Schiff&Hafen | Ship&Offshore

ENERGY at SEA

The European Offshore Wind Compendium | 2023

TENDER DESIGN

Reforming the process in Germany is necessary

HYDROGEN

Floating wind brings a boost for the economy

NUCLEAR POWER

Floating generation could become part of the energy mix


Switch on
the energy
transition

European action

Kathrin Lau
Editor in Chief
Schiff&Hafen | Ship&Offshore

This is the second issue of the special publication Energy at Sea, which we launched in 2022 right on time for the WindEnergy show in Hamburg. The attentive reader may have noticed that we have changed the subtitle from German to European Compendium for the Offshore Wind Industry. This has of course been decided for a good reason. With our international publications, we show time and again what know how and innovative strength is demonstrated by German companies in the maritime industry. Which is very relevant and important.

However, to be able to defy the continuing (unfair) competition from Asia, we need to join forces with other European nations. This has been an issue in German and European shipbuilding for a long time; satisfactory solutions have unfortunately been lacking so far.

But it is precisely here that the expansion targets of offshore wind energy in Europe but also overseas in the United States and Asia, offer enormous potential. If wise decisions are made – especially by politicians – and the right course is set, the local value chain will sustainably benefit. The sheer volume of assets that are needed in the coming years is vast. Especially in terms of service and supply vessels.

Our neighbouring countries show an impressive and lucrative range of offshore energy projects; projects from which German companies can learn or participate, too. And of course, we don't want to deprive our readers of this.

What's more, the variety of ventures happening offshore has grown once again over the past twelve months: that much is certain. And while we are indeed still predominately focusing on offshore wind energy, the expansion targets and the required assets to reach them, this is by no means the only source of energy that can be harvested on or from the sea.

We are confident that the 2023 edition of Energy at Sea will provide a good overview of current developments, trends, and future prospects. ≈

Content

Source for both images: German Offshore Wind Energy Foundation

Modified tender design puts strain on supply chain

EXPANSION TARGETS Germany has ambitious targets when it comes to the expansion of offshore wind energy. However, bureaucratic hurdles, lack of funding, and an inappropriate tender design can jeopardise not only the creation of national value but also the achievement of the goals, writes Karina Würtz, managing director of the Stiftung Offshore-Windenergie (German Offshore Wind Energy Foundation).

According to the evaluation of the consulting company Deutsche WindGuard, 24 new offshore wind turbines went into operation in Germany in the first half of 2023. The total capacity of these turbines amounts to 229 megawatts (MW). In total, 1,563 offshore wind turbines with a total volume of around 8.4 gigawatts (GW) are in operation in the German North and Baltic Seas to date (see graphic). But at least 22 GW more offshore wind capacity will be installed by 2030, according to Germany's political targets.

As was mentioned in this publication one year ago, by January 1st, 2023, the amendment to the Wind Energy at Sea Act (Windenergie-auf-See-Gesetz – WindSeeG) came into force with a modified tender design. In June 2023, the first tender round comprising four areas of an equivalent of 7 GW took place; 6 GW in the German North Sea and 1 GW in the Baltic Sea. None of these areas had been centrally pre-investigated, meaning that the necessary preliminary investigations, such as ground surveys or environmental assessments, will be carried out by and at the risk of the successful bidders. As this article is being written, auctions are underway for four centrally pre-investigated areas with a total capacity of 1.8 GW, where the preliminary investigations were commissioned by the Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH). The results will be handed over to the successful bidders of the auction in return for payment of the incurred costs. And next year, another 8 to 9 GW of offshore wind power is to be put out to tender, again comprising both non-centrally and centrally pre-surveyed areas.

Coming back to the most recent auction results for the four sites that received several zero-cent bids. A dynamic bidding process was used for the first time in German offshore auction design, with the bidder most prepared to pay for the right to build and operate being awarded the contract. An unexpectedly lengthy tender duration already gave a hint towards the expensive outcome: finally, after twelve workdays, the German Grid Authority, responsible for the tender procedure, announced the winners.

As a result of the tender design, just two winners emerged, both of them big oil. Two sites went to bp (N-.1 zone in the German North Sea (2 GW) with a bid value of 1.83 million EUR/MW and N-12.2 in the German North Sea (2 GW) with a bid value of 1.56 million EUR/MW) and two sites to Total Energies (N-12.1 in the German North Sea with 2 GW and a bid value of 1.875 million EUR/

MW and O-2.2 in the German Baltic Sea with 1 GW and a bid value of 2.07 million EUR/MW) for a total of EUR 12.6 billion.

This result gives several pointers: (a) it shows the high appeal of the German offshore market; (b) a stable market with interesting long-term perspectives, political support, and a grid connection paid for by the public; (c) the widespread concern that the tender design would foster just another "race to the bottom", with a tendency towards very few bidders, hence oligopolistic structures and consequential pressure on an already suffering supply chain, turned into reality. There are other examples of offshore wind auctions that raised record fees, such as the New York Bight offshore wind auction. Therefore, it was to be expected that a small number of financially and equity-strong companies would be successful with very high bids. Equally, it can be expected that few winners for large sites will translate into high pressure on the industrial chain. Something that causes concern in the industry is that the outcome of these negative bidding auctions will encourage governments to keep that mechanism for future auctions, with the short-term financial and political gains being too attractive to consider reforms towards a more sustainable tender design that fosters diversity of players over oligopolistic negotiation playgrounds.

How should such a more sustainable tender be designed? Amongst other things, the industry suggested limiting the bid amount, strengthening so-called "qualitative criteria" to differentiate bids and promote innovation, and limiting the quantity per bidder to preserve the diversity of players. If the current bidding design remains in place, there is a risk of an oligopoly in the German offshore wind market, in which the financially strong giants outdo smaller companies – probably resulting in a loss of player diversity in the industry, and massive pressure on value chains as well as electricity prices.

As the author postulated last year in the first edition of "Energy at Sea", Germany has a massive supply chain challenge that can only be overcome if the right industrial policy incentives are put in place. At the moment, there is a lack of everything: converter platforms, foundations, turbines, ships for construction, maintenance and service. And there is also a huge shortage of capacity in the ports. The industry also urgently needs qualified, skilled personnel.

Beyond that, there is yet another risk looming on the horizon. In order to maintain social support for the energy transition, at least some of the manyfold political objectives associated with the transition should include value- and job-creation in Europe. Rising populist party movements that endanger exactly that political support can already be observed in many German regions, particularly in the East.

That should raise a strong argument in favour of conscious industrial politics, but so far there seem to be no observable signs of proactive will to shape our industrial policy basis. There is a widespread and genuine belief in the invisible hand of the markets, without recognising that liberal markets work best when there is a level playing field. Germany does not have this, given widespread subsidies in shipbuilding, for example, or steel foundation production in other regions of the world, notably China, and market transitions take time.

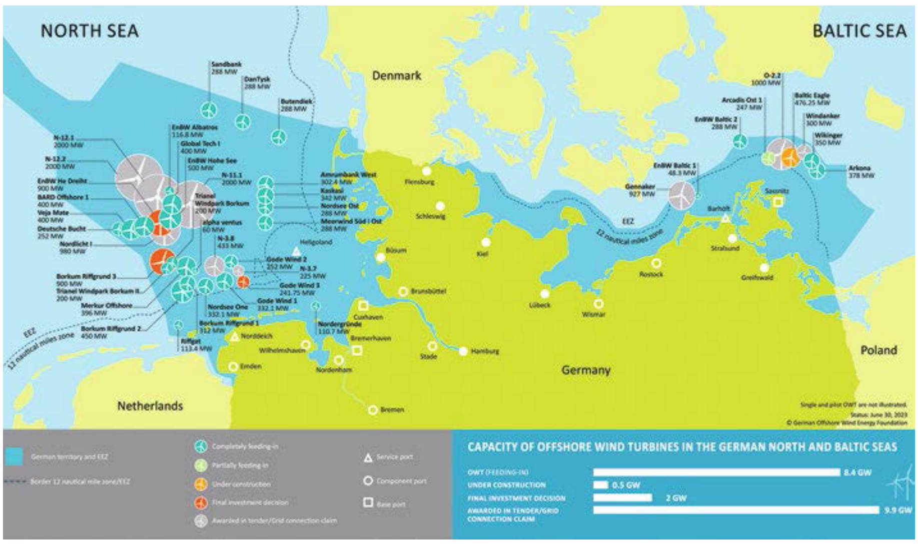
Given the country's 2030 offshore wind targets, this is one of the major challenges. A new heavy-load quayside takes at least five years to build, the same as a new foundation production site.

