, fast and simple as today's diesel technology. Just 10 to 15 minutes are all it takes to refill 80kg of hydrogen and then customers are good to go for another 1,000+ kilometres. Daimler Truck is now calling for it to become an industry standard.

A drone shot of the GenH2 Truck at the Daimler Truck testing facility.

The Daimler Truck sLH2 refuelling station at its Wörth research facility and test track. The liquid hydrogen technology allows for longer range and faster refuelling of its fuel cell trucks.

One thousand kilometres

Daimler Truck achieved a remarkable milestone at the end of 2023.

The Mercedes-Benz GenH2 Truck covered a distance of 1,047 kilometres between Woerth am Rhein and Berlin – without refuelling - via a route designed specifically to cover the most frequent freight routes through Germany's heartlands.

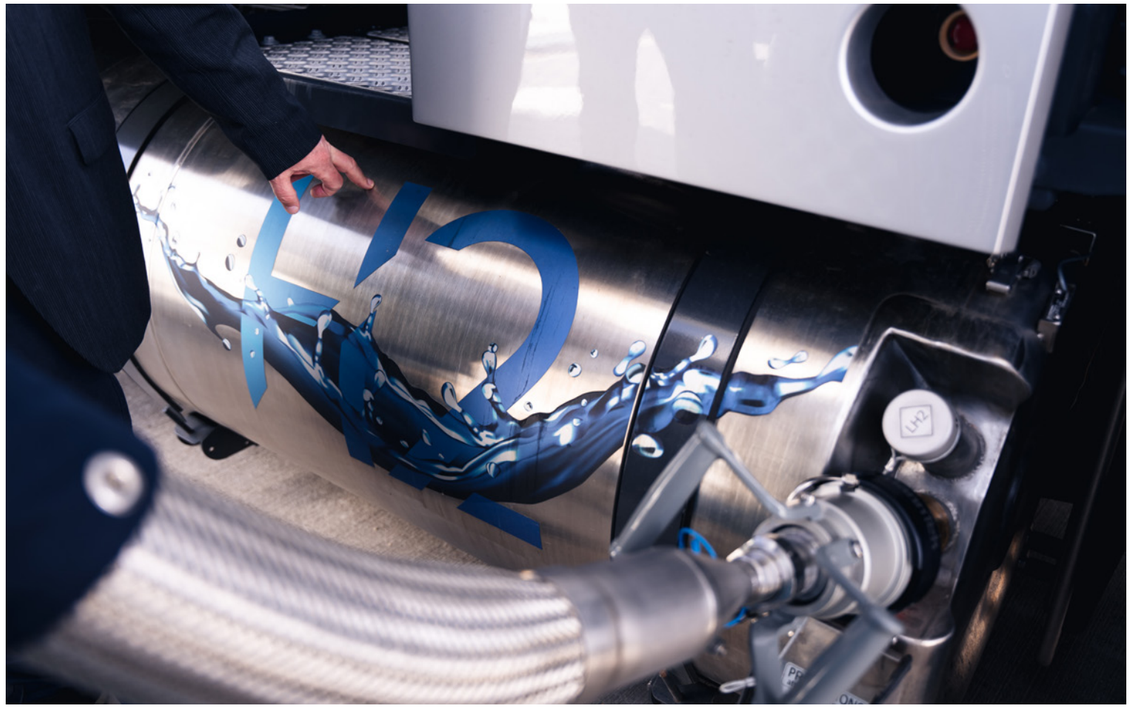
This achievement was a perfect demonstration of the benefits of hydrogen-based zero emission transport. Unlike passenger cars, which spend most of their lifetime parked, and therefore with constant access to refuelling time, vehicles which frequently cover long distances with very few stops other than to refuel – such as trucks and buses – will benefit from longer range and shorter refuelling times. And the prospect of a non-stop run of more than 1,000 kilometres is surely appealing to freight companies.

"The record run shows the system's performance and how much a customer can enjoy the freedom of range. The route chosen was very close to what our customers are actually doing. That's why many of them, when they realised what we'd achieved, saw its relevance to their day-to-day business," Manfred says.

With this milestone under the belt, and early positive feedback from customers using the trial fleet, the next step for Daimler is the development of the technology for mass production and recognition of its importance in the overall picture by legislators and consumers alike.

Going for a drive in the GenH2 Truck on the Daimler Truck test track. The truck can travel over 1,000km on a single fill.

The Mercedes-Benz GenH2 Truck zooms past on the Daimler Truck test track. The truck can comfortably maintain the industry average speed of 85km/hr over long distances, as it proved on the 1,000km run.



A Mercedes-Benz GenH2 Truck being refilled with Daimler Truck's and Linde's sLH2 liquid hydrogen.

A cylinder storing liquid hydrogen at the Daimler Truck research and testing facility.

Manfred Schuckert and members of the Daimler Truck team in front of the truck and fuelling station at the company's research and testing facility.

A crucial joint venture

They say it takes two to tango. And though it might not be quite as necessary to develop a company dedicated to zero emission road mobility and capable of pulling it off, it must certainly help.

Enter cellcentric which, since its 2021 founding by Daimler Truck and Volvo Group, has been on a path to becoming a leading global manufacturer of fuel cells able to contribute in a big way to a climate-neutral transportation sector.

Andrea Engelen is global head of external affairs & government relations at cellcentric. Having begun her career in the automotive sector with Smart, its acquisition by then Daimler AG brought her into the fold, where she has remained ever since. Having been introduced to hydrogen mobility while working in the strategic development of the Mercedes portfolio when tasked in 2008 to prepare a business case recommending it to the board, she was assigned to the fuel cell division of Mercedes-Benz Canada in 2018.

"I finally realised then what I had calculated on paper a decade before. I became very passionate about fuel cell technology, and everything changed quickly when we started the joint venture," Andrea remembers.

cellcentric has become one of Daimler Truck's largest investments into hydrogen technology – a dedicated fuel cell producer for both Daimler Truck vehicles and the market at large.

"To be able to push forward in cellcentric with my own energy and experience makes this job so special. It's an opportunity for me to drive the progress of hydrogen technology, whatever my influence can bring," Andrea enthuses.

Andrea Engelen, global head of external affairs & government relations, cellcentric.

A drone shot of the new cellcentric production facility, where fuel cells and their components will be manufactured for Daimler Truck and Volvo Group, as well as for future third-party customer applications.

The cellcentric production facility hosts more than 100 employees and contains offices, development, manufacturing and logistics facilities.

In June 2024, cellcentric inaugurated its pilot production plant for fuel cell systems at its Esslingen-Pliensauvorstadt site near Stuttgart, a huge step towards future large-scale production. The joint venture is targeting large scale supply of its system before 2030, by which time it expects that fuel cell powered long-haul heavy-duty trucks will be well recognised as key solutions for sustainable transport.

The very same fuel cell system is found in the GenH2 Truck that achieved the 1,047-kilometre run with less than 80kg of hydrogen, demonstrating its effectiveness and potential as a transformative piece of equipment for the future of zero emission trucking.

"This is really the whole story of decarbonising. Trucking is a significant part of emissions we currently have, and having it won on the roads will be a significant accomplishment in changing to a sustainable world," says Andrea.

Andrea and Manfred meet with cellcentric executives at the company's production facility.

Daimler Truck and cellcentric are demonstrating the importance of moving together, all at once, to our decarbonisation goals. The well documented issues facing the hydrogen value chain – lack of infrastructure, lack of offtakers, excessive prices – can only be solved all together, or not at all.

By providing the technology and building the vehicles, as well as designing the refuelling system, Daimler Truck has taken charge of this narrative and, as the many companies signing on as partners or customers demonstrate, this approach is already paying dividends.

"With this lack of infrastructure, there is an insecurity in the market. The question is asked, when do I invest, how much? When we have the chicken and egg problem, it's not about what has to happen first. It all has to happen first," explains Andrea.

Inside the cellcentric production facility, where the fuel cells go through rigorous testing.

Stack assembly inside the cellcentric production facility.

A cellcentric staff member walks past a wall of Membrane Electrode Assembly (MEA) equipment for fuel cells.

A cellcentric employee checking up on some of the company's testing equipment.

Building up sustainably

The 10,300 square metre facility also includes logistic and office and administration space to cater to more than 100 employees. As Andrea and Manfred were both quick to remind, this site is only the beginning of a long-term plan that will see the massive increase in production capacity of the fuel cells, and their individual components, to cater to a wide range of customers in the value chain.

The company is also planning to offer a 'comprehensive service package' to customers including all maintenance and repair services. That said, a rigorous testing and surveying process during manufacturing is designed to minimise as many unforeseen failures as possible.

The commitment to decarbonisation – both through cellcentric's product and the means by which it makes it – is part of the knowledge that the energy transition is both a legal and moral imperative.

"There is no choice, because we aren't where we should be in terms of our climate goals and the regulations are already set. But it should be intrinsic and, luckily, there are lots of people who want to make it happen, which will make the difference," enthuses Andrea.

Employees of the cellcentric team pose for a photo in front of a fuel cell.

Complex technology requires complex machinery and infrastructure to produce and test.

As part of the expansion plans, cellcentric is expected to expand into the North American market, bringing its transformative fuel cell across the Atlantic. Together, Daimler Truck and Volvo already boast more than 50% market share in both EU and North America, and already own truck production locations in the US and Canada.

As Andrea says, *"it's not a question of if we go there, but when. Our objective is to be ready for that market, and we already have a good connection with OEMs there."*

"Over the past three or four years, north America may have been a bit behind Europe on hydrogen. But in the US, it's often the case that once they make a decision, things move very fast. So we are prepared," she adds.

Both Andrea and Manfred exhibit justified pride in the work achieved so far and determined resolve in their next steps. Neither of them concern themselves with issues of competition, arguing that the opportunity is so vast that neither battery electric vehicle manufacturers nor fuel cell technology suppliers are any cause for concern.

"The reality is we need to work together now, especially when it comes to fuel cell systems, to create this critical mass and deliver the much-needed infrastructure. Hydrogen brings us all together," says Andrea.

And when it comes to bringing its liquid hydrogen technology to the fore, Manfred is confident that the quality will shine through: *"Just use the truck, and you will see how smooth and calm the driving experience is, how sustainable it really is, and how affordable it can be,"* he urges.

By building up its hydrogen business model step by step over several decades, Daimler is now ready to drive the future of zero emission mobility.

Story 2

Reaching for the stars

In a coastal Baltic capital city, one company is working to unlock renewable hydrogen by maximising the efficiency and minimising the costs of electrolyser technology.

A variety of solutions are tested in Stargate Hydrogen's Tallinn laboratory to find that which offers the best combination of efficiency and durability within the electrolyser stack.

Tallinn, Estonia – Clean technology development is a race against time. Under the threatening shadow of climate change, scientists, engineers, entrepreneurs and researchers are working around the clock to develop decarbonisation solutions as quickly, and as cheaply, as possible. From solar photovoltaic to wind and battery storage, the challenge is the same.

Renewable hydrogen is no different, and in fact has an arguably tougher task ahead. While it is sorely needed for decarbonisation efforts, it is in need of a great leap forward to catch up on the economic progress that solar and wind have made before it, albeit with a 20-year head-start.

Marko Virkebau, co-founder and CEO of Stargate Hydrogen, understands this challenge well. His company is in fact, rather fittingly, named after the film and TV series of the same name, after the titular ring-shaped device built by an ancient intergalactic civilisation allowing almost instantaneous travel across vast distances.

"The main problem on the market today is that the price of renewable hydrogen is too high. So, the founding motivation and focus on everything we do at Stargate is to significantly bring down the cost, and we believe that by doing so, we can add the most value into the whole hydrogen economy," says Marko.

A portrait of Marko Virkebau, co-founder and CEO of Stargate Hydrogen.

