GLOBAL OFFSHORE WIND REPORT 2021

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Foreword

Another year has passed and GWEC is proud to share with you its Global Offshore Wind Report 2021.

At the end of 2020, we had a total of 35 GW of offshore wind across the world, that is 14 times higher than 10 years ago. New capacity was stable last year at 6.1 GW, roughly equivalent to 2019. It's good to note that the COVID-19 pandemic did not heavily impact the sector, though there were delays in permitting and some projects have taken longer to install.

Offshore wind is a healthy sector with a very promising future.

And that future is alive and well as Europe expands, the US takes flight, and particularly in Asia. Notably, China is a substantial part of the market throughout this decade and beyond. This year China will overtake the UK as having the largest installed capacity. However, other markets within the region are moving from early stages to concerted deployment. How countries in the region work together will be interesting to watch, and whether the economies of scale and regional cooperation that happened in Europe will play out in Asia.

One dynamic we continue to see around the world is the dramatic fall in the Levelised Cost of Energy (LCOE) from offshore wind. Prices are becoming more and more attractive for countries that have the fundamentals for offshore wind and are looking for a high-capacity renewable energy to bridge fossil fuels, solar PV, and onshore wind.

When talking with governments around the world, low-cost, high-quality, renewable energy is very desirable, but it is the associated benefits which make it even more attractive. The benefits that I hear most about are reducing imports whilst tackling climate change; the huge economic growth in terms of investment; and the creation of jobs that makes it compelling for politicians.

A case in point is the United States, where the Biden administration has embraced offshore wind as part of the green recovery, setting a target of 30 GW by 2030. It is also great to see the Vineyard Wind project receive approval of the construction and operation of the first large-scale, US offshore wind project, located off Massachusetts.

Over the last year we have seen a much wider appreciation of how offshore wind can contribute at scale in tackling climate change. One of the drivers is the increasing number of countries, cities, and companies declaring a net zero commitment. When they look at how they are going to meet their commitments, offshore wind features large in their plans.

In the last year we've seen floating wind move from concept to practical reality. The size of these projects is increasing, and fully commercial scale projects can be expected towards the end of this decade. Next decade, we expect floating

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wind to compete directly with fixed foundations, partly because floating wind trebles the size of the addressable market.

The next innovation that will spur offshore wind to even greater deployment is the topic of energy islands. In Denmark this has moved forward with locations in the North Sea and Baltic Sea being identified and survey work commenced. The plan is to have the first phases operational in the early 2030s.

In terms of going wider, the subject of hydrogen and Power-to-X is expanding and creates numerous routes to market which don't require a large local power demand. It is interesting to note that this area is a focus for oil and gas players who bring their considerable experience and skills to the opportunity.

The health of the offshore wind sector is reflected in GWEC's outlook for 2030 which is more than 15% higher than last year's assessment. This is the decade when offshore wind truly comes of age and, to meet the IEA and IRENA's 1.5°C scenario, we need to ramp up significantly over the next two decades.

In 2021 GWEC expects that newly installed capacity will be more than double 2020's figure, driven mostly by a boost in China where projects seek to secure the feed-in-tariff that expires at the end of the year. GWEC's outlook is that offshore wind will continue to grow as a proportion of global wind new installations, reaching 20% by 2025 in capacity terms.

In the run up to the COP26 conference later this year, considerable effort is going into asking governments to make further commitments to offshore wind. The time is right to attract trillions of dollars to a sector that has proven its credentials and is going from strength to strength.

GWEC looks forward to working with governments, industry and wider stakeholders, as we realise the massive and broad benefits of offshore wind to nations and their people.

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Foreword

The publication last month of the sixth assessment report on Intergovernmental Panel on Climate Change could hardly have been more timely. It came three months before the critical COP26 meeting is due to begin in Glasgow. And it arrived at a time when the world was experiencing first hand a destructive demonstration of the dangers climate change brings.

On the evening I write this, Siracusa in Italy has registered Europe´s highest ever temperature of 48.8°C. At the same time wildfires are currently raging in North America, Siberia, Algeria, Tunisia, Greece, Italy and many other places beyond. Not long before we had witnessed terrible flooding in northern Europe, India and China.

The IPCC report could not be clearer: It is "unequivocal" that human activity has warmed the planet and that without concerted action to cut carbon emissions "global warming of 1.5°C and 2°C will be exceeded during the 21st century".