Recommendation

In order to overcome obstacles and tackle the current challenges, the German Offshore Wind Energy Foundation recommends the following steps: first, reform the tender design for upcoming auctions as elaborated in the first part of this article; and second, defeat the time challenge. Helping the industry overcome the first major obstacle to investing in new production capacity of all kinds needed for the offshore-based energy transition: financing.

Public finance support does not necessarily come along with increased public spending, as governmental bond provision should, on average, be a net-zero mechanism. And the provision of public bonds would help the supply chain to put together a private finance package for investments in additional production sites, and could significantly speed up the whole process.

Knowing the major challenge of securing a political consensus in the current German governmental coalition, it is questionable if these two tasks outlined above can still be achieved by the current coalition. However, the alternative would be waiting for the "invisible hand". But by the time this hand finally appears, it will likely be Chinese, as could be observed in recent deals for offshore wind turbine foundation provisions. ≈



Overview map of offshore wind energy in Germany

Necessary measures to strengthen the contribution of national shipbuilding

PAPER In December 2022, the German Shipbuilding and Ocean Industries Association (VSM - Verband für Schiffbau und Meerestechnik e.V.) published a paper containing the requirements necessary to strengthen the contribution of the German shipbuilding industry in the development of offshore wind energy. This was undertaken at the request of the Federal Minister for Economic Affairs and Climate Protection, Dr Robert Habeck.

Under the title "Shipbuilding for Offshore Wind Energy", important stakeholders from the offshore wind energy and shipbuilding sector were brought together by the German Shipbuilding and Ocean Industries Association (VSM – Verband für Schiffbau und Meerestechnik e.V.) to formulate concrete requirements in a policy action paper. The initiative was in direct response to a request by the Federal Minister of Economics, Dr Robert Habeck.

The conclusions were handed over to the Minister before the turn of the year and published in the context of the joint Nordenham Declaration in late May. This called for a focus on the build-up of domestic industry capacity, adequate finance instruments and measures to secure skilled labour for the domestic offshore industry. The paper addressed various concrete measures to be decided and implemented politically.

The German shipbuilding industry wants to make its contribution to the easing of crucial bottlenecks that could hinder fast expansion of the offshore wind industry in the European domestic market. At the same time, this is expected to add value at specialised domestic industrial facilities and expand the maritime industry sector's know-how and jobs.

In addition, important capabilities will be maintained by German industry in the internal market. These are essential for the resilience and security of the European economy.

VSM's CEO, Dr Reinhard Lüken, commented: "The implementation of expansion targets all over the world is also a race for industry capacity, in which it is particularly important who gets off the blocks quickly. We're ready, but we can only get going if the orders are finally placed."

Currently, capacities in the value chain are not yet sufficiently available to supply the large number of different ship types and large platforms needed to meet the politically defined goals, he continued. However, this bottleneck can be significantly reduced in the short term by German shipbuilding locations with the right framework conditions. This promising market also offers the opportunity to strengthen Germany as a shipbuilding location and reduce new international dependencies.

The 28-page paper formulates the following measures to achieve the goals.

Pilot projects

Clear, reliable signals to the market are needed quickly to develop real impetus and progress. These can best be conveyed through the completion of successful pilot projects. This requires pragmatic intervention to remove any obstacles that currently stand in the way of such initiatives. A particularly prominent example is the discussion about the Warnemünde site. Allocating available shipyard capacity to non-maritime purposes would call into question the commitment of German politicians to the offshore expansion goals.

Fresh momentum would also result from other projects that are already well developed and have been under discussion for some time. These include commissioning of the planned test centre, IFAM, near Helgoland and the planned test field in the Baltic Sea. Other projects aim to improve mobile phone coverage in the German Bay and progress on developing a feeder construction dock at a German shipyard.

Such initiatives could noticeably underpin positive market perceptions. However, to make rapid progress here, interdepartmental coordination must be significantly strengthened, for example through active coordination by the Chancellery.

Improving industrial policy and the regulatory framework

The specific, appropriate tendering criteria for critical infrastructure must target and incentivise the production of all strategically relevant vessels and equipment. This would strengthen the systemically relevant contribution of the shipbuilding industry in the context of the expansion of offshore wind energy as well as participation within the European internal market. Exceptions should only be allowed if all suitable production capacities in the European internal market are fully stretched.

Production locations where there are safety or security concerns should be excluded without exception. The CO_2 footprint as a qualitative tending feature for ships and converter platforms as well as foundations or, in the medium to long term, the use of "green" steel could be effective and WTO-compliant instruments.

Local value-added requirements already established in other EU member states can also serve as possible solutions. Market access conditions defined appropriately protect against distortions of competition, ensure a level playing field and provide a necessary hedge for the targeted investments.

Financing instruments

Lack of or inadequate financing instruments including guarantees has been a well-known hurdle for the shipbuilding industry for many years. Therefore, the removal of sector restrictions related to shipbuilding in the

Federal Government's large-scale guarantee programme would be an important and easy to implement first step.

Similarly, the scope of the German Hermes instrument needs to be adjusted, as it so far does not consider offshore installations and ships operating in Germany's exclusive economic zone (EEZ) as eligible for domestic investors, whereas, other European export credit agencies in Belgium, Netherlands, Denmark and Norway, for example, are increasingly involved in the financing of domestic projects.

In addition to the known instruments, the development of new solutions for Germany, should also be tackled. There are numerous examples of interesting schemes in other shipbuilding nations which have been in operation successfully for decades, especially for their respective domestic markets.

Incentives for long-term partnerships

The necessary expansion of shipyard capacity requires viable investment calculations. Long-term contractual relationships and long-running framework contracts based on partnerships could make a decisive contribution to laying the foundations for this. Various models might be appropriate, including:

- Long-term guarantees for purchases to secure availability. These are already used today in the offshore market, but so far do not extend to large-scale floating equipment. Where developers already have long-term planning certainty, as is the case with grid connections, corresponding purchase commitments could be agreed for longer periods.
- In tenders for offshore wind farms, contractually secured access to sufficient production capacity in the internal market for ships and equipment for the construction and operation of the wind farms should be firmly anchored as qualitative award criteria. These capacity reservations also extend to relevant service providers and subcontractors.

Supporting infrastructure measures

Expansion and upgrades at shipyard sites include significant infrastructure adjustments, which are essential especially for the upstream and downstream logistics of shipyard production. The availability of financial support under relevant instruments will facilitate and accelerate the planning and implementation process. Tax incentives should also be considered. Additional land development is essential in the context of port logistics but may also become necessary for shipyard sites. The VSM expressly supports the demands for additional, suitable port sites.

Acceleration of approval procedures

Many projects will have to be carried out in parallel if the planned expansion goals are to be met within the tight timeframe. Approval procedures must therefore be carried out quickly within the applicable legal framework. For this purpose, the authorities involved need to be strengthened in terms of personnel.

This applies to approval procedures for the construction of wind farms as well as for infrastructure development requirements at shipyards, for example. Likewise, permits for federal and state measures such as roads and fairways should be processed more quickly.

Innovation programme

Construction, maintenance, repowering and dismantling of offshore wind farms have specific requirements that are different to those of traditional offshore markets. Nevertheless, due to corresponding availability, vessels from the existing oil and gas support fleet are mostly in operation.

The volatility of the offshore wind energy market to date has prompted owners to order less efficient but more versatile vessels. A market for consistently optimised vessels for different applications in the offshore wind energy sector has hardly developed so far.

Corresponding reference products that prove their superior performance criteria in operation could also trigger considerable potential on export markets. A specific funding instrument for the construction and operation of corresponding demonstrators could contribute significantly to the necessary increase in efficiency.

The scope of the innovations, the risk associated with their operation and the exploitation risk for investors are significantly higher compared to commercial shipbuilding. This should be taken into account accordingly in the funding criteria.

Securing skilled labour and training offensive

With its often family-run structure, the shipbuilding industry in Germany has a long tradition of excellent in-company training. A joint training campaign with the offshore wind industry and the hydrogen industry, supported by state investments in the training infrastructure at vocational colleges and universities, should create significant synergies.