Peering inside an electrolyser stack produced by Stargate Hydrogen.

Changing the recipe

Stargate has two pillars in its business. The first is selling turn-key electrolyser systems, while the second is selling their own stacks to other companies who make their own electrolysers. A “stack” is the essential component to hydrogen production in electrolysis, consisting of multiple cells that are stacked to form what engineers call an electrolyser stack. These stacks are what allows for the electrochemical reaction that occurs during electrolysis – turning water into hydrogen.

The most commonly known, and most advanced, types of stacks are proton exchange membrane (PEM), alkaline electrolysis (AEL), and solid oxide electrolysis cells (SOEL). Each have their own advantages and characteristics. For Marko and his colleagues at Stargate, the best results have come from uniting the best properties of different systems.
“We combined the best parts of alkaline technology – its long lifetime, robustness, and low cost, with the best part of solid oxide technology, which is the ceramic-based high efficiency catalyst,” Marko explains.

Specifically, Stargate have zeroed in on the ceramic-based catalyst most often found in solid oxide electrolysis stacks. In PEM and alkaline stacks, the catalyst – that which helps to trigger and speed up a reaction – is usually based on a precious metal.

A big advantage of ceramic catalysts is therefore, besides efficiency, its cost and availability. Marko says it is an “order of magnitude” cheaper than precious metals, while also being extremely abundant, thereby imposing no limits on the scale up.

"Oxides are not usually conductive – they have to be tweaked, which is also why you put them on a substrate," explains Jan Grolig, Stargate's chief of operations, who joined the company from solid oxide fuel cell and electrolyser manufacturer Hexis AG in May 2022. His experience and understanding have proven invaluable as the company works to leverage the best of the solid oxide technology.

Grolig describes the fascinating process of getting these chemical compounds to perform the required task.

"What some oxides have is the ability to catalyse reactions. But if you have a very pure and clean oxide it would actually be very inactive. So, the solution is to put a little dirt in, make it less perfect, and by being imperfect you actually get a higher catalytic ability."

Having demonstrated, through experiments, higher efficiency than iridium-based commercial catalysts, the job is now to optimise for ability and durability. And at Stargate R&D laboratories, located on the campus of Tallinn University of Technology (TalTech), that is precisely what is being done in an effort to speed up the development of a sector that is key to achieving net zero.

"If you read the IPCI reports and look at the timeline, usually the predictions end in 2100. I remember once reading a report during my sister's wedding. My sister introduced the oldest guest, our grandmother, aged 96, and the youngest guest, my son. And I realised he would turn 96 after 2100. He will see what the predictions will turn out to be. I do think it's my duty as an engineer to put my efforts towards something that is doing good. Hydrogen is not the answer for every problem we have, but it can be used in a way to decarbonise some sectors which is why I do this," Jan muses.

A portrait of Jan Grolig, Stargate's COO, holding models of the company's electrolyser stacks.

A Stargate Hydrogen scientist explains the company's approach to scaling up its proprietary electrode technology in the company's research lab.

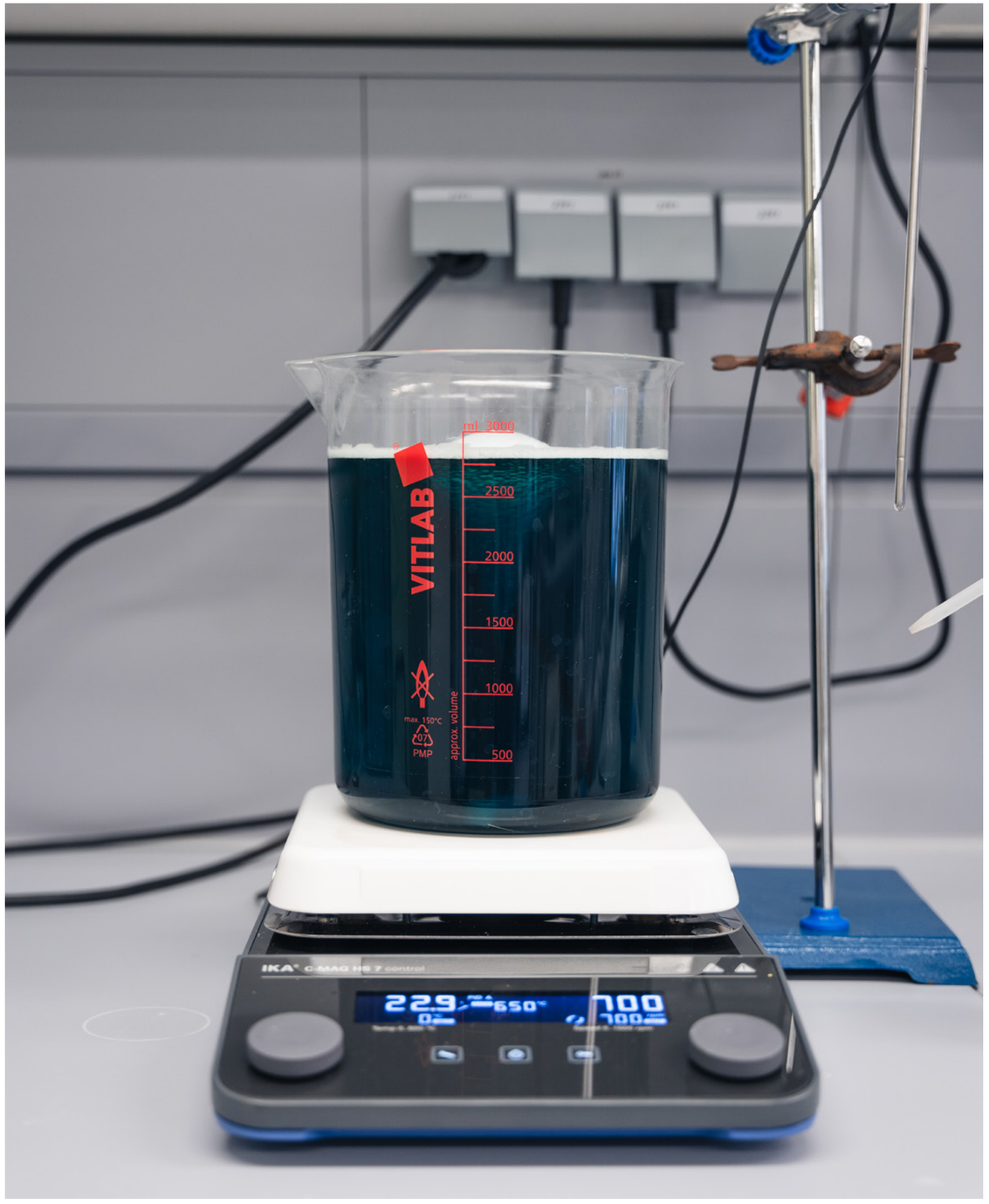
Rainier Küngas, Stargate's chief technology officer (CTO) and co-founder, has led the development of the company's next-generation electrolyser product.

The core innovation of Stargate R&D lies in its ceramic electrode materials, which as mentioned contain high current densities, high efficiencies and contain no platinum-group metals and usage of critical raw materials is minimized. This results in significantly lower hydrogen production costs and makes the electrolysers affordable for end-users like utility companies, refineries, and green ammonia producers among others.

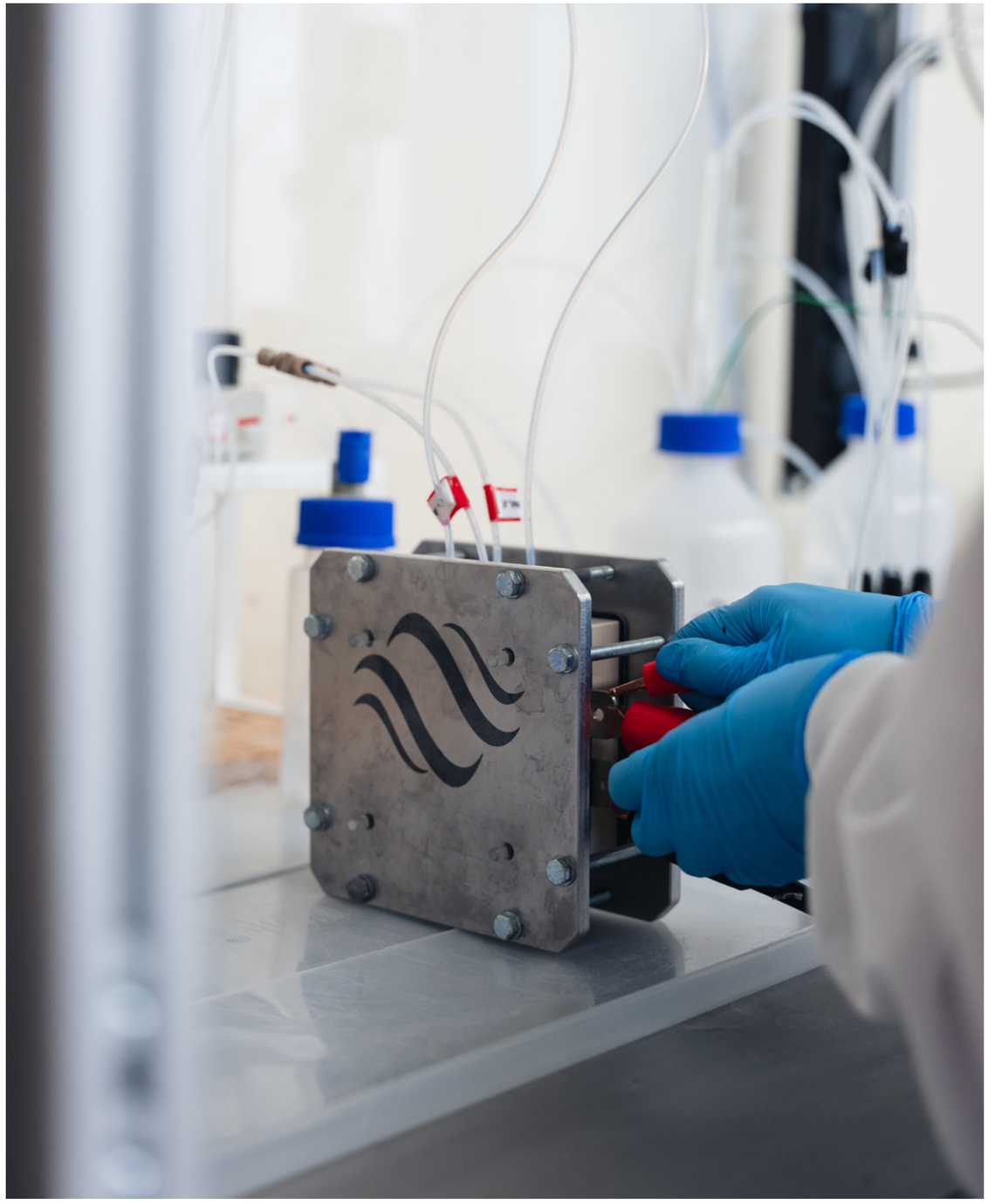
Supporting Stargate in its mission to commercialise its novel electrode and stack technologies is the EU's Important Projects of Common European Interest (IPCEI) programme, specifically the Hy2Tech wave which was granted state aid approval in July 2022.

The project involves developing a new 1MW electrolysis stack ready for mass production. The ultimate goal is to establish a first-of-its-kind manufacturing facility for high-efficiency alkaline electrolysers.

Rainier Küngas, Stargate Hydrogen's chief technology officer, in the gardens of TalTech.



A catalyst solution being prepared for testing at Stargate's laboratory.



Working on catalyst testing at Stargate's research laboratory.