That in turn means, "Increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic sea ice, snow cover and permafrost". Which is to say more of the catastrophic scenes we have seen in these past weeks with consequences that we cannot begin to imagine.

We appear to have reached a pivotal moment in the battle against climate change and what happens between now and the end of 2021, and in particular in the resolutions agreed later this year in Scotland.

A great many of those of us working in the wind energy industry do so because we are passionate about addressing the threat of climate change and we know that wind energy has a crucial role to play in providing clean, affordable sources of energy that can decarbonise energy supply.

We are very proud therefore to be working with our peers in the industry and GWEC in the Global Wind Energy Coalition for COP26 with aims including intensifying engagement with policy makers in key wind markets to create wind energy acceleration plans that include more ambitious capacity targets and pragmatic, workable regulation for project development.

Offshore potential

Our industry is ready to meet that challenge. We have the proven technology, the people, and the determination to deliver wind turbines that can accelerate the energy transition, and the contribution of offshore wind will be critical.

This report outlines the incredible progress that has been made in offshore the last decade, but equally shows the scale of the task to come.

With 2020 installations of 6.1 GW of capacity being the second best year for installations in our industry´s relatively short history, we now have

Marc Becker

CEO of Offshore Business Unit, Siemens Gamesa Renewable Energy

SIEMENS Gamesa RENEWABLE ENERGY

cumulatively deployed more than 35 GW of wind offshore.

For those of us who have been working in offshore for some time, it is sometimes difficult to believe how far we have come. But our industry´s success in delivering a safe and affordable source of sustainable energy should give us all confidence that GWEC´s outlook of a further 235 GW installed by the end of 2030 is within our collective grasp.

With new markets such as the US and Taiwan coming on stream and accelerated targets in northern Europe, which has been the cradle for Offshore development and remains a key hub for development and deployment.

Everywhere you look there is evidence of the innovation and resourcefulness that will be required to deliver to offshore wind's full potential. The size of the turbines now being designed and deployed dwarves those upon which we have built our industry. Floating turbines will be a key part of the mix in the future and we are now seeing important steps taken in the journey to making Offshore wind a key energy provider to the emerging hydrogen economy. Advances in digitalisation are helping us to make our machines safer, more productive and more efficient.

Are there challenges? Of course. Our industry needs greater clarity and support from policy and regulatory frameworks in both new and mature markets. Governments and industry must continue to work together to significantly reduce the timelines for offshore wind projects. The current cycle of, in some cases, over 10 years from volume announcement to first power will not see us reach our climate goals. We can bring the lessons learned from established markets, sharing best practices and designing optimal market structures that can ensure offshore wind can satisfy the energy, environmental and economic needs of new markets.

We need to build a new and enlarged workforce and support them with a commercial environment in which each part of the wind energy value chain can thrive. We also need to ensure that our own activities evolve in a sustainable way.

These are not new challenges, however. We have faced them down before and built an industry of which we can all be proud. And we will do it again, expanding our promise to safely design, develop, build and install wind turbines that can deliver the clean, renewable energy our planet so clearly needs.

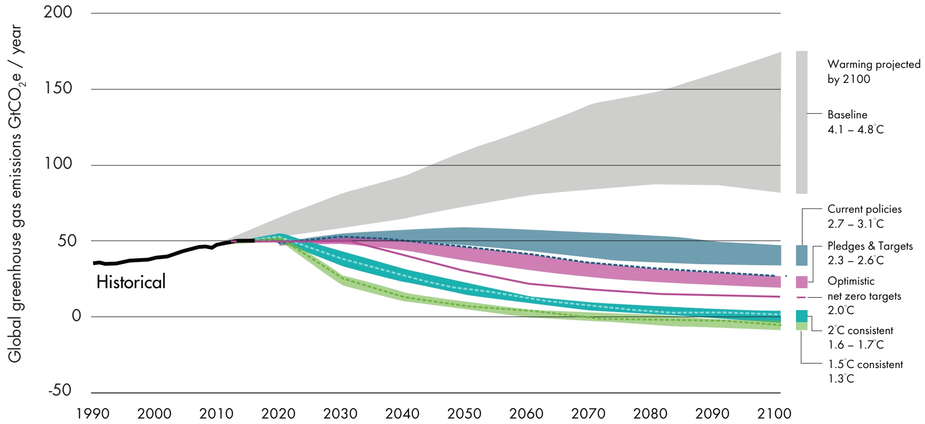
OFFSHORE WIND CHARTING NEW WATERS IN THE RACE TO NET ZERO

The world is in uncharted waters when it comes to climate action. On the one hand, there is a narrowing window of time to act decisively in this decade to halt global warming. Under current policies and pledges as of May 2021 – and these are still to be implemented – the global average temperature increases will hit 2.4°C by end of century, spelling out significant hardship and unprecedented environmental impacts ahead[1].