Industry agreement

All those involved in offshore wind industry development, including maritime stakeholders, should undertake to work together and operate in a goal-oriented manner within the framework of an industry agreement to be able to support the realisation agreement of the Federal Ministry of Economics and Climate Protection, including both the necessary financing instruments and the other measures mentioned above, in the best possible way. The industry agreement should also contribute to achieving a balanced, fair distribution of risks. The additional financing instruments described above are essential components for viable successful results. ≈

Marine technology is crucial for the offshore wind industry

BLUE ECONOMY There are many good reasons why the oceans will be the next major area of business applications for the future. Innovation and investment are two sides of the same coin that drives economic activities in the oceans. To meet the growing global demand for more renewable energy, higher efficiency, resilient supply chains and other expanded commercial opportunities in a sustainable way, the development of the blue economy, especially marine technology, is crucial.

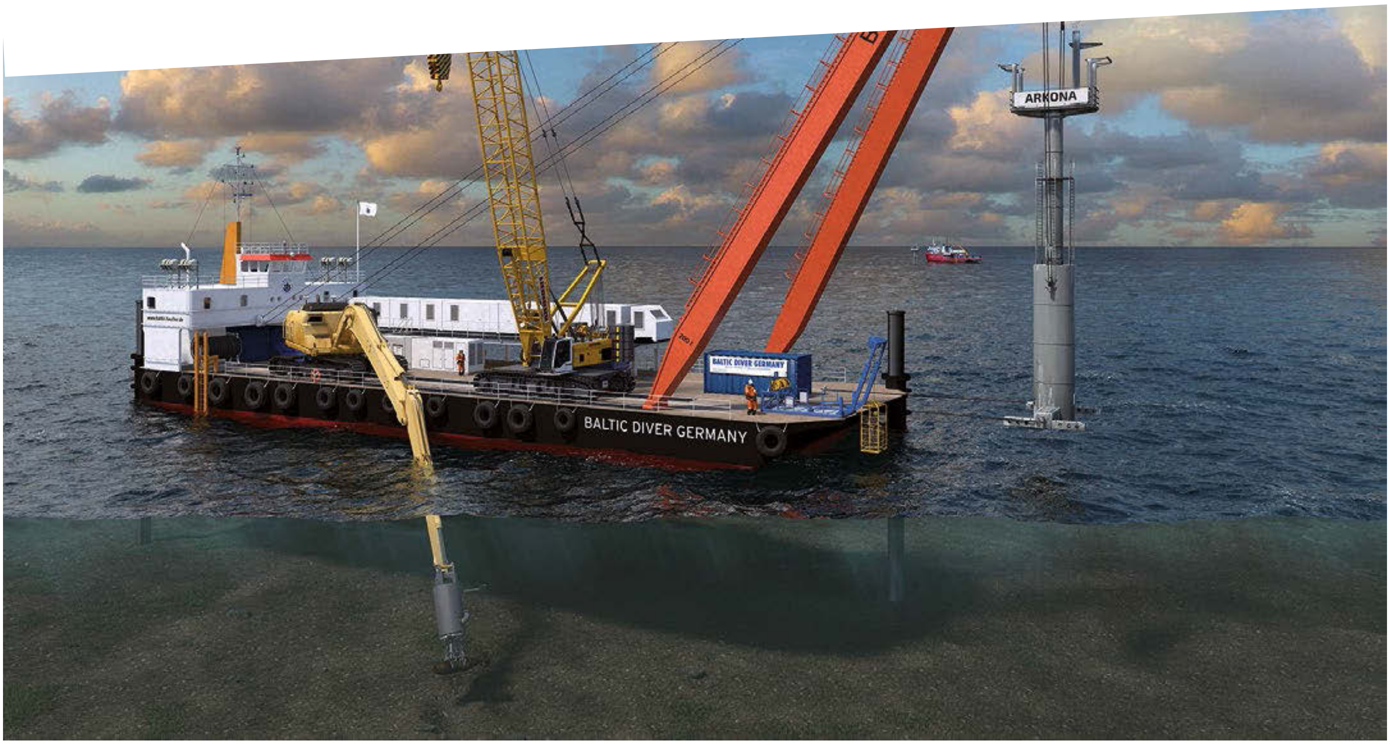
With 316 GW of installed capacity expected by the Global Wind Energy Council by 2030, offshore wind resources are imperative for the energy transition. As offshore wind farms experience more challenges related to design, fabrication, installation, operation and maintenance, and lifetime extension compared to onshore wind farms, the more integrated involvement of the marine technology industry will definitely be required. Three decades have passed since the first offshore wind farm was constructed. Today, offshore wind energy has been rapidly evolving with the aim of deploying larger wind turbines at increasing water depths and under complex external conditions. Recently, floating wind power has attracted interest as part of the exploration of deeper waters with undisturbed higher wind speeds. The installation of floating wind turbines brings additional degrees of freedom that affect the performance and safety of the turbines. Therefore, sustainable design, construction, and installation methods, hydrodynamics, aerodynamics, and controls of such structures are different from solid structures and require special attention and involvement of marine technology.

Due to the increased involvement of marine technology companies, there has been continuous progress in foundation design, control strategy, transport and installation methods, marine operations execution, computational methods, and model testing, just to name a few.

The global offshore wind market grew at almost 30% per year during the last decade, benefiting from rapid technological improvements, and much more than 100 new offshore wind projects are under active development worldwide. Europe was driving the development of the technology, led by the UK, Denmark, and Germany, but China added more capacity recently than any other country. Now the United States and other Asian markets are also becoming more involved.

However, today's offshore wind market is far from realising its full potential – with high quality resources available in most major markets, offshore wind has the potential to generate more than 400,000 TWh per year globally. That's almost 20 times the world's electricity needs of today.

The German Association for Marine Technology (GMT) is already a major contributor of a smart and sustainable energy transition toward offshore wind. Its members are heavily involved in offshore wind projects and operations, including bathymetric surveys, acquiring aero- and hydrodynamic data, design, fabrication, installation, inspection, decommissioning and repowering of offshore wind farms. Based on this, the GMT network creates continuously new opportunities to exchange and explore new horizons in research, development and business applications. ≈



Source: BALTIC Taucherei- und Bergungsbetrieb Rostock GmbH

The areas of applications for marine technology are vast


FLOW-SV
DAMEN OFFSHORE WIND SERIES
We're with you
every step of the way.

Floating wind brings the hydrogen economy a step closer

ENERGY STORAGE Hydrogen has often been mooted as one way that offshore turbines could reduce their costs and accelerate their time to market. Being functionally infinite, their energy is cheap, but it has a problem; the variability of wind means that power yield changes from moment to moment, making planning difficult, writes freelance journalist Charlie Bartlett.

One way to address the issue of unpredictable wind power is to build so many turbines that even a small amount of energy generated from the wind is enough. But this leaves the problem of a huge amount of wasted energy when the wind blows strongly, and power grids cannot cope with it.

During 2022, Scotland generated 35.3 TWh of renewable electricity, of which 27.5 TWh was onshore and offshore wind. Some 18.7 TWh of this was exported. Had Scotland had the means to store this energy, it could have powered every household in the country for three years.

However, according to International Energy Agency (IEA) numbers, around 4 TWh of mainly Scottish wind energy was 'curtailed' – wasted – over the course of 2022, thanks to weak transmission capability between Scotland and England.

Ever-present throughout the UK's buildout of on- and offshore wind has been the notion of using hydrogen electrolysis to bridge this gap. "Curtailed energy provides a potentially attractive source of electricity, which can reduce the overall cost of hydrogen production through installing electrolyser units which can utilise this power that would otherwise be curtailed," says one report by the University of Strathclyde. "The hydrogen produced can then be used for a variety of applications, including industry, heat, and transport."

Pumped storage hydropower (PSH) offers comparable efficiencies at around 80%, and the UK is planning to increase its PSH capacity from the current 2.8 GW to 7.7 GW, allowing much of this spare energy to be harnessed. But the number of suitable sites is a limiting factor.

Containing drastically more energy than a lithium-ion battery, hydrogen has been mooted as an energy storage medium for grids. But this would generate a huge requirement for new energy storage infrastructure, and hydrogen offers something the economies of Northern Europe much prefer: a tradeable commodity.