Scaling up

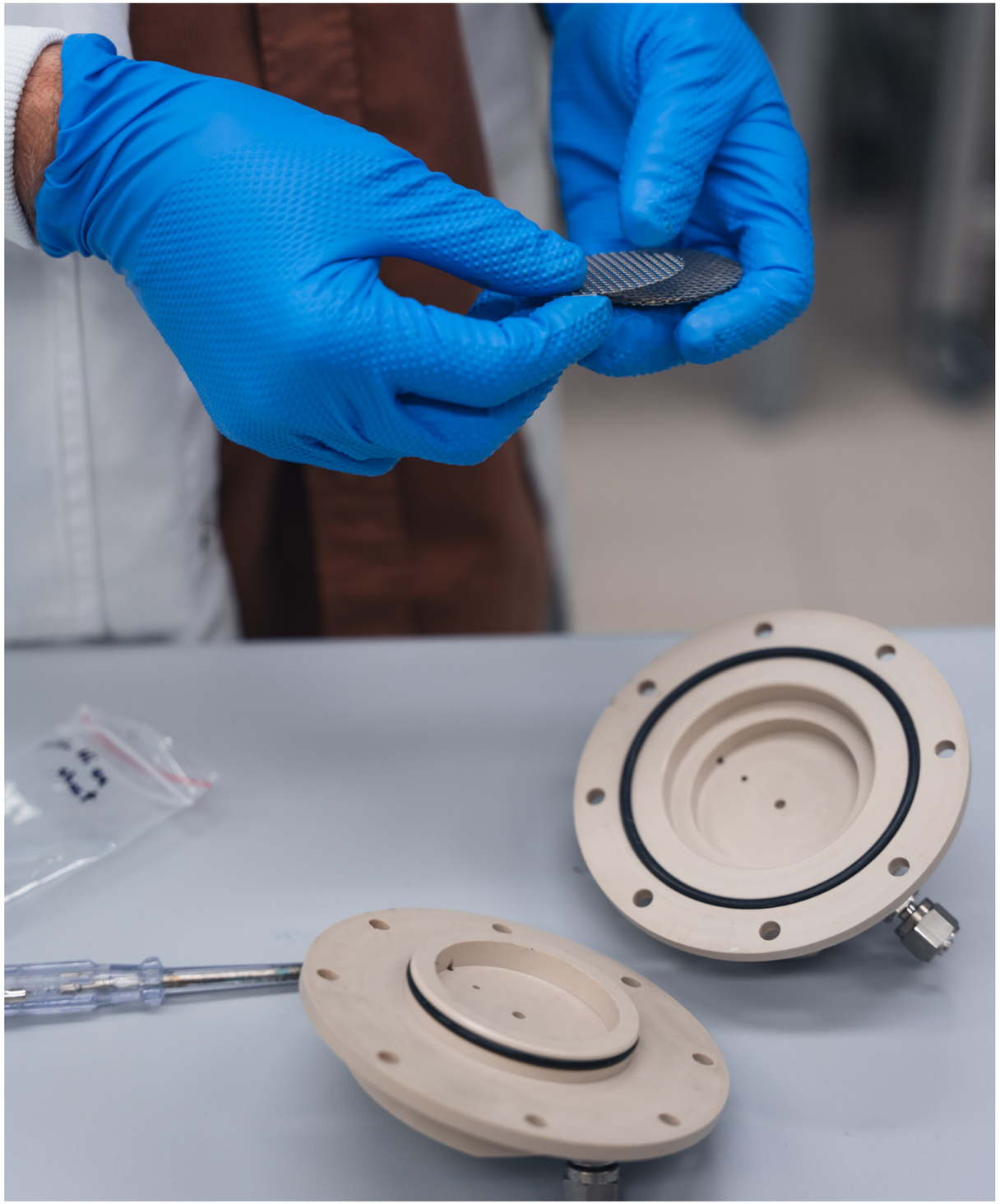
Since its founding in 2021 and designing its first stack model in only six months, Stargate has grown to 57 employees as of today. It has recruited people from Nel, Mitsubishi Heavy Industries, Gencell, and Topsoe, among others. Additionally, it has also struck partnerships with the likes of Fortum, Rockfin, Milani, the Fraunhofer Institute, Agfa-Gevaert, and ABB. The growth trajectory is clear.

The company is working on its second-generation product line – the one which will include the ceramic catalyst – while it is already executing multiple MW-scale projects with its first-generation product in the Baltics, Nordics, South and East Europe. The Gen 2 stacks will enter market by the end of 2025. The number of employees and clients are not the only things growing. While manufacturing capacity in Tallinn is still relatively small, the company is already building its 140MW megafactory with plans for a proper gigafactory in the future. This is all to meet the clear projected market demand.

"What we see on the market is that projects will get larger, and therefore products will get larger. We are working on scale-up on both these fronts," Marko says.

Stargate is currently working with 1MW system-level products and 0.5MW stacks, enough to execute projects on a 1MW-10MW scale. But they have also begun the development of 'Starbase' – which is a larger single stack for bigger projects from 100MW up to even gigawatt scale.

In response to market signals, the company is scaling up the product, the manufacturing, and the organisation itself to meet the opportunity.



Preparing electrodes for testing.

A Stargate employee examines the experimental data collected on a series of catalysts that will help the company determine the optimal configuration.

Growing Eastern European hydrogen

While Stargate has not been set up solely to cater to Eastern European clientele, it is notable and beneficial for the heavily industrialised region to have a successful electrolyser and stack manufacturer in its heart.

Stargate is active in countries like Poland, which *"have all those hard to abate industries that we're looking to decarbonise - refineries, ammonia production, chemicals, steel, all of those where hydrogen has the biggest potential,"* says Marko.

In the Nordic countries, good renewable energy resources and consequent low energy prices make them ripe for hydrogen production – another good customer base on Stargate's doorstep. Finland in particular is a key market for the company, which has just set up its regional subsidiary there.

While the Baltics themselves lack Poland's industrial heartlands and Finland or Sweden's energy prices, there is only limited existing industry to decarbonise. But with the rise of greenfield projects and a commitment to decarbonised transportation, there is still plenty of potential.

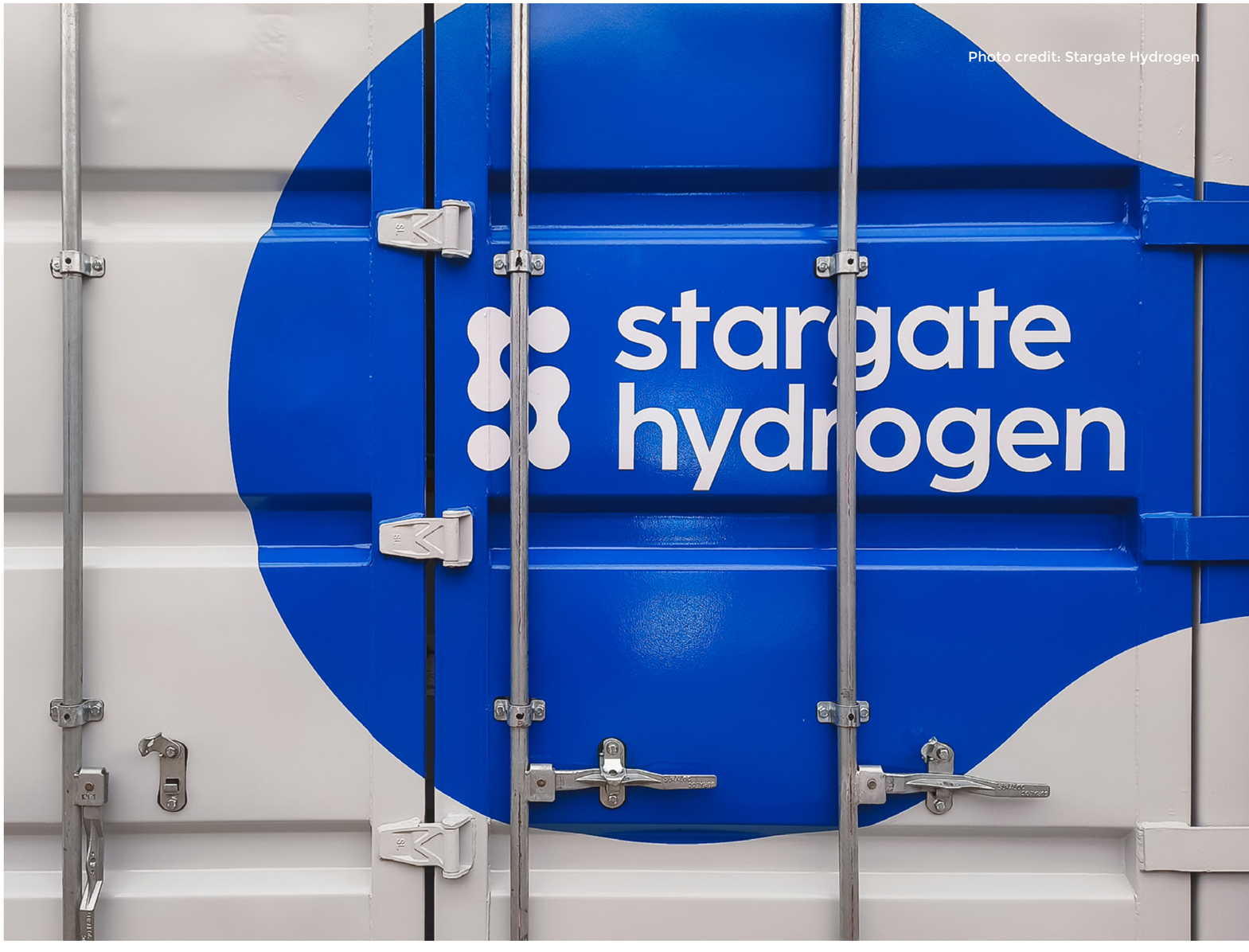
One project that is about to launch is a renewable hydrogen taxi fleet in Tallinn itself. A 1MW Stargate electrolyser is powered by a solar farm and combined heat and power plant owned by Utilitas, the Tallinn-based utility. A fleet of 30 taxis in the city will use the two hydrogen refuelling stations to get the produced hydrogen.

A view of the Utilitas combined heat and power plant which, alongside a solar farm, produces hydrogen for a fleet of 30 taxis.

Preparing an electrolysis cell for electrochemical testing at Stargate's research laboratory.

Tightening the bolts on an electrolyser stack at Stargate's production facility.

Worker welding piping connections for the electrolyser system.



Close up of Stargate's containerised turn-key electrolyser.

"What makes us contribute to the region is having local knowledge so we can support our customers with the experiences we've made in our own demonstration project. Due to our locations, we have close connections to Eastern European customers. We interact a lot with local policy makers to address the challenges we see," says Jan.

When asked to share advice to other Eastern European entrepreneurs interested in the hydrogen space, Marko and Jan approached the question from different, but equally valid, angles.

"Just start! Try to get your hardware in place quickly, and don't stay stuck as a 'power point company'," says Jan, referring to the speed at which Stargate was able to build up its technology and staff in its beginning.

Marko, meanwhile, encourages people to follow Stargate's lead in the form of concrete and useful innovation: *"The main advice is to look at things more on the fundamental level. We see many companies in this space doing small evolutionary adjustments. But what we need is more revolutionary innovation! Looking at the material science level, what can be done differently? What materials can be used? Do more of the fundamental innovation!"*.

Along such an intricate and complex value chain, there are many ways to approach hydrogen. Focusing on improvements to the existing technology – still in its relative youth with many avenues for optimisation available – will ensure customers get more 'bang for their buck' and mean we will need less to achieve more. With uncertain supply chains always a risk, the type of advancement illustrated by Stargate will always have a place in the ecosystem.

Stargate's offices in Tallinn, Estonia.

Assembly of Stargate's containerised turn-key green hydrogen production systems named Gateway.

COO Jan Grolig poses next to different sized electrolyser stacks manufactured by Stargate in their Tallinn manufacturing facility.