On the other hand, consensus on the scale of change needed, from energy systems to behavioural change, has never been stronger. There is growing momentum from policymakers recognising climate change as the preeminent challenge facing our way of life. The spate of NDC updates and net zero targets made over the last year from the US, the EU, China, Japan, the UK and other nations have closed the emissions reduction gap required by 2030 for a Paris-compliant 1.5˚C pathway by up to 14%, according to Climate Action Tracker.

2100 Warming projections

Emissions and expected warming based on pledges and current policies



Source: Climate Action Tracker, May 2021.

Offshore wind will be a key vector in the global response to climate change. Energy production accounts for around three-quarters of global greenhouse gas emissions and will be the focal area for climate change mitigation efforts.

The map of hitherto competing policy recommendations has become much clearer, now that the leading international energy institutions are in agreement on the primary role of renewable energy required to meet the Paris targets and deliver carbon neutrality by 2050.

Both the IEA and IRENA have mapped out roadmaps whereby wind and solar PV energy supply around 70% of electricity generation by 2050, and both technologies dramatically scale up to deliver the required deep emissions reductions.[2] **From now to 2050, offshore wind becomes a central plank of global decarbonisation, transforming the electricity system in generation, infrastructure, flexibility** and production of green

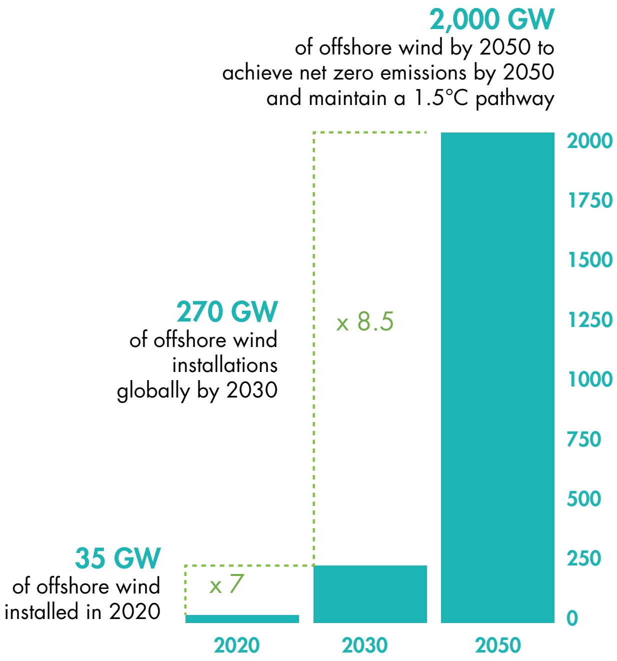
1 https://climateactiontracker.org/publications/global-update-climate-summit-momentum/
2 https://www.iea.org/reports/net-zero-by-2050; https://www.irena.org/publications/2021/Jun/World-Energy-Transitions-Outlook

fuels like hydrogen. Its application does not discriminate between emerging economies and advanced economies, nor one region of the world over another.

Offshore wind is a key technology in these net zero scenarios, with fixed-bottom offshore wind set for rapid acceleration over this decade and floating offshore wind unlocking tremendous potential for fossil fuels displacement from 2030 onward. The IEA calls for offshore wind to grow as a share of total wind deployment, from 7% in 2020 to more than 20% from 2021 onward. Its roadmap requires offshore wind annual installations to grow 13-fold, from the 6.1 GW installed in 2020 to 80 GW by 2030.

Closing the offshore wind gap by 2050

Unit: GW



Source: GWEC Market Intelligence; IRENA World Energy Transitions Outlook 2021.

IRENA foresees more than 2,000 GW of offshore wind installed capacity by 2050 in its 1.5°C scenario, nearly one-quarter of total wind power capacity at that time.

Where will offshore wind be built by 2050?