The International Renewable Energy Agency (IRENA) says that 19 exajoules (EJ) of green hydrogen – as much as 158.3 million tonnes per year – will be needed by 2050 to decarbonise energy systems completely. Making up some 43% of that demand is transport, which is a good deal more challenging to decarbonise than houses.

As the maritime industry is discovering, hydrogen is very useful from this point of view: with nitrogen added via the Haber process or carbon via CO_2 hydrogenation, it can be turned into ship fuels such as ammonia and methanol. Hydrogen could be used to replace or supplement natural gas in heating systems, provided problems with leaky pipes could be addressed. It could even be manufactured into synthetic kerosene, which could be used to power today's aircraft with zero capital investment needed from airlines. But plenty of opex.

An end to curtailment

According to various analyses, the main bottleneck for hydrogen production will be the availability of electrolysers. These share almost all their components with fuel cells – the equipment that would be used to convert hydrogen fuel into useful energy in-situ – another challenge to their manufacture. Proton exchange membrane (PEM) electrolysers – the type better suited to dealing with fluctuations in power generation like wind energy – also contain a variety of expensive metals like titanium, iridium, and platinum.

In all, just 47 GW of annual electrolyser production is likely by 2030, according to US investment bank Jefferies. But in a recent report entitled World Energy Transitions Outlook 2022, IRENA pointed out that solar installations had fallen in price by 82% between 2010 and 2019 thanks to improvements in production.

A similar cost-reduction in electrolysers is not unreasonable to expect once factories are properly tooled-up. IRENA said: "A similar decline [in cost] is expected for electrolysers in the coming decade, thanks to the large pipeline of green hydrogen projects." Research indicates that not only the proliferation of electrolysers could be better, but also their efficiency. Currently, around 80% of the energy that goes into the process is ultimately used to generate hydrogen; the rest is wasted.

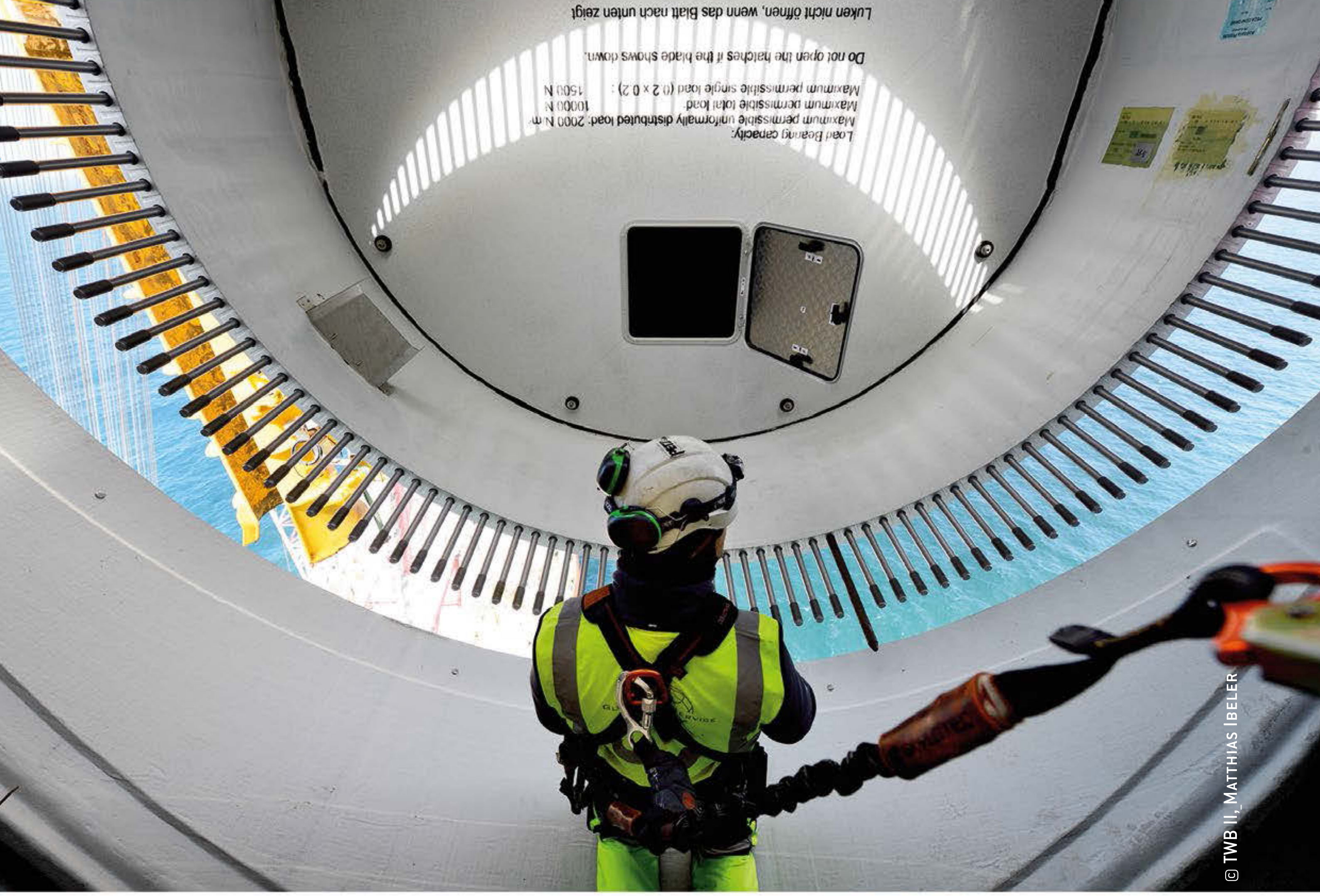
But early last year, a study was conducted into a new form of 'capillary-fed' electrolysis, which proved it possible to electrolyse water into hydrogen at efficiencies of 98%. Although quite some work will be necessary before this principle could approach commercialisation, the results are promising.

For the offshore wind sector, any potential reduction in the spread of efficiencies between transmitted power for homes and businesses, and wind-to-hydrogen (or Power-to-X, to give it its trendy new moniker) is good news. A low cost-of-entry is the reason the North Sea is now so chock-full of existing and planned offshore wind farms. It benefits from a combination of shallow waters – making cheaper pile-driven turbines an option – and high winds.

Argentina, China and New Zealand are fortunate enough to be sitting on a goldmine of similarly affordable, shallow water turbine potential. Iceland, a country with all the luck in renewable energy resources, is surrounded by it.

Norway's Equinor, by now becoming famous for its brand of wind-energy Trotskyism, is exporting its offshore wind revolution worldwide, despite not much of anything happening off its own coast thanks to a continental shelf which drops abruptly into the depths, leaving little room for seabed pile turbines. The same is true off India, as well as Japan's east coast; the entire western coastline of the Americas, too, has little room for freestanding turbines, with the notable exception of Alaska, which, with its wind energy potential of 12,087 TWh/year, could power the entire continent by itself.

Their technology may be developing at breakneck pace, but typically doubling the capital cost of freestanding installations, the pressure >