Two Stargate scientists working on catalyst research at the company's laboratory.

A Stargate employee puts the finishing touches on an electrolyser stack.

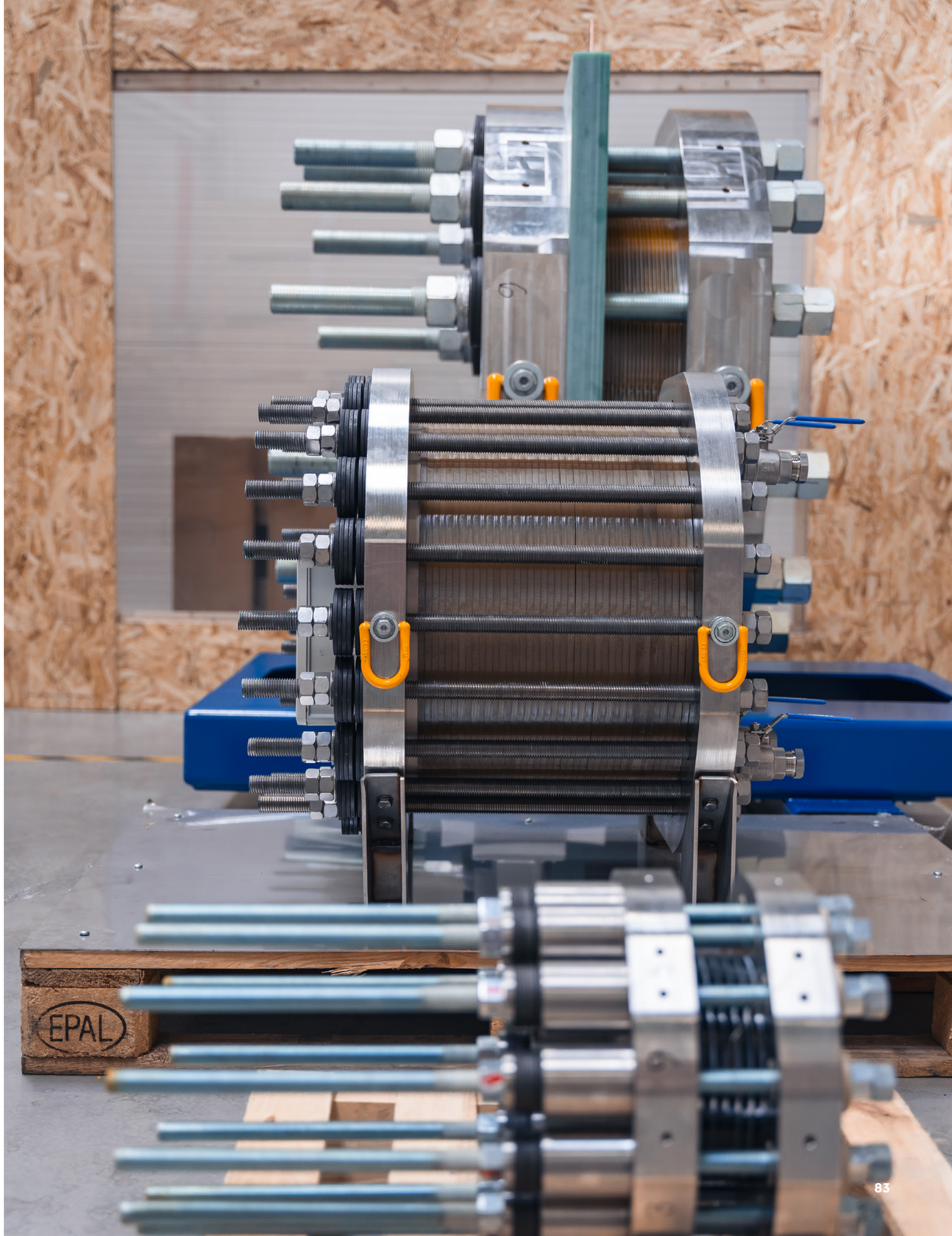
Deburring of an electrolyser component.

Improving the framework

As with any technological pioneer in a relatively nascent industry, there are challenges and obstacles to overcome, and puzzles to solve.

For Marko, legislators in the EU and at national level must reduce the uncertainties that continue to slow down the uptake of new hydrogen projects.

"We felt this uncertainty in our early years that when it wasn't clear what is and isn't renewable hydrogen and lots of projects were being put on hold. Now there is more confusion about low carbon hydrogen – there's a new piece of legislation, but developers are confused. What is it? How does it fit into the regulatory landscape? What does it mean for their projects? Removing those kinds of uncertainties is clearly something we need," explains Marko.



A profile of Stargate's different electrolyser stack footprints assembled as short stacks, both commercial and developmental prototypes.

An array of electrodes coated with different catalysts on display at Stargate's laboratory in TalTech.

Named after the Estonian national epic, Kalev is the laboratory sized electrolyser used by Stargate's scientists to test their new catalysts' performance.

Meanwhile, Jan addresses the clear need for more renewable energy throughout Europe as well as the need to consider how to address foreign competition, highlighting the benefits of non-price criteria to ensure a "made in Europe" element survives and thrives.

Jan relays the themes of a conversation he recently had with local politicians. There, three priorities were highlighted that will prove familiar to those who are invested in the hydrogen space. First, the issue of education and skills which so often flies below the radar but is essential to allowing the sector to grow as it is projected to. Governments and institutions must ensure there is enough talent entering the sector. A time-consuming task, no doubt, but one which will be rewarded with time.

Second, the simplification of permitting and harmonisation of standards which will ensure frictionless hydrogen trade between countries and regions. Clear definitions of hydrogen products and technologies will be essential.

Third, Jan highlights the need for an ecosystem for new companies to enter, Stargate having *"been challenged without having legacy or references. We need to really create opportunities to gain technical validation at large scale without being fully exposed to commercial competition,"* he says.

These have all become familiar refrains for all hydrogen innovators and actors, and the consistency in opinion should send a clear signal to legislators about what is needed to make this a success for the energy transition as well as for European economies.

An electrolyser stack being assembled vertically demonstrating the placement of the many layers of cells within.

An electrolyser stack with the Stargate Hydrogen logo.

Stargate employees holding enormous wrenches which were used to lock nuts on Stargate's first prototype stacks.

Innovating the future

Marko, Jan, and the whole Stargate team have pushed the boundaries of electrolysis technologies in a way that will surely reverberate through the European value chain.

There is much work left to do and, in Stargate's case, much expansion still to go. But from these small vials of catalyst solution grows the fruits of a decarbonisation revolution: one which will hopefully ensure a future for Jan's young son, and the generations to follow.

Story 3

Scaling up essential infrastructure

Europe’s largest port is gearing up to lead in hydrogen export and import – providing the molecule to the industrial heartlands of the Netherlands, Germany, Belgium, and beyond.

A map of the Port of Rotterdam at the company's offices. The port stretches more than 45km.

Rotterdam, the Netherlands – When it comes to establishing a coherent and robust supply chain, hydrogen brings with it many layers and considerations. While the welcome arrival of solar and wind power benefitted from a pre-existing power grid to which these new renewable projects simply needed to be connected, hydrogen projects require a new infrastructure. Pipelines and storage infrastructure, as well as maritime and inland ports to take the influx of the molecule, are sorely needed. A limitation, no doubt, but one which can certainly be overcome.

And overcome it must be if we are to decarbonise every facet of our economies and achieve net zero by 2050. Port of Rotterdam and its partners understand this fact and have every tool at their disposal to make it a reality.

As Europe's largest seaport and one of the largest in the world, Port of Rotterdam has been committed to bridging the gap left by electrification since 2018. With hydrogen flowing through its pipelines to Europe's industry and beyond, the port – with its strategic North Sea position and proximity to its neighbours – can be a catalyst for the decarbonisation of the continent's steel, cement, chemicals, and fertiliser sectors, just to name a few. Randolf Weterings, program manager, New Energy Systems at Port of Rotterdam, knows the scale of the challenge at hand, and the massive opportunity on offer, better than most.

With a background in electrical engineering and management of technology and experience in the energy and industry sectors, his time at Dutch utility Eneco saw him exposed to the world of renewable energy and electric vehicle charging at a very early stage. *"Even Tesla wasn't there yet,"* he says.

Randolf returned to the University of Delft for his master's degree, focusing on the topic of battery integration into electricity system.

"I concluded that batteries are a very important of the storage picture. But electricity is just a fraction of current energy system, and batteries therefore can't be the only storage solution," he explains.

Randolf Weterings, program manager, New Energy Systems at Port of Rotterdam.

Randolf at Port of Rotterdam's head office: *"hydrogen is a no-regret technology".*

The full picture

Following his master's degree, Randolf's started to work with hydrogen as the missing complement to batteries, and quickly realised it was the answer to the question 'what is the next step after oil and gas?'. The company he worked with at the time was using grid electricity to power its experimental electrolysers. Randolf wanted to test it with renewable power, so he left to start his own company and do just that.

Following a successful feasibility study, supported by the region of South Holland, he built his first kilowatt-scale electrolyser in Rotterdam powered by solar photovoltaic. Finally, Randolf had his proof of concept, but knew that a decentralised machine like the one he had built would only scratch the surface. He had to dream bigger.

A ferry passes another vessel heading into the port of Rotterdam.

Joining Port of Rotterdam, his first involvement was in the first large scale carbon capture and storage development, now known as the Porthos project. Soon after, he set up a programme which included a power-to-hydrogen section, and quickly identified that the industrial sector – the heartlands of which are a stone's throw from the port – would be the perfect match for this new product.

In 2016, Port of Rotterdam's energy transition team launched a study called "decarbonisation for industry", focused on creating decarbonisation pathways for Port of Rotterdam. *"If you look at pathways leading to net zero, we found that hydrogen would play a significant role – it was a 'no regret' technology to invest in,"* explains Randolf.

Construction of the Gasunie hydrogen pipeline will connect Port of Rotterdam, its hydrogen production centres, and the nearby industrial centres.

Collaboration across the value chain

The Port of Rotterdam has signed memoranda on hydrogen with Australia, South Africa, the Middle East, and North and South America, amongst others. Additionally, its strategic North Sea position, adjacent to a number of industrial clusters, and its proven ability to develop the required hydrogen infrastructure has led to one important collaboration closer to home.

In July 2022, Shell took a final investment decision (FID) to build Holland Hydrogen I, soon to be Europe's largest renewable hydrogen plant once operational.

A 200MW electrolyser is being built on the Tweede Maasvlakte in the port of Rotterdam to produce about 60,000 kilograms of renewable hydrogen per day. The renewable power for the electrolyser will come from the offshore wind farm Hollandse Kust (north), which is partly owned by Shell. The hydrogen will then be supplied to Shell's Energy and Chemicals Park Rotterdam via the HyTransPort pipeline, to replace the existing grey hydrogen and thus helping to decarbonise the processes. Now known as Hydrogen Network Rotterdam, it is being built by Gasunie subsidiary Hynetwork with the support of Port of Rotterdam, demonstrating both the benefits of, and need for, collaboration in the hydrogen space.

"Hydrogen started out as a mobility play but it soon became obvious to take on other sectors. Our 2018 strategy update included the build up of hydrogen production and Rotterdam was a brilliant place to do it because the value chain comes together here," says Dr. Katharina Gruenberg, commercial manager for Holland Hydrogen, Shell.

"I was so convinced by this strategy that I moved into full time development, to walk the talk."

In 2016, Katharina, who began her Shell career in the 'scenarios team', had returned from assignment in Brunei as Shell was founding its new energies business and became one of the first employees of the section, receiving "the honour" of being responsible for the company's hydrogen strategy. She has been in the thick of it since the beginning.