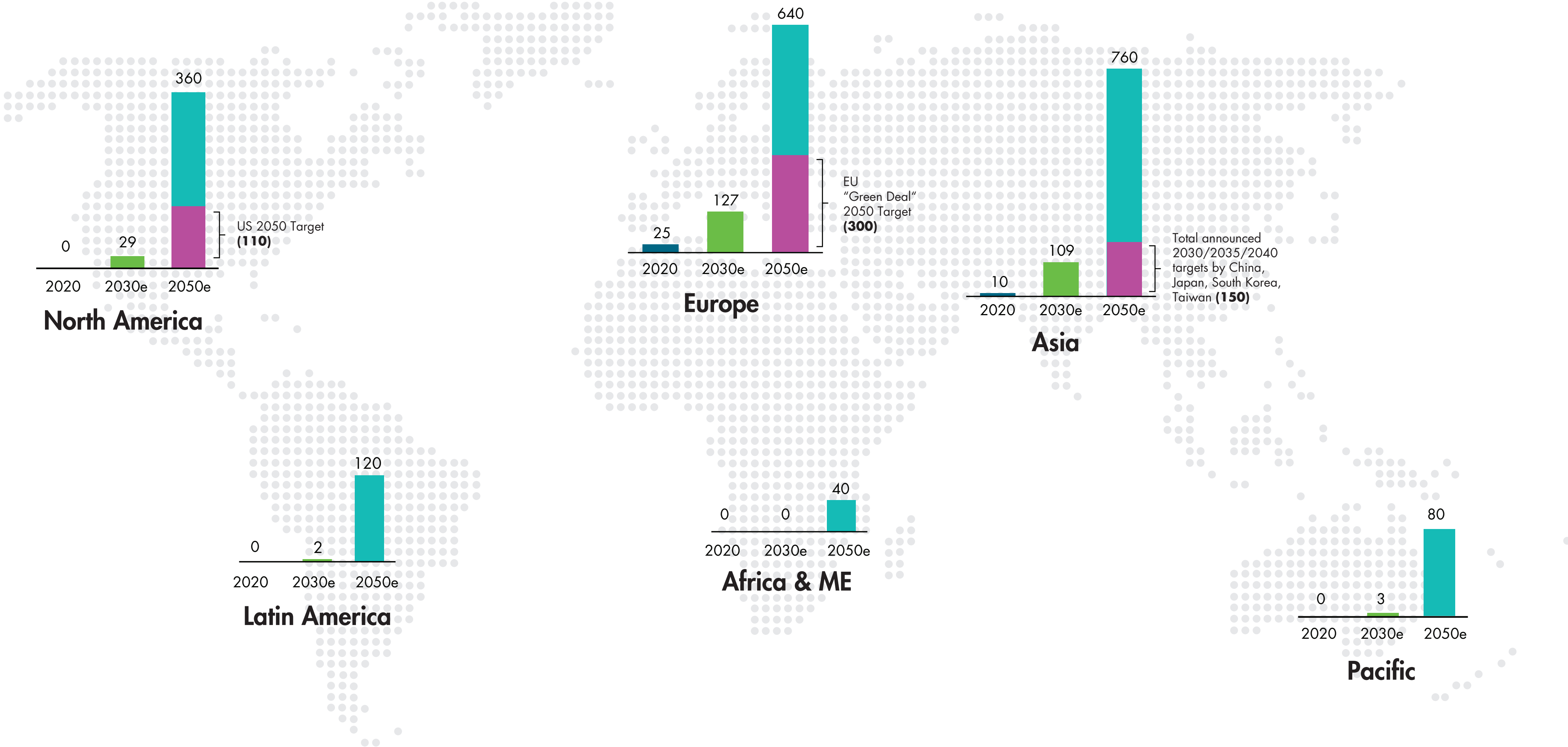
We have only begun to scratch the surface of offshore wind potential. With 35 GW installed today, primarily in Europe and China, offshore wind comprises less than 0.5% of global installed electricity capacity. Nonetheless, the offshore wind resource available worldwide is formidable. The World Bank has identified more than 71,000 GW of technical resource potential available worldwide – nearly 10 times the world's current installed electricity capacity. [3]

The Offshore Wind Resource Hub, launched by GWEC on World Ocean Day in 2021, consolidates territorial maps of fixed and floating offshore wind potential in nearly 100 countries.[4] These illustrate the potential for offshore wind, as an indigenous and sustainable resource, to be distributed in every region of the world, from the Caribbean to East Asia to sub-Saharan Africa.