© TWB II_Matthias Ibeler

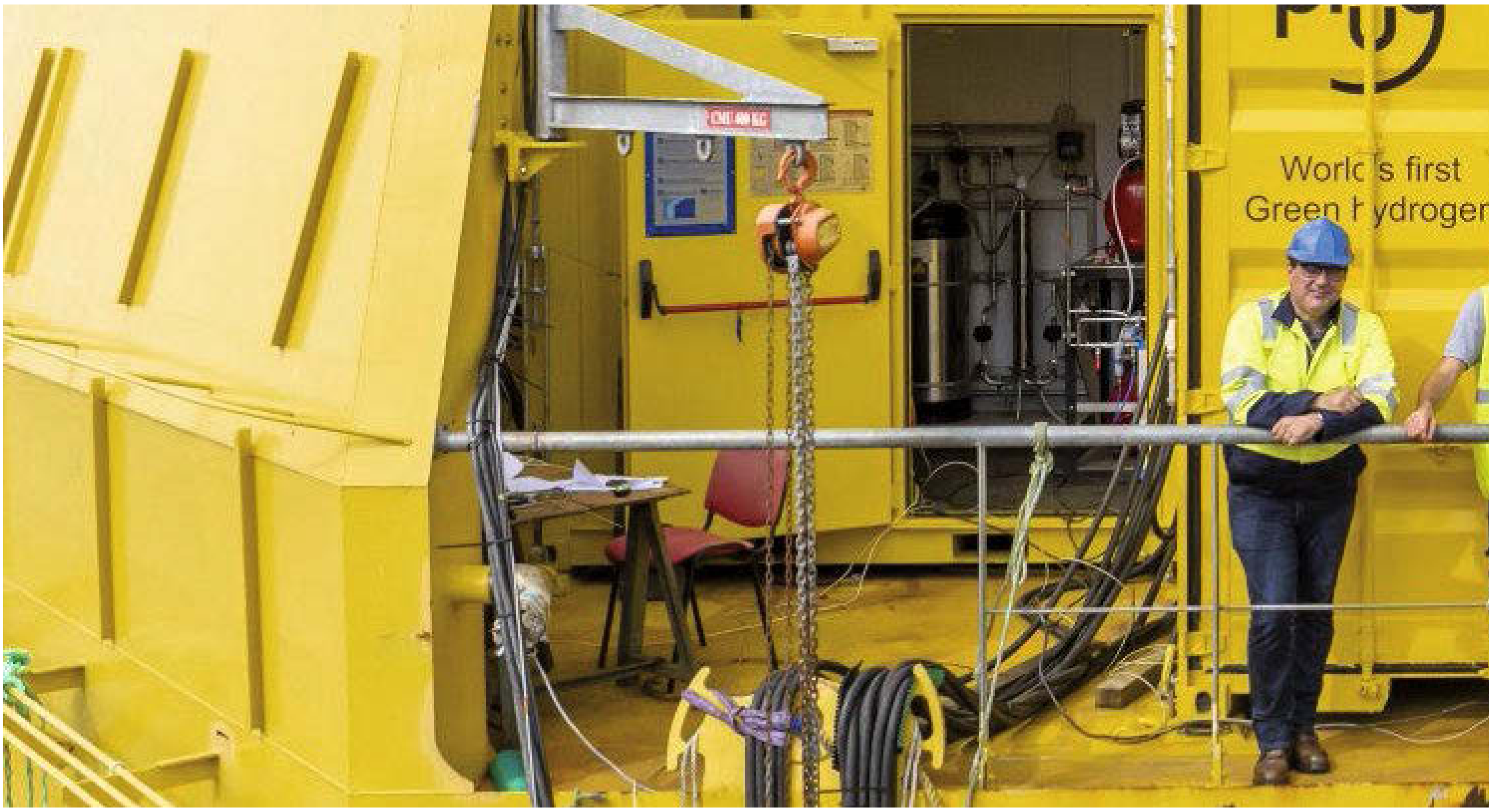
STRONG CONNECTIONS FOR A RENEWABLE FUTURE

FOUNDATION OFFSHORE WIND ENERGY

Since 2005, the German Offshore Wind Energy Foundation has established itself as a non-partisan, supra-regional and cross-sector think tank as well as an independent communication platform for the entire offshore wind energy industry. Its overall purpose is to consolidate the role of offshore wind energy in the energy mix of the future in Germany and Europe. Guided by its scientific advisory board, the foundation promotes the expansion of offshore wind energy in the interests of environmental and climate protection. The foundation's board of trustees includes key federal and state ministries for offshore wind as well as operators, manufacturers, transmission system operators, suppliers, banks, and insurance companies.

Together, we forge strong connections for a renewable future!

WWW.OFFSHORE-STIFTUNG.DE



French company Lhyfe has installed a demonstration rig that electrolyses about 400 kg of hydrogen per day

is on to find new ways to improve the profitability of floating offshore turbines. This might mean foregoing the enormous cabling infrastructure required to connect them with domestic grids.

Sharing the load

When it comes to generating hydrogen offshore, there are two schools of thought over how this should be undertaken. In one scenario, hydrogen electrolysis would act as a load-levelling mechanism to allow a better turbine capacity factor at times when grids do not require so much of it. In the UK grid, for example, demand reliably fluctuates between 30 GW during the day and 20 GW at night, meaning that this would be a good time to switch on electrolysers, and generate hydrogen using cheap wind energy.

However, this load-levelling scenario suffers from a number of drawbacks in practice. Foremost among them is that electrolysers prefer to run continuously, and do not like ramping up and down from moment to moment in the way suggested.

In a 2014 study, Novel Electrolyser Applications: Providing More Than Just Hydrogen, researchers found that a 40-kW proton exchange membrane (PEM) electrolyser took nearly seven minutes to ramp up from a cold start and one minute to turn off. The research also suggested that in doing so on a regular basis – necessary for load-following power applications – would create wear and tear on the electrolysers.

"Another important factor to consider when exploring new operating strategies is the impact on stack lifetime," the study read. "Cycling the equipment more is likely to accelerate stack degradation."

A version of this strategy would use the resulting hydrogen in-situ, with fuel cells to convert it back into electricity. This could help to stabilise the output of each wind farm, insuring against times of low wind. However, to manage this efficiently, it would require a considerable volume of local hydrogen storage capacity.

The second approach is simply to devote entire turbines to the generation of hydrogen. This certainly results in a less complicated operating profile, and the likelihood is that even a relatively calm day can still produce enough energy to keep an electrolyser ticking over.

Experimenting with this configuration is a company called Lhyfe. Located 20km off Le Croisic on France's west coast, an area with middling luck when it comes to shallow water construction areas, Lhyfe's demonstration rig, *Sealhyfe*, is constantly battered by Atlantic wind and waves.

It now electrolyses around 400kg of hydrogen per day with the help of a 1-MW plug electrolyser. It is hoped that *Sealhyfe* will yield a resilient and flexible system of decentralised hydrogen production.

In pursuit of its new endeavour, Lhyfe has initiated the Hydrogen Offshore Production for Europe (HOPE), a 10-MW project aiming to produce and transport around 4,000kg of hydrogen daily via pipeline. Having secured a EUR 20 million grant from the European Commission in late June, the project's goal is to expand and commercialise Lhyfe's decentralised hydrogen production concept.

If it works, it will demonstrate the potential for wind to be harnessed virtually anywhere – even, theoretically, in the middle of the ocean. This could generate a requirement for even more monstrous turbines than the Chinese MySE 16-260, the world's largest, with a blade-span of 260m, and an energy production capacity of 16 MW.

From the outset, Lhyfe has stated its intention to convert disused drilling rigs into hydrogen electrolysis facilities, giving them a new lease of life and overcoming some of the cost barriers to entry. It is also hoped that opening up the ability to locate wind farms well out to sea will overcome some of the popular opposition to these facilities close to coastlines. ≈

Source: Lhyfe

Floating nuclear – a catalyst for low-carbon energy

ENERGY MIX The drive for low-carbon energy and industrial-scale e-fuel production is likely to add further urgency to accelerating electricity demand. Core Power's director of Analytics, Rory Megginson, explains that as further electrification becomes increasingly urgent, floating nuclear power generation could become part of the energy mix.

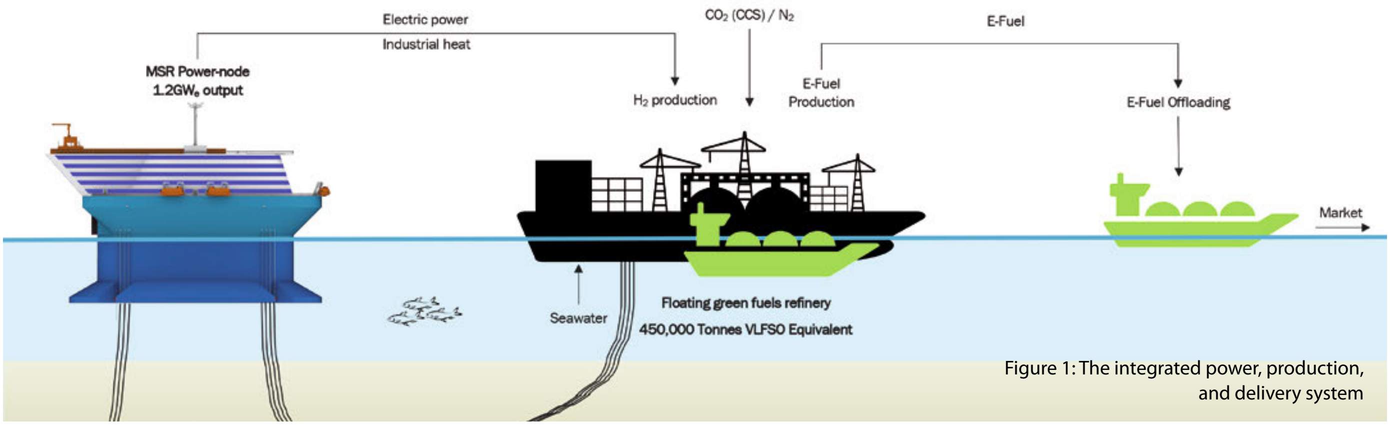


Figure 1: The integrated power, production, and delivery system

Source for all images: Core Power

The past few decades have seen a rapid expansion of global electricity demand, creating an ever-increasing strain on electricity generation capacity. Simultaneously, the sector has grown in importance as the world continues the drive towards decarbonisation, encouraging the rapid electrification of numerous end-users.