With the massive increase in renewable energy supply, the limit of electrification and the electricity system have become more apparent. The issues of Intermittency, curtailment, storage, and energy security all come to the fore, and this has been at the front of Katharina – and Shell's – minds when developing Holland Hydrogen.

"We need system integration, and solutions for hard-to-abate sectors. We must be aware of the role of energy diversification from a geographic perspective," Katharina explains.

Dr Katharina Gruenberg, commercial manager for Holland Hydrogen I, Shell.

The port and the industrial cluster located there are targeting carbon neutrality by 2050, meaning that by 2030 at least half of CO_2 emissions must be eliminated compared with 1990 levels, according to the company. In 2020, more than 22 mega tonnes of CO_2 were emitted here, representing approximately 14% of all Dutch emissions. These figures demonstrate the importance of the task ahead and, thanks to the Hydrogen Network Rotterdam pipeline, it becomes all the more feasible.

The pipeline is open access, meaning that it will be opened to all companies that want to purchase or supply hydrogen. In the first phase it will be 32km long and, in the future, will be connected to the Dutch national hydrogen network that Gasunie, through its subsidiary HyNetwork, is realizing. Eventually, there will be a connection to Chemelot in Limburg, North Rhine-Westphalia in Germany and other European regions, making Port of Rotterdam the beating heart of hydrogen supply to Northwestern Europe, and the pipelines the arteries of a truly European network.

The expectation is for the network to be up and running by 2030, allowing for producers and consumers in the region to confidently finalise hydrogen business cases for years to come, safe in the knowledge that there is an infrastructure ready and waiting for them.

The project site of the conversion park where Holland Hydrogen I's electrolysers will be the first of a total 1GW renewable hydrogen cluster.

"Rotterdam is so interesting for a first project because there is offshore wind landing, you can leverage the infrastructure, you can produce hydrogen here and tie it to the first customers. But despite having all these components you still need the pipeline to be built by another partner, and you need a further 150 partners to make this project work," adds Lydia Boktor, corporate affairs manager, Hydrogen, at Shell.

Lydia began her Shell career nine years ago, like Katharina in the 'scenarios team', looking at the energy system 30 to 50 years into the future. With her chemical engineering background, it was not long before she saw that the conversation had to go beyond electrification if a true energy transition was to succeed.

"I would already see 10 years ago that some areas of our economies couldn't be electrified. How big this part was, and what it consisted of, was exactly what we were exploring," Lydia explains.

Following a stint in the LNG department and postings in Europe and Asia, Lydia returned to the Netherlands to become one of the first members of Shell's hydrogen team and was involved with Katharina in the development of its external hydrogen strategy – in time for the EU and Netherlands to come out with theirs at more or less the same time.

Randolf Weterings and Lydia Boktor listen intently to Katharina Gruenberg's explanations at the Holland Hydrogen site in Rotterdam.

Wind turbines spin in the wind on the shores of the port of Rotterdam.

Lifting the pipe on
the Welplaatviaduct.

Lydia Boktor, corporate affairs
manager, Hydrogen, at Shell.

Lesons learned

Of course, building up such large-scale and ambitious projects as part of the hydrogen value chain does not come without its challenges. With so many moving parts and stakeholders, including the need to get the timing right on each final investment decision, each lesson learnt is a valuable gem of wisdom that can be passed on. Port of Rotterdam, Shell, and Gasunie are paving the way for projects like Hydrogen Network Rotterdam and Holland Hydrogen that will need to be replicated and imitated in some shape or form across Europe for the hydrogen transformation to flourish.

The many challenges facing the build-up of crucial hydrogen infrastructure in these early stages, as Lydia explains, range from the self-inflicted like the *"fickle implementation of targets"* by member states and lack of incentives that will help bridge the gap in cost between renewable hydrogen and its polluting alternative, to the natural issue of complex coordination across multiple stakeholders and sub-sectors and *"getting the right value chain to the right end customer"*.

Holland Hydrogen I took a final investment decision two years ago, but supply chain issues exacerbated by the war in Ukraine have created uncertainty. When it comes to personnel, the industry has been hit by *"a wave of retirements which we had been warning about for years,"* Katharina says, resulting in having to bring people back from retirement to coach younger staff..

"We will get to a system that is easier once there is scale and once the storage infrastructure is in place, but the way there is hard. We are certainly suffering from 'first mover disadvantage' and have had our own realisations over the years relating to costs and other aspects. The energy transition is difficult, but not in the sense that we should walk away and give up. It is obviously worth doing, but we need support, we need stable regulation, and we need subsidies," Katharina explains.

The value of the project therefore is not only measured in what it will achieve in terms of hydrogen transport and use, but in the light that it will shine on best practices to succeed and looming limitations to mitigate on future projects of this kind.

Dr. Katharina Gruenberg speaks by a scale model of Holland Hydrogen I.

1.4GW of offshore wind arrives at this onshore substation and 220/380kV transformer station, located in port of Rotterdam.

Gigawatts of potential

With work well underway and a number of committed partners up and down the value chain, it's only a matter of time before hydrogen starts leaving its mark on Port of Rotterdam and the wider region's carbon profile.

"The port is part of the chain, and if we can max out our capacity for renewable and low carbon hydrogen, as well as deliver the expected energy efficiency improvements, we can save up to 200 million tonnes of CO_2. That's the focus for 2050," explains Randolf.

By 2030 already, the port is expecting to be host to 2.5GW of installed electrolyser capacity. Shell is first partner, but already more companies are signing up to build large scale electrolysers. A joint venture of Vattenfall and Copenhagen Infrastructure Partners (CIP) is building a 2GW offshore wind project with 50 MWp floating offshore solar farm on site and a new gigawatt scale electrolyser at the port. Eneco, the Dutch power utility, is planning to build an 800MW electrolyser too.

Randolf Weterings walks among the wind turbines powering operations at the port of Rotterdam.

A worker putting the finishing touches on the welding process of two pieces of pipeline as part of the Porthos carbon transport and storage project, required for low-carbon hydrogen production.

"Large scale electrolysers better fit the energy system's needs, so when you look at a project like Vattenfall and CIP's, it's the best combination because it will help with grid congestion, improves efficiency by integration options and provide the minimum required space we need to decarbonise the area," Randolf says.

Besides local production, Randolf and Port of Rotterdam are anticipating the first imports of renewable hydrogen before 2030. Europe's ambitions of 10 million tonnes of imports by 2030 may not be met but large quantities of the molecule are still expected to arrive on European shores in the coming years. Port of Rotterdam is, naturally, best placed to receive it. The company has nine terminals in preparation for hydrogen import.

For Randolf, the important message when it comes to imports is simplification of the rulebook, citing the two years it will take to implement 3rd party access rules, among other issues, creating uncertainty and slowing progress.

"So please help the first pilots even if legislation isn't there yet. Especially with those high targets, you cannot afford to wait 2 years for the legislation," he implores legislators.

The construction site
at Holland Hydrogen I.

A portion of steel pipeline ready for installation in the Porthos project.

When it comes to the build-up of hydrogen infrastructure, Port of Rotterdam is demonstrably one of the more advanced and ready to pump the molecule from producers to customers. From an investment perspective, it has positioned itself as one of the first ports of call for any stakeholder seeking scale and certainty.

That said, the company is not resting on its laurels and is taking the long-term view on what is very much a marathon, not a sprint.

"This is one of the areas where the hydrogen economy starts, but it definitely won't be the only area. So, we want to collaborate with projects worldwide and ports inside Europe because that's only way to get to a large-scale hydrogen economy. If you have a good idea about your next steps, please come to Port of Rotterdam," Randolf says.

With the ports of Antwerp, Hamburg, and Sines also working on hydrogen, there is plenty of room for collaboration, and for Rotterdam this does not stop in Europe with connections being established all over the globe.

And, on the question of competition, Randolf had a simple answer: *"We aren't competing on the energy transition - we all need to reach net zero together."*

Another view of construction work at Holland Hydrogen I.

Story 4

Photo Credit: Fincantieri

Setting sail with hydrogen

In Italy, one of the world's largest shipbuilders is ready to decarbonise maritime transport with the hydrogen molecule

Fincantieri's research vessel Zeus (Zero Emission Ultimate Ship) is equipped with a fuel cell and lithium-ion battery for zero carbon propulsion

Photo Credit: Fincantieri

Trieste, Italy – The Transport sector is responsible for about 15% of total GHG emissions and about 23% of global energy-related CO_2, according to the Intergovernmental Panel on Climate Change (IPCC). International shipping is the second contributor with 9% of the sector's total emissions. Maritime transport is responsible for 3% of all global greenhouse gas emissions, the same as aviation, and that figure is projected to rise if no action is taken. Within the maritime sector itself, emissions rose by 20% in the last year. if we are to complete the decarbonisation of our society, we must turn urgently turn our attention to shipping.

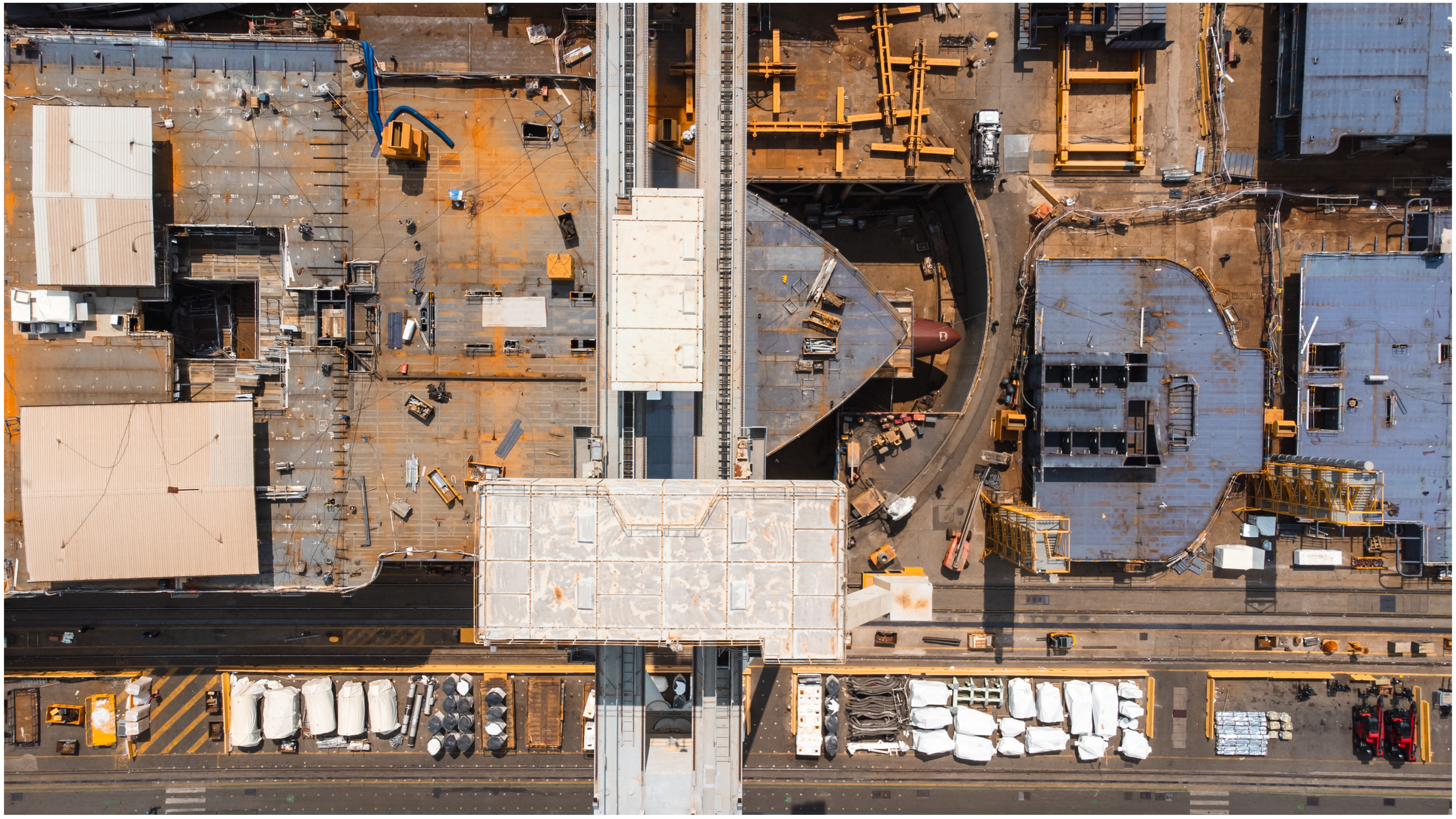
Fortunately, the world has started to take note. In the EU, the first-ever indicative target, a sub-target of 1.2% of renewables in the maritime transport fuels sector by 2030, was set in last year's (2023) Renewable Energy Directive (RED). This is an important beginning to what will be a much needed and urgent transformation of the maritime sector.