Based on IRENA's target OF 2,000 GW, which would be required to achieve carbon neutrality and sustain a Paris-compliant pathway, GWEC Market Intelligence foresees Asia emerging as the world's most prominent offshore wind region, home to nearly 40% of installations by 2050, followed by Europe (32%), North America (18%), Latin America (6%), the Pacific region (4%) and Africa and the Middle East (2%).

3 https://datacatalog.worldbank.org/dataset/global-offshore-wind-technical-potential; the IEA's World Energy Outlook 2020 identifies global electricity capacity as 7,484 GW in 2019
4 https://gwec.net/offshore-wind

Where could 2,000 GW of offshore wind by 2050 be built?



Unit: GW

Source: GWEC Market Intelligence

Installations as of 2020
Installations by 2030 under current policies
Regional forecast by 2050, based on 2,000 GW global target
Current regional or national targets

However, the volumes of offshore wind required in every region of the world are still drastically higher than current targets, and miles ahead of current capacity. Only in Europe is there a target to 2050, set at 300 GW under the EU Offshore Renewable Energy Strategy. Even this falls far short of Europe's foreseen share for the world to reach 2,000 GW, although volumes from the UK, Norway, Turkey and Russia will help to make up the difference.

The growth story is most pronounced in Asia, which GWEC Market Intelligence forecasts as the forerunner for offshore wind in this century. Around 760 GW of offshore wind capacity must be delivered by China, Japan, South Korea, Vietnam, the Philippines and other geographies in the region; however, current targets only stretch to 2040 and amount to 150 GW among the region's major offshore wind leaders (China, Japan, South Korea and Taiwan).

In other regions of the world, a dramatic scale up of offshore wind is called for over the next three decades from near-zero capacity levels today. To date, the US has set cumulative federal and state targets of 110 GW but will need to raise its ambition and be joined by Canada to meet the continent's potential. Pathfinder markets will need to activate wider interest and ambition in offshore wind in each region, such as Brazil and Colombia in Latin America, South Africa and Morocco in Africa and the Middle East and Australia in the Pacific.

To kickstart activity in countries with near-zero offshore wind, countries will need to introduce national policy frameworks for offshore wind in this decade. Targets alone will not suffice to make offshore wind the bridge for the fossil fuels-to-clean transition – long-term vision, forward-planning in enabling infrastructure and clear regulation will be required to accelerate offshore wind deployment.

System decarbonisation potential of offshore wind

While the carbon-free production profile and increasing cost-competitiveness of wind and solar energy give them an edge in energy markets, system planners are also focused on the need to maintain energy security and a balanced grid as power demand grows. As the share of renewables grows in energy

A message from the UNFCCC Race to Zero Campaign

Race to Zero is the UN-backed global campaign rallying non-state actors across the global economy to take rigorous and immediate action to halve global emissions by 2030 and deliver a healthier, fairer zero carbon world in time. We need all companies to join the race, including the offshore wind industry.

In this race to a resilient, net zero world, ocean-based climate solutions such as offshore wind play a critical role. We know that the potential of offshore wind is high. A key enabler to tap its full potential is a sustainably managed ocean. Therefore, governments, in collaboration with relevant stakeholders and informed by science, need to allocate the necessary space for the offshore wind industry to grow, in harmonious co-existence with other ocean users.

Parallel to this growth, offshore wind companies should contribute to the restoration of marine and coastal ecosystems by ensuring that all operations have a positive impact on nature. All ocean-based renewable energy companies should commit to publicly report on actions taken to protect and restore marine ecosystems by 2030, as outlined in the Ocean and Coastal Zones Climate Action Pathway 2021.

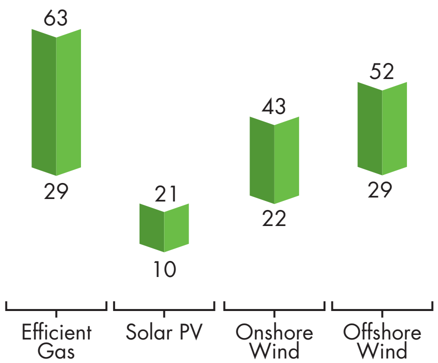
With input from: Ignace Beguin, Ocean Lead, UNFCCC Climate Champions

"The growth story is most pronounced in Asia, which GWEC Market Intelligence forecasts as the forerunner for offshore wind in this century."

systems, system operators will focus on optimising clean power sources to ensure predictability, dispatchability of generation and consistency of load factors, particularly as large commercial and industrial users in energy-intensive sectors commit to lowering emissions.