Consequently, demand has risen by 3,320 TWh over the last five years and is predicted to continue increasing by 2-4% each year, reaching a projected market value of nearly USD 2 trillion by 2030. This is because electrification will continue to be one of the first decarbonisation levers, being the most inexpensive and accessible option suitable for most sectors.

Core Power proposes the deployment of advanced floating nuclear power plants (FNPPs), combining the benefits of advanced nuclear and floating power, and offering a reliable and scalable form of dispatchable, sustainable electricity production. The next generation of advanced nuclear reactors, such as the molten salt reactor (MSR), presents a step change in nuclear safety and security while retaining the benefits from previous iterations.

The MSR is an ambient pressure reactor, vastly reducing the risks of breach and dispersion of radioactive material. Its dimensions open opportunities for modular construction in factories, offering a route to cheaper, faster and safer nuclear power.

Nuclear energy has already emerged as the only resilient, emission-free electricity source. However, progress for traditional land-based reactors has been slowed by construction overruns, complex siting issues, and capital overspending. Core Power facilities will be able to overcome these challenges, benefiting from the efficiencies of shipyard construction, faster deployment times and cost, while remaining flexible in their location.

A number of MSRs could be installed on FNPPs, with a maximum capacity of 1.2GWe when four MSRs are used, making a single unit capable of producing up to 28,800 kWh per day. This matches the scale of even the largest land-based "stick built" plants.

Despite clear operational benefits, nuclear energy has often been undervalued as an energy source owing to uncertainty around the inflated capital requirements of the technology. This is because traditional nuclear reactors have been built on a large scale with high complexity and usually not in series, ensuring they are almost always "first of a kind."

This, in turn, has meant cost and schedule overruns. However, most of these costs are not actually associated with the nuclear and turbine island. Instead, roughly 80% are accounted for by 'non-nuclear' costs, including site construction, installation, vast and often largely 'newly skilled' labour, cooling infrastructure site works, and financing costs.

This is where shipyard construction could play a game-changing role. Shipbuilding has thrived on the repetitive large-scale fabrication of complex assets, using a skilled, consistent workforce in a single place to achieve low-cost, high-productivity, and high-quality construction.

As a result, the shipbuilding industry has seen substantial productivity gains at the same time as land-based nuclear projects have struggled. However, it would be possible to repurpose and specialise certain shipyards to construct floating nuclear facilities, thus benefiting from modular factory-like construction.

The key benefit would be the increased speed of construction. Unlike "stick built" plants, where the site must first be outfitted before construction can start, a shipyard is already perfectly equipped for use, offering a factory-like environment. This means labour productivity can be maximised, helping to avoid extensive delays that have become common for terrestrial deployments.

There would also be a decoupling between plant construction and site licensing, with no need for site evaluation and preparation. These processes could commence independently and in parallel, further reducing construction time.

Studies analysing the benefits of construction in this way have found that SMRs have the potential to be significantly more cost-effective. This is because, unlike current pressurised water reactor plant construction, very high-efficiency shipyard fabrication enables many identical SMRs to be constructed in a single factory, where the effects of learning can reduce both unit cost and construction time. This learning rate is quantified as the relative reduction in construction time that accompanies the increase in the cumulative number of units.

Shipbuilding was one of the first industries with verifiable learning effects, having continuously to manage an increased volume of work in a shorter time to meet market demands. In turn, this would enable large-scale SMR fabrication, encouraging serial production and a transition from "1st" to "nth" of a kind.

Adopting this construction method would provide the economic and scheduling advantages of factory production while reducing construction costs by eliminating excavation work, resource requirements, temporary facilities, and the associated labour requirements. In turn, this could aid faster commercial deployment, something that is particularly important for highly capital-intensive projects, reducing interest on debt and lowering discount rates on capital investment.

This would bring the competitive cost levels of large ships to floating nuclear power plants. As a result, for a Core Power FNPP, manufacturing costs could be reduced by up to 50% when compared to a single large land-based facility, with the potential to exceed even this.

Therefore, the financial risk currently associated with nuclear power would be reduced, fostering wider commercial investment and closing the gap between expected and realised cost increases and the economic competitiveness of new nuclear. With marine nuclear able to offer cost-competitive, reliable electricity, a colossal growth opportunity and diversification of the offshore industry would open up.

In fact, there is a case for deployment in conjunction with the existing offshore oil and gas industry. Offshore oil extraction companies are increasingly being asked to reduce their emissions by powering facilities with electricity. However, current proposals for this rely on either the use of variable renewables paired with storage (but in practice still high use of gas-turbines), or by laying expensive subsea cables to shore.

Then the facility is only as green as the main grid, and both cases could end up with stranded assets when the facility is decommissioned. Marine nuclear power however would be able to offer reliable clean energy to these facilities while being a cost-competitive source that is flexible and can be re-located between basins.

Hydrogen and e-fuel production is another one of several areas where marine nuclear could play an important role. While many parts of the energy system will be able to electrify some sectors such as steel and

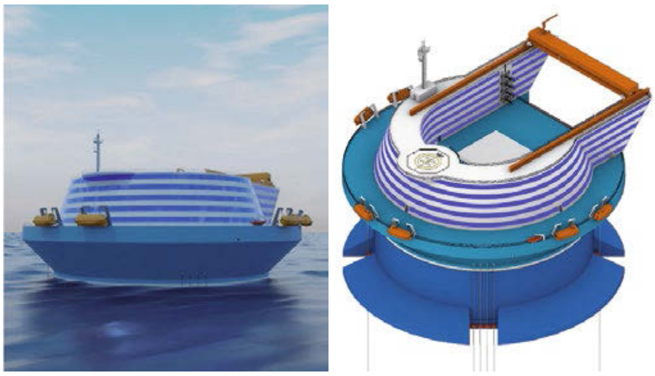


Figure 2: A Core Power floating electricity production facility

cement manufacture directly, the chemical industry and much of short-sea shipping will require a source of low-carbon fuels.

Large amounts of green electricity will be needed for the electrolysis of water to produce hydrogen. Floating nuclear can produce this electricity at a scale and cost to ensure that these fuels are not prohibitively expensive. Arrangements could even include making the fuels on co-located chemical process facilities.

Core Power is currently working on a project with Idaho National Laboratory and researchers from Massachusetts Institute of Technology on the deployment of these structures and their economic feasibility. A conceptual field layout for such a facility is shown in Figure 1. ≈

Unique wave current flume commissioned


At the opening ceremony of the centre

Source: Leibniz Universität Hannover

COASTAL RESEARCH CENTRE A new large wave current flume has been commissioned in the Coastal Research Centre, which is operated jointly by Leibniz University Hannover (LUH) and TU Braunschweig in Hannover-Marienwerder. Until now, the 40-year-old facility has only been capable of generating waves. After an investment of more than EUR 35 million, however, the expanded facility can now model the impact of offshore wind, tides, and tidal currents.

The new research infrastructure was formally commissioned recently by Robert Habeck, Federal Minister of Economic Affairs and Climate Action (BMWK), and Stephan Weil, Minister-President of Lower Saxony. Other senior members of both universities and leading researchers were present at the ceremony, where, at the push of a button, a 3m wave was generated in the 300m-long wave current flume.