Fincantieri, the Trieste-headquartered Italian shipbuilder, Europe's largest and the world's fourth largest, is working hard in the present to be prepared for the future. With an expansive portfolio that includes passenger ships, merchant vessels, and naval vessels, it is enthusiastic about embarking on this important decarbonisation journey.

Caterina Cobino is head of special projects and partnerships at Fincantieri as well as program manager for Wave 2 the Future, an Important Project of Common European Interest (IPCEI) for the creation of a hybrid hydrogen propulsion system and for the design, development, construction, and certification of cruise ships with different zero emission technologies slated for operations between 2027 and 2028. The project will create an innovative production chain for the expanded and continued use of hydrogen in the maritime sector.

Caterina calls Fincantieri's hydrogen initiative *"a priority project for the company."*

Fincantieri's head of special projects and partnerships and program manager for Wave 2 the Future, Caterina Cobino.



An overhead image of a cruise ship being assembled at Fincantieri's Monfalcone shipyard near Trieste, Italy. The company's Wave 2 the Future IPCEI will develop hydrogen technologies to be integrated into two next generation cruise ships.

A statement from Fincantieri's CEO

Fincantieri aspires to be recognised as the enabler for the energy and digital transition in shipbuilding, not just for its supply chain but for the entire industry, acting ahead of the regulations and as a driver for change, securing a competitive advantage. More specifically, decarbonising maritime transport means designing and building the ships of tomorrow: both green and digital, because one can't have one without the other.

We are working on this product transition - the ships of the future - and even before that on process transition: the shipyards of the future. Focusing on the on-board transition, which is the theme of our contribution to this worthy publication, Heroes of Hydrogen, the questions we want to answer are: how can we contribute to combating climate change, how can we make ships more sustainable, and how can we reduce the emissions of a huge and complex floating smart city like today's cruise ships?

By taking an agnostic approach, we are experimenting with all existing technologies to deliver the best solutions for achieving the strategic goal of net zero Fincantieri considers interesting any type of system or fuel that can help shape our path towards the energy transition, from renewable low-carbon fuels and hydrogen derivatives, including synthetic liquefied natural gas with which we have already halved CO_2 emissions on our ships, to biofuels, ammonia and methanol, looking one day at using next-generation nuclear power.

Of all the molecules, I consider hydrogen to have almost magical properties; the heir apparent of the energy transition, capable of playing a key role in the decarbonisation of shipping.

The industry is currently focusing on resolving some critical issues that the implementation of hydrogen on ships presents. These include the cost, the space it takes up on board, the production of green hydrogen, and its large-scale availability.

Fincantieri has taken the decision to initiate its own research and industrialisation process to open the door to a technology that may prove to be decisive. The first step is to make it technically feasible to accommodate hydrogen and fuel cells on ships. For the same power, fuel cell systems are around three times bigger than a traditional heat engine and need to be located in an environment, the ship, where space is at a premium.

Fincantieri is leading the "marinisation" of the transition and has demonstrated this by testing the first hydrogen storage system combined with fuel cell system, certified by ship registers, on the ZEUS-Zero Emission Ultimate Ship. This is the first ship prototype capable of being propelled entirely by hydrogen, where we have leveraged experience gained underwater with fuel cells on submarines, thus showing that Archimedes' principle and hydrogen power can coexist even above the water's surface.

Today, we'd like to take a leap forward together with the most visionary shipowners in the cruise sector, where we are already developing solutions that allow completely zero emission operations to be carried out in port.

Current technology still doesn't provide enough power to operate a modern cruise ship, which needs a total of 60 MW, but it is the start of a journey that we wanted to embark on as pioneers, and which makes this project, named Wave 2 the Future, the spearhead of our innovation projects for the development of technologies aimed at enabling a new ecosystem.

Because that's what we mean when we talk about the ships of the future: the zero-emission ship not only marks an incremental evolution, but a disruptive one, representing the start of a new era; a bit like the transition from oars to sails, then from sails to steam, and from steam turbines to the diesel engine. The ships of the future, with zero emissions, represent the next revolution in the history of maritime evolution. And I'm sure that hydrogen will play a decisive role in this challenge.

Pierroberto Folgiero,
CEO of Fincantieri.

A Commitment to Net Zero

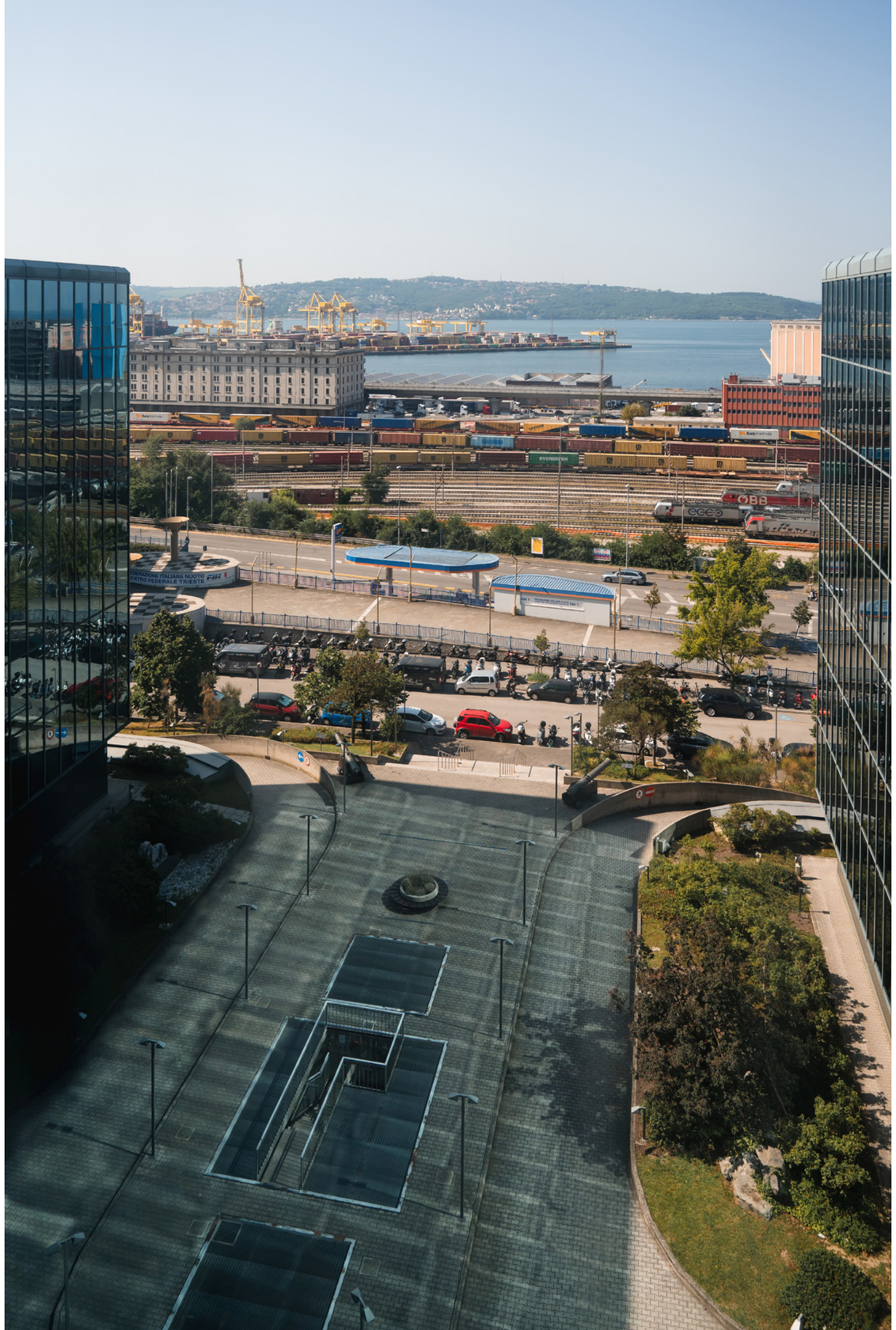
Wave 2 the Future is the Fincantieri evolution of a long path through research, Energy Efficiency solutions to reduce emissions, up to present Net Zero goals. Caterina, who joined the company in 2013 following stints with General Electric, ENI, and Electra, says that from her arrival energy efficiency was continuously growing in importance.

"Energy efficiency topics immediately captured the sector's attention, and the value of the relevant solutions was increased by the benefits in terms of fuel and emission savings. This was significant for the customer in a period where an emissions trading scheme (ETS) for maritime was still far away," explains Caterina, who has a mechanical engineering background from the University of Pisa.

Caterina was no stranger to the concept. During her time in the power sector prior to joining Fincantieri, the idea of decarbonising industry was already gathering steam. But, at the time, the exact solution for how to make it happen was less apparent.

"ETS was implemented during this period and energy efficiency became an important task for industry: The application of Kyoto was the first step in global decarbonisation: it boosted renewable energy development and brought attention to energy efficiency for the first time, bringing with it initial success in cross-sectoral solutions. But the idea of Net Zero was still far away - a real solution for that challenge wasn't yet available," Caterina says.

As hydrogen finally began to receive recognition in the upper echelons of European politics in 2019, it generated huge interest in the industry. Discussions began in earnest in Fincantieri's Trieste headquarters about its application as a proper deployable technology for maritime.



The view from Fincantieri's head office in Trieste, Italy, with a view of the city's harbour on the Adriatic Sea.

Fincantieri's shipyard in Monfalcone, Italy, which has more than 8,000 employees.

Before beginning with hydrogen, Fincantieri had already achieved significant gains in improving the energy efficiency of its vessels, recovering around 15% of fuel consumption through a variety of innovative solutions. This success demonstrates the company's commitment to decarbonising and its ambition to go even further.

"Decarbonisation is totally central to our strategy. Our management strongly insists on the importance of a disruptive innovation to the products we were going to offer," Caterina says.

"Working on this project means understanding every day how the commitment of each individual, with their own skills and competencies, within a large team involving hundreds of engineers and a wide supply chain, allows us to achieve high levels of innovation. This commitment transforms the maritime sector, achieving concrete results for decarbonisation and bringing great ethical significance. It enables us to leave a significant mark for the future," says Paolo Guglia, Partnerships and Special Projects in Innovation dept and Policy Manager for Wave 2 the Future.