Offshore wind can support energy security by displacing fossil fuels baseload generation with clean power operating at lower intermittency compared to other renewable energy technologies, particularly when paired with storage solutions. Offshore wind offers the highest capacity factors of all renewables, on comparable with the most efficient gas-fired power plants, as shown in the graph below. New offshore wind projects are delivering capacity factors ranging from 40-50% utilising 5 MW turbines, while floating wind projects like Hywind Scotland delivered a record-breaking average capacity factor of 57% in its third year of operation to March 2020[5].

Average annual capacity factor (%) by technology in year 2018



Source: IEA

The daily generation profile for offshore wind also reflects greater consistency, with around half of the hourly fluctuation typically seen in solar PV. As turbine sizes continue to scale to 15 MW power rating and beyond in the decade ahead, average capacity factors at operational offshore wind farms will continue to increase, particularly for projects with large aggregation of turbines.

Cost reduction should not be understated either. Around one-third of offshore wind project lifetime costs are drawn from wind turbines and installation, while nearly 30% is drawn from OPEX[6]. The evolving efficiency of manufacturing, installation and O&M, combined with increasing turbine size and economies of scale, have brought offshore wind LCOE far below what industry experts could have predicted.

A 2020 expert elicitation survey of more than 140 wind experts found that cost reduction pathways for offshore wind had been drastically underestimated over the last five years[7]. Surveyed experts now predict fixed-bottom offshore LCOE to continue declining from 35-49% from 2035 to 2050, while floating offshore wind will decline from 17-40% from 2035 to 2050. This reduction will be driven by innovation in turbine technology, as well as improvements in cost of capital, project design life, overall capacity factors and OPEX optimisation.

Continued innovation will be needed to harness offshore wind from a wider variety of geographies, including strengthening turbine resilience in regions prone to tropical cyclones, typhoons or hurricanes, as well as pushing towards the commercialisation of floating wind before 2030 ***(see:* Floating Wind chapter**). These factors in turn pose a regulatory challenge to ensure

5 https://www.iea.org/reports/offshore-wind-outlook-2019 ; https://www.equinor.com/en/news/20210323-hywind-scotland-uk-best-performing-offshore-wind-farm.htm
6 https://guidetoanoffshorewindfarm.com/wind-farm-costs
7 We note that members of GWEC Secretariat took part in the expert elicitation survey; https://www.nature.com/articles/s41560-021-00810-z.pdf.

common recognition and certification of project and component design elements, as the sector continues to expand to new markets.

As the offshore wind industry expands, so will its demand for structural materials such as concrete and steel, critical minerals such as copper, nickel, chromium and manganese, and rare earths such as the neodymium and boron magnets in wind turbines. This not only deepens existing dependencies where minerals and rare earths are mined – for instance, China is the main exporter of rare earth metals globally – but sheds light on the carbon intensity of upstream processes in the offshore wind supply chain.

The materials extraction process is the primary source of CO_2 equivalent emissions in the lifecycle of an offshore wind project, dominated by steel manufacturing, which comprises nearly two-thirds of materials-related emissions[8]. There are emerging innovations to address the steel challenge, such as Modvion's modular wind turbine tower made from laminated wood, envisioned for eventual deployment in offshore environments.

But coordination with heavy industries, including steel and concrete, will be the key to decreasing the offshore wind sector's carbon footprint. Greater coalition-building for value chain sustainability can strengthen acceptable standards for procurement, support suppliers in switching to renewable energy sources for manufacturing and foster peer-to-peer guidance on sustainable practices. Collaborative efforts will also be needed for cost reduction of green hydrogen production and application to fuel production of steel and other products (**see: Power-to-X section**).

Manufacturing capacity will also scale up for blades, with latest models exceeding 100 metres in length. Around 85-90% of a wind turbine's weight is already commercially recyclable, but blade composites, resins and fibres form a hurdle to end-of-life recycling and management. The concern around composite waste creation and circular economy in the onshore wind sector is on the horizon for offshore

8 https://www.siemensgamesa.com/-/media/siemensgamesa/downloads/en/products-and-services/offshore/brochures/siemens-gamesa-environmental-product-declaration-epd-sg-8-0-167.pdf

Case Study: Offshore wind and steel - a huge mutual dependency