The facility will open up a wide range of research opportunities relating to offshore energy development and new marine-related energy sources. The research infrastructure now includes a powerful tidal current system, a deep section for investigating foundation structures of offshore wind turbines, and a wave machine capable of generating waves up to 3m high. An important feature of the new setup will be the ability to generate waves and currents at the same time. It is thought that no other facility anywhere in the world can do this.

Speaking at the commissioning ceremony, Minister Habeck said: "Wind energy plays a crucial role in Germany's electricity supply today and will continue to do so in the future. The use of wind energy must be expanded quickly and efficiently to meet the growing demand for electricity resulting from the electrification of other sectors, such as heating buildings with heat pumps or e-mobility.

"The wave current flume in Hanover will make an important contribution by facilitating research into optimising offshore foundations," Habeck continued. "This will make the expansion of offshore wind energy even more cost-effective and reliable. For this reason, and because of the many other aspects that can be investigated via the wave current flume, the EUR 35 million in research funding provided by the BMWK is money well spent for the future."

Minister-President Weil added: "I am delighted that we now have this wave current flume in Lower Saxony, which is unique worldwide. This opens up new opportunities for research and industry to develop offshore turbines. Coastal protection, which is particularly important for Lower Saxony, can also be improved and investigated further by the simultaneous generation of waves and currents. Overall, this is a truly impressive facility. I would like to congratulate everyone involved in this process."

Prof Dr Torsten Schlumann of LUH and Prof Dr Nils Goseberg of TU Braunschweig, board members of the Coastal Research Centre, explained the significance of the new wave current flume for new research. Schlumann revealed that it will now be possible to study the simultaneous strain caused by swells and currents, and thus realistically investigate their impact on a large scale. Goseberg said that the new deep section also makes it possible to simulate the part of offshore wind turbines that is in the ground and to study the movements of the ground and the turbine that occur.

In the future, experiments will also be able to simulate steeper and higher waves, as predicted by climate change, and simulate the loads on structures. For the first time, tidal currents can be studied as they occur in the sea with the new circulating current system.

The BMWK approved the research project 'marTECH – Development of Renewable Maritime Technologies for Reliable and Sustainable Energy Supply' in 2017. The purpose was to meet the requirements of research and industry in the context of the expansion and operation of renewable energies. ≈


RWE
We produce power
to keep things running.
And running. And running.
And running.
Cars, phones, tools – nothing runs without power. And the demand is growing.
We're shaping the green energy world of tomorrow. To keep things running.
With a clear target: to be carbon-neutral by 2040.
rwe.com

Floating wind platform now on site in Spain

DEMOSATH The 2-MW floating wind platform demonstrator, *DemoSATH*, has now been installed in open sea at the BiMEP test site, 18 km from the Port of Bilbao. The installation, in 85m-deep waters about 3 km off the coast in the Cantabrian Sea, was undertaken by the WindStaller Alliance and its *Norman Sapphire*, an anchor handler supported by local tugs.

The hook-up involved connecting six pre-laid mooring lines to the structure's single-point mooring turret. Then the dynamic and static cables and pull-in to the unit's turret were connected, enabling the export of power to the Spanish grid ashore. *DemoSATH* is expected to generate sufficient electricity for about 2,000 Spanish households per year.

Now that the unit has been installed, it will be commissioned, and electricity generation will start. During the two-years of operation at the BiMEP site, SATH technology developed for floating offshore wind by Saitec Offshore Technologies will be tested. The requirements for its operation and maintenance will also be analysed. The project will focus on metoceanic challenges in the open sea, especially under the harsh conditions that prevail in the Cantabrian Sea.

Project partners all made positive observations. Saitec Offshore Technologies' chief operations officer, David Carrascosa, commented: "This milestone in the installation of the *DemoSATH* floating offshore wind project validates the years of steady commitment, resilience, and teamwork. Along the journey, we have overcome some challenges that now serve as valuable lessons for future projects. We are proud of the achievements of our team, and the combined efforts of our collaborators. It's thrilling to witness the *DemoSATH* project set sail, playing an integral role in the progression of renewable energy."

Speaking for RWE Offshore Wind, Sven Utermöhlen, CEO, said: "The offshore installation of the *DemoSATH* project is an important milestone on our way to the commissioning of RWE's second floating demonstration project. We see great potential for floating wind farms around the world as they unlock opportunities in countries with deeper coastal waters. As a floating pioneer, the first-hand learnings from our demonstration projects are key to us optimising our upcoming commercial-scale projects and securing their safe delivery."

Kazumi Ogura, executive officer in the Renewable Energy Division of The Kansai Electric Power Co., Inc., declared: "We take great pride in our achievement of pioneering a new frontier in offshore wind power generation by installing the innovative floating wind platform demonstrator, thanks to major contribution from our partners. We will continue to prioritise safety and work together as a team to advance the pioneering *DemoSATH* project. Through *DemoSATH* project, we remain committed to continuous learning from the project and harnessing this knowledge to make progress towards achieving a zero-carbon society." ≈

Solar energy plant to be installed at offshore wind farm

A solar energy plant will be added to the *Hollandse Kust Noord* offshore wind farm

HOLLANDSE KUST NOORD Offshore solar energy developer, Oceans of Energy, has been awarded a contract to install and operate the world's first offshore solar plant at the *Hollandse Kust Noord* by CrossWind, a joint venture between Shell and Eneco. The wind farm, located 18.5 km off the Dutch coast, is due to be commissioned by the end of this year, and the solar farm is expected to become operational in 2025.

The combination of offshore wind and solar increases efficiency in various ways, the companies said. For example, it is possible to produce solar energy on sunny but less windy days, thereby raising energy production and increasing utilisation of the offshore power grid. Since the solar panels will be installed between the wind farm's turbines, the sea space will also produce more energy across its footprint.

In a statement, the partners listed three pioneering features:

- Hollandse Kust Noord will be the world's first wind farm to combine offshore battery storage and green hydrogen produced from offshore wind power on a megawatt scale;
- It will also be the first facility to commit to mature and demonstrate offshore wake control technologies such as closed-loop active wake steering in combination with active wake mixing to reduce energy losses and increase efficiency;
- It will be the first time that a solar system has been electrically connected and operated at an offshore wind farm in harsh sea conditions.

Maria Kalogera, Crosswind's Innovations Manager, commented: "Offshore floating solar is an exciting area of renewable energy development that is poised to play an important role in the energy transition. This project marks a significant milestone for our CrossWind Innovations Team as we continue to push on our commitment to create better energy solutions for the future."

Ocean of Energy founder and CEO, Allard van Hoeken, said: "We are very pleased that Crosswind and their shareholders, Shell and Eneco, have trust in Oceans of Energy for realising this first-off amazing project. We will add offshore solar to offshore wind. Our performance and our system will be crucial to the success of the innovative part of the offshore wind farm. This is a large responsibility, as *Hollandse Kust Noord* will function as an example for combined offshore wind and solar parks in the future."

When all 69 turbines are installed and connected, the wind farm will have a total installed capacity of 759 MW, generating at least 3.3 TWh of energy each year, sufficient to provide green electricity for more than one million Dutch households. Siemens Gamesa Renewable Energy is supplying the turbines, and Van Oord is supplying foundations and cables and installing the turbines on site. Meanwhile, CrossWind is cooperating with TenneT, the developer of the 'offshore power socket' that connects the wind farm to the grid. CrossWind is also in contact with relevant ministries, coastal authorities, and other stakeholders. ≈

Partners to commission newly designed wind support ships

Source: deugro


Illustration of the new larger cargo ship

CARGO FLEXIBILITY Special project freight forwarder, deugro Danmark AS and partners Siemens Gamesa and Amasus Offshore BV, have ordered two newly designed wind farm support ships, *Rotra Futura* and *Rotura Horizon*, at Jiangsu Zhenjiang Shipyard in China. The vessels, due for delivery in the spring and summer of 2025, will be deployed on a long-term charter agreed between deugro and Siemens Gamesa.

The design of the ships builds on the initial 'Rotra' concept adopted for the existing vessels, *Rotra Mare* and *Rotra Vente*. These ships have proved to be very successful over the last seven years, reducing risk, loading times, and costs, with a unique roll-on, roll-off, and gantry system for offshore wind turbine components.