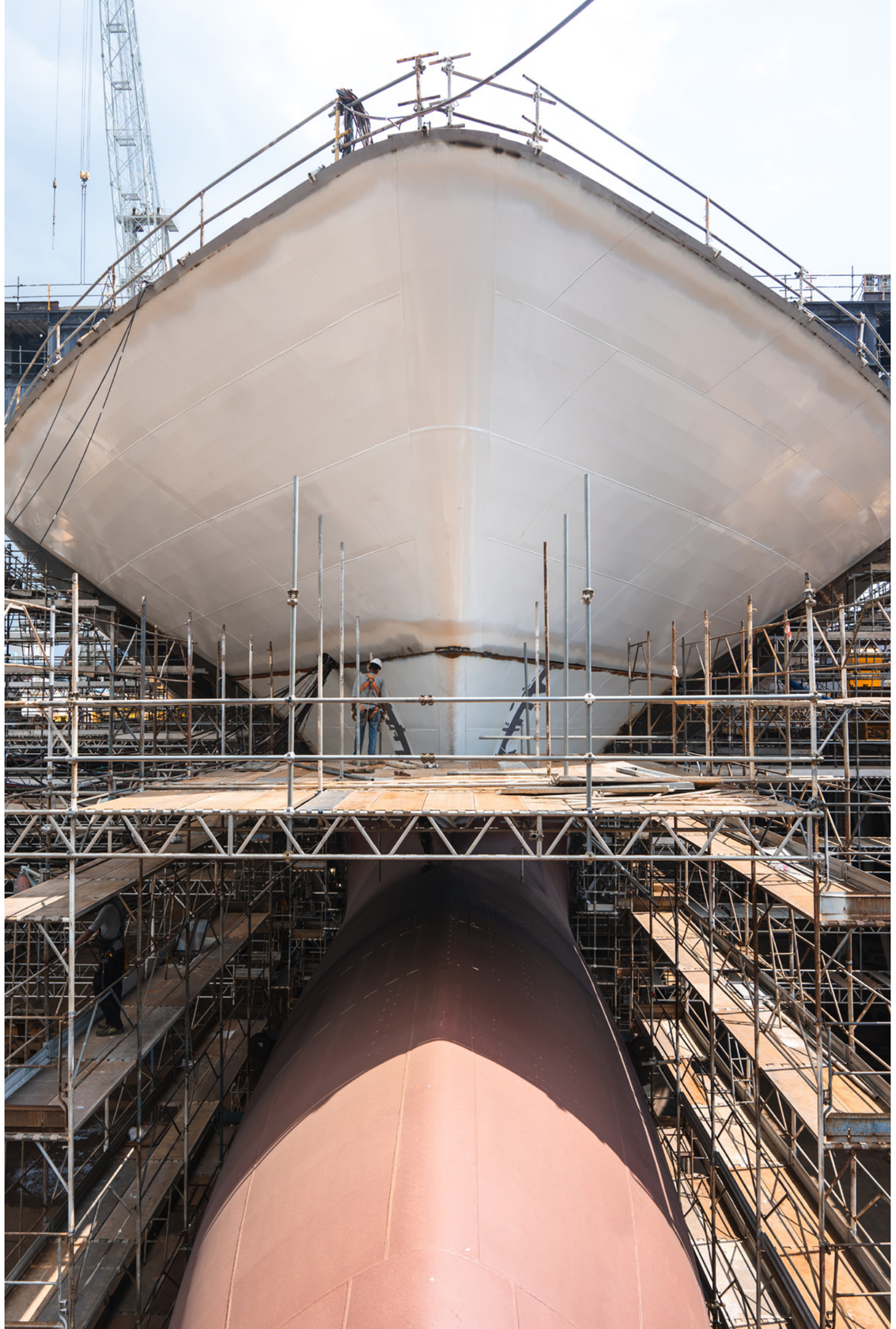
Observing the importance that hydrogen had gained from the EU and the growing ecosystem of first movers in the space, Fincantieri was ready to not only participate – but lead.

"One of the most important things in developing a disruptive and complex new technology is knowing that you're not alone and that there is an industry around you to support this change. At this point it was clear that the EU and member states were ready to invest, and this allowed us to take on the challenge. We're really excited about our contribution to this ecosystem, which should allow us to create a competitive product in a competitive new market based on the use of hydrogen," recalls Caterina.

Fincantieri staff in a meeting in the company's head office in Trieste, Italy.

Caterina Cobino alongside Paolo Guglia, Innovation and Policy Manager at Fincantieri.

An innovative design of ship propellors has led to significant savings in energy efficiency – lowering the fuel consumption of Fincantieri's vessels.



Pioneering hydrogen shipping

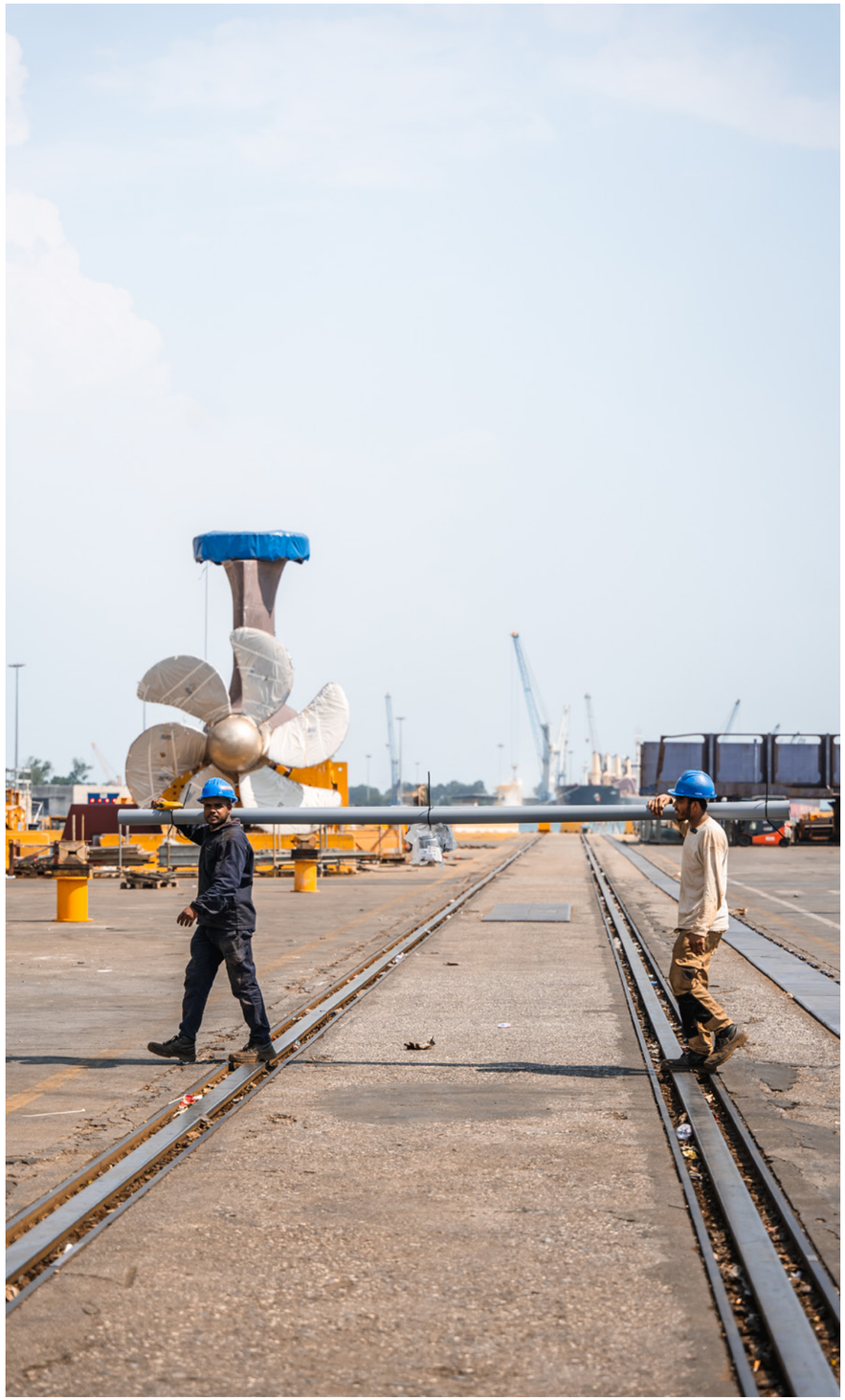
Wave 2 the Future is the most advanced hydrogen-based project Fincantieri has embarked on. The company is exploring multiple avenues to coincide with its broad portfolio of vessel types – all of which must be decarbonised and views the likes of green and e-fuels as enablers for further hydrogen development.

In fact, Fincantieri began its hydrogen journey with the construction of the U212 submarine model, which features a diesel propulsion and an additional air-independent propulsion (AIP) system using Siemens proton-exchange membrane (PEM) compressed hydrogen fuel cells. The submarines can operate at high speed on diesel power or switch to the AIP system for silent slow cruising, staying submerged for up to three weeks with little exhaust heat. The next step, as Caterina tells it, was to apply this technology to a surface vessel.

In comes ZEUS (Zero Emission Ultimate Ship), a Fincantieri project delivered in 2023 which aimed to design and build an experimental net zero emission research vessel. The integration of a 140kW hydrogen fuel cell and 160kWh lithium battery system powers two electric propulsion systems alongside two standard diesel generators provide for approximately 6 hours of zero emission travel at a speed of 7.5 knots. The fuel cells are powered by about 50kg of hydrogen stored on board in metal hydride cylinders.

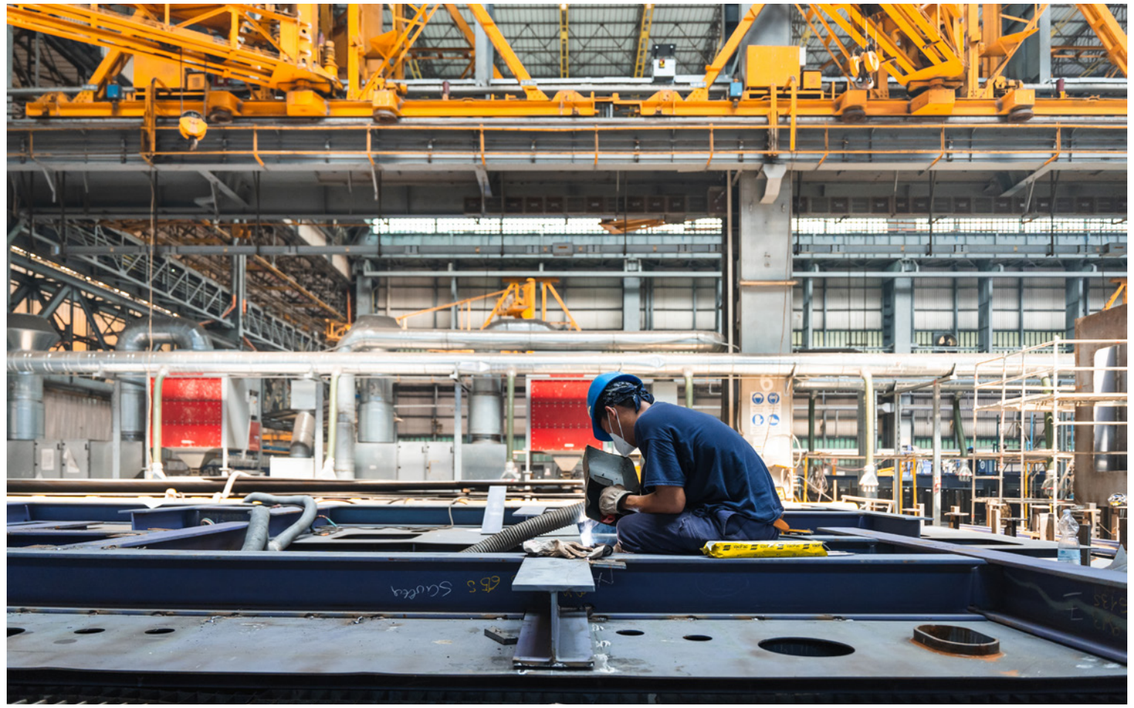
"PEM is the most developed technology for hydrogen to power, and our intent with Zeus was to demonstrate you can use them on surface vessels. The results we want to prove are done and it gives us a basis for the development of an operating vessel that is scaled and optimised," Caterina says.