The new ships will be larger, with a length of 167.6m and a beam of 26m, capable of transporting the increasing size and weight of next-generation offshore wind turbine components. The deckhouse and accommodation will be located forward to ensure maximum cargo intake with no line-of-sight issues. They will have a stern ramp and three Liebherr cranes. The gantry system will enable turbine blades to be stowed in three tiers, maximising cargo flexibility.

Meanwhile, minimising the ships' carbon footprint has been a top priority in the design phase. Energy consumption has been reduced by aerodynamic and hydrodynamic optimisation. A low-resistance hull coating will be used, and the ships will be powered by Wärtsilä diesel engines, with an estimated 15% savings in fuel consumption compared with similar engines in operation today. Hybrid propulsion, exhaust gas cleaning, and waste heat recovery systems also feature in the new ships' specifications.

Hans Henrik Groen, deugro Danmark A/S branch manager and managing director, said: "deugro Danmark A/S and its partner, Amasus Offshore, are delighted and proud to again be selected by Siemens Gamesa as the preferred supplier of a groundbreaking and trendsetting concept in the offshore wind industry. This also clearly underlines the success of the trilateral collaboration in the past and in the future. And I personally want to thank the joint project team, and their hard work that made this possible."

Siemens Gamesa's Christian Johansen, global commodity manager for Ports & Transportation in the company's offshore unit, commented: "With our record order backlog, we will be installing a significant number of wind turbines at sea globally, with increasingly larger and more complex components. With this agreement, we have taken another step towards securing our ability to execute projects safely, on time, and at the right cost level." ≈

Lithuania completes first offshore wind auction

BALTIC SEA A consortium of the Ignitis Group and OceanWinds has agreed to pay EUR 20 million in a so-called 'negative bid' to develop Lithuania's first offshore wind project, which is likely to be commissioned before 2030. The consortium has been awarded a 41-year permit.

The country has beaten its Baltic neighbours with the first successful regional auction, but other states are also planning to harness offshore wind resources before the end of the decade. Their development will help to underpin energy supplies in the Baltic region and could result in lower energy prices.

States could even become energy exporters rather than importers. Estonia, for example, is already planning to build a subsea electricity cable to export power to Germany.

Despite the apparent success of the Lithuanian auction, however, industry body Wind Europe has been critical of the auction design. The Ignitis-OceanWinds consortium's negative bid for the right to build the wind farm will need to be supplemented by at least EUR 5 million for environmental protection and a one-euro per megawatt-hour levy for the support of local communities.

The price may not be as high as some previous negative bids to build offshore plants in Germany, for example. But auctions based on the negative bidding process are not viewed favourably by Wind Europe, amongst others. "Uncapped negative bidding leads to extra costs that need to be passed on to the supply chain and consumers who are already struggling," Wind Europe said in a statement.

"In addition, the Government hasn't done any of the site and environmental surveys yet – something that is common in other countries," the statement continued. "This will add about two years to the project development timeline. This also meant that developers were bidding without much knowledge about important factors such as wind speeds and, therefore, potential electricity production. This decreased interest in the auction for many developers, and only two parties entered a bid."

Lithuania is hoping to stage another offshore tender later this year. This time, a contract for difference (CfD) structure will be used across a price range that has already been set. Developers will be able to bid between EUR 64.31 and EUR 107.81 per megawatt-hour. Wind Europe believes that a CfD structure provides a more stable structure for offshore developments in the future.

Gary Dickson, WindEurope CEO, commented: "It's good to see Lithuania taking its first steps on offshore. It'll help reduce their energy imports. And it'll bring wider economic benefits, including to local communities. But this tender could have been structured better. Negative bidding is not the way forward. It's good that the next auction in September uses CfDs. This will generate more interest from other offshore wind developers." ≈

Floating ammonia plant takes next step

AIP An industrial-scale concept for a floating green ammonia plant developed by Netherlands-based SwitchH2 BV and Norway's BW Offshore has been awarded Approval in Principle (AiP) by classification society DNV.

The concept, known as NH3 FPSO, will be developed by converting an existing very large crude carrier or building a new one. The unit will receive green energy from a wind farm, produce hydrogen by the electrolysis of seawater, and generate nitrogen from an air separation unit.

The hydrogen and ammonia will then be combined in an ammonia synthesis unit. When condensed, the ammonia will be stored as a liquid in the hull of the unit before being transferred to ammonia shuttle carriers. A floating hose will be used to pump ammonia from the stern of the NH3 FPSO to a midship manifold on board the ammonia carrier. Although the unit will be permanently moored, it will be possible to relocate it if necessary, the partners said.

Conn Fagan, DNV's vice president, Business Development for Floating Production, said: "The AiP covers all aspects of the integrated vessel concept, including structural integrity, mooring, ammonia production, ammonia storage, and cargo handling. We are pleased to see such developments, both with regard to the use of renewable energy and as a contribution to emission reduction across many potential applications in different industry sectors."

SwitchH2 board member, Bob Rietveldt, commented: "We are delighted we have been awarded the AiP from DNV for our concept, and we look forward to working with DNV in the next stages of the project."

Speaking for BW Offshore, senior vice president, Project Development, Fredrik Savio, said: "At BW Offshore, we leverage our offshore experience to support and expedite the energy transition by engineering next generation floating production solutions. Achieving this AiP is an important milestone and an encouraging step towards a cleaner energy mix." ≈

MSS and GustoMSC to design next-gen WIV

EUROPEAN MARKET Maersk Supply Service (MSS) and GustoMSC have entered into an agreement to design a new generation of wind installation vessels (WIV) aimed at Europe's rapidly expanding offshore wind sector. The new design will be based on the same patent and characteristics of the feeder concept, developed for the US market, the companies said.

The patented design will focus on maximising uptime. The jack-up WIV will remain on station at the wind farm, supplied by tugs and barges transporting components such as turbine towers, nacelles, and blades from supply bases ashore. The arrangement will be less prone to weather delays, enabling continuous installations throughout the year, contributing to a lower levelised cost of energy. The partners expect the supply system to be 30% more efficient in terms of vessel uptime compared with conventional jack-up vessels.

MSS chief commercial officer, Jonas Munch Agerskov, commented: "Europe is an attractive market for offshore wind, and we believe that our concept is also suitable for this region. As the Wind Installation Vessel itself does not sail into ports, this can solve some of the bottlenecks we currently see in Europe, where only a few ports are large enough to handle the growing wind turbine sizes. We look forward to collaborating with GustoMSC on getting this new basic design ready."

Speaking for GustoMSC, Nils van Nood, managing director, said: "At GustoMSC, a subsidiary of NOV, we look forward to working with the Maersk Supply Service team on a next generation wind turbine installation jack-up for the international market. Having a decades-long history of working together, both companies will combine their years of offshore experience and design know-how in this collaboration. Against the backdrop of growing turbine sizes, we jointly aim to further improve installation efficiencies and development economics in the bottom-fixed offshore wind market." ≈


Source: MSS

Maersk Supply Service and GustoMSC expect to conclude the basic design process later this year

Imprint

Publisher
DVV Media Group GmbH
Postbox 10 16 09, DE-20010 Hamburg
Heidenkampsweg 73-79, DE-20097 Hamburg
+49 - 40 - 2 37 14 - 100

Managing Director
Martin Weber

Publishing Director
Manuel Bosch
manuel.bosch@dvvmedia.com

Editor in Chief
Kathrin Lau, +49 - 40 - 2 37 14 - 237
kathrin.lau@dvvmedia.com

Advertising Director
Markus Wenzel, +49 - 40 - 2 37 14 - 117
markus.wenzel@dvvmedia.com

Advertising Sales
Jan-Michael Jasper, +49 - 40 - 2 37 14 - 248
jan-michael.jasper@dvvmedia.com

Gerald Ulbricht, +49 - 6195 - 9 76 97 34
gerald.ulbricht@dvvmedia.com

Technical Department
Vera Hermanns, +49 - 40 - 2 37 14 - 293
vera.hermanns@dvvmedia.com

Advertising rate card
No 15 valid from January, the 1st, 2023

Printing House
Silber Druck OHG, Lohfelden

Credit for cover picture:
Stiftung Offshore-Windenergie

ISSN: 2191-0057

Advertisers