An innovative keel design has led to significant energy efficiency savings in Fincantieri's ships – part of a broader campaign by the company to decarbonise which includes the use of hydrogen.



Connecting the pieces of the puzzle. Each cruise ship takes up to four years to build.

Fincantieri shipbuilders carry a section of pipe through the Monfalcone shipyard.



A mural depicting every maritime vessel ever built by Fincantieri in Monfalcone since the shipyard's founding in 1907.

Fincantieri is maintaining a razor-sharp focus on these emission reduction ambitions both because it wants to be a leader in the space and because it has set itself lofty targets to reach. And in a sector like shipbuilding, in which it takes up to four years from planning to delivery, it is important to start yesterday.

Leveraging these new technologies, Fincantieri's industrial plan targets the design of a completely net zero cruise ship by 2035.

And while, as stated, the company is exploring all possible technologies – including nuclear shipping – there is a sense that hydrogen and its derivatives are leading the pack.

"Hydrogen ships in one sense are ahead of the game because they are truly zero emissions. But some challenges still have to be solved, and with the ecosystem's development we will find innovative answers for the main challenges," she explains, adding that Fincantieri and its partners have already identified partial or initial solutions to the issues of transport, flammability, and leakage. Others, like storage, power density, and space limitations, are expected to be solved and made cost competitive as the market matures and stakeholders develop the answers.

"Since 2022 we've been designing these hydrogen vessels which will be sailing between 2027 and 2028. We have to follow these prototypes and pilots with more, because it's about producing a new class of ships, not just a one off. We expect to have three or four more ships ready by 2030. We have received strong interest from shipowners to build them, however we have to accept the impossibility of sustaining associated risks and costs relating to the current most advanced technology. This is something we are constantly working to improve," Caterina explains, demonstrating that there will be a multi-pronged approach. It is not just about building new vessels for clients but about adapting existing ones too.

"In the cruise ship sector the fleet has a capital importance in terms of business profitability. In particular when adopting a new technology you must be in position to integrate it on all the ships of a class. For this reason the availability and competitiveness of the supply chain is crucial for the Customer interest in that new technology", says Fabrizio Chiodi, Lead Project Engineer with specific delegations on Hydrogen, Project Manager WP3 of Wave 2 the Future.

A Fincantieri employee welding together pieces that will eventually form part of the hull of a cruise ship at its shipyard in Monfalcone, Italy.

Hydrogen on the waves

Fincantieri expects to complete the first cruise ships between 2027 and 2028. They will be equipped with different technologies developed specifically for the maritime sector.

Wave 2 the Future also includes development of two different power production technologies for marine application. Firstly, a combined cycle turbine based on gas and steam is set to use 100% hydrogen.

The advantage lies in the system's energy density, as combined cycle turbines occupy small amounts of space – an important factor on cruise ships, which must pack in many elements into a finite space.

"We are developing a Green CCGT combining the challenges linked to new processes and products that are not yet completely available from the market and the additional constraints typical of applications on board a ship: the goal is to ride the wave of the improvements in the hydrogen-related technologies to offer a practical and scalable solution for achieving ambitious climate goals," declared Giacomo Schiaffino, VP New Generation Systems in Mechanical and Component Business Unit, and Project Manager for WP2 of Wave 2 the Future.

Fincantieri's Zeus research vessel, delivered in 2023, was designed to prove the viability of using hydrogen fuel cell technology in shipping. The company is now seeking more partners to test technologies on board.

Fincantieri's U212 submarine is one of the first navy vessels in the world to make use of fuel cell technology.

Also under development is a hybrid green power generation system consisting of a hydrogen-fuelled engine, fuel cells, batteries and solar photovoltaic panels.

"After ten years of experiencing first-hand solutions for propulsion or energy generation with diesel, today we look to the future with alternative fuels such as hydrogen. A big step that will change naval and land motoring history," adds Piero Violante, a project manager on Wave 2 the Future.

"Developing and installing new technologies on vessels requires the development in partnership with suppliers on new generation equipment. We are leading to bring these technologies to market," Caterina explains, adding that engagement from institutions is *"vital for the ecosystem, vital for Europe to reach its goals, and vital for the successful development of hydrogen pioneer project,"* she concludes.

Looking towards the assembly area of Fincantieri's cruise ship vessels, where every floating city begins life as a collection of steel sheets that need to be welded together.

Instructions for a portion of the ship's hull assembly at Fincantieri's shipyard in Monfalcone, Italy.

Tech diversity for the best solution

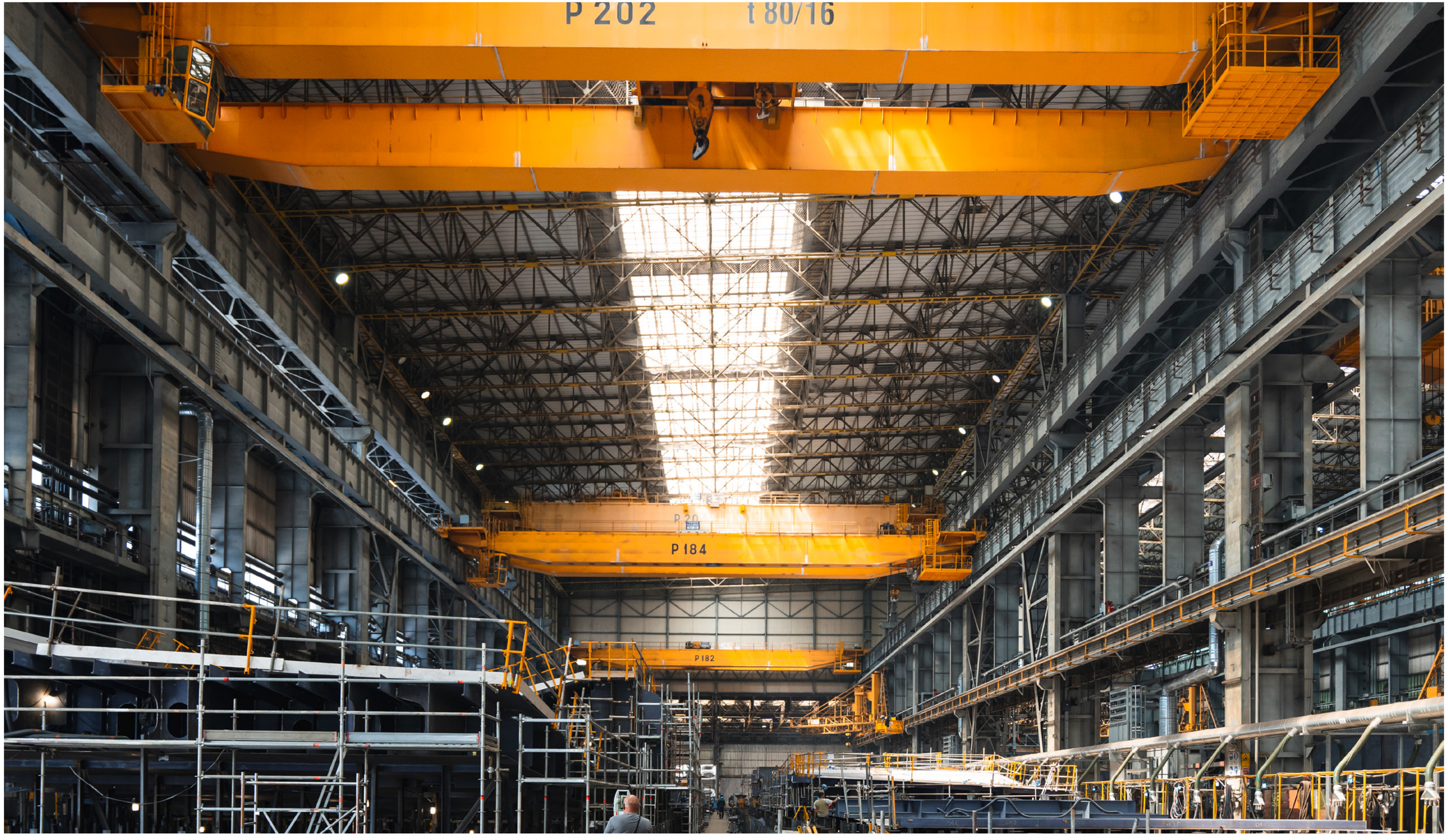
Fincantieri's decarbonisation story does not begin or end with just hydrogen. The company, which already delivers LNG-fuelled ships, is also developing the use of methanol, ammonia, and e-fuels to evaluate their use cases and offer a 'complete set' of new low carbon shipping technologies.

Electrification, while not ideal at sea for large ships due to the substantial size and limited capacity of batteries, is a solution while at shore. Even when docked, cruise ships and merchant vessels consume a large amount of power.

So, while hydrogen is but a piece of the puzzle, it is a big one, for one big reason.

"Renewable hydrogen has a lot of challenges, but is the cleaner fuel, the only one that doesn't pollute in any way. Hydrogen is the solution for shipping where zero emissions are required. Alongside carbon capture and e-fuels, hydrogen will allow us to achieve the EU net zero target," Caterina explains.

Hydrogen can cover a significant part of the power a cruise vessel needs. However, today hydrogen systems have considerable dimensions and weight. As such, Fincantieri is looking long term at developing technologies to facilitate hydrogen production and transport on board, for example by using seawater.



Fincantieri's assembly warehouse on its Monfalcone shipyard.

Challenges and opportunities

Fincantieri's position as one of the world's largest shipbuilders means it has a relationship with every major fleet owner. So, any progress in decarbonisation it can achieve will reach the ears of those who need to hear it, providing it with a customer base that is seeking solutions amid an ambitious and urgent global energy transition.

While solutions exist for many of the challenges associated with such a monumental endeavour, some remain that are yet to be solved.

Those in the hydrogen space will be all too familiar with the current limitations affecting hydrogen shipbuilders: a lack of infrastructure, fuel supply and transport, and an absence of certification standards, to name but a few.

"You cannot put a vessel in the water if it's not certified. And today there are no rule for hydrogen vessels, and current guidelines need further development. Fincantieri is developing its projects to contribute to defining the rules and regulations and certification," she explains, adding that the company is in contact with a number of stakeholders, including classification societies, to contribute to their development.

Another common refrain, applicable here too, is the fact of the hydrogen transformation being a collaborative effort through a multi-faceted value chain. Everyone must play their part.

"We are focused on enabling the consistent use of hydrogen in ships. Working with shipowners, ports, and decision makers we must enable the ecosystem in the rest of the supply chain," Caterina urges.

Sparks fly at Fincantieri's shipyard in Monfalcone, Italy as the long process of hull assembly carries on.

A seagull perches on a quay in Fincantieri's Monfalcone shipyard as work continues on an advanced-stage cruise ship.

Residual material from the milling of the steel plates edges for their welding in the panel line, performed by the one sided welding hybrid laser plant.

Inspecting the blueprints
for the next big ship.

A view of Trieste's
Ponte Rosso.

The future is now

Through its innovative projects and laser focus on its energy transition goals, Fincantieri will help to shape the future of maritime transport. Amid a technology neutral approach, buoyed by energy efficiency improvements across the board, hydrogen stands out as a realistic and desirable fuel for ships worldwide.

The next five years will be key for Fincantieri and Europe as the supply chain develops, more zero emission vessels set sail, and legislators are compelled to support the market's expansion.

Caterina urges institutions to leave no doubt and *"continue to support decarbonisation as much as possible. Knowing that there is still a lot to do for rules, regulations, legislation, where institutions have to act so that these new technologies can be effectively implemented. We are ready to build more."*

Remaining true to its convictions and its propensity for innovation, Fincantieri will surely be a catalyst for setting sail with hydrogen.

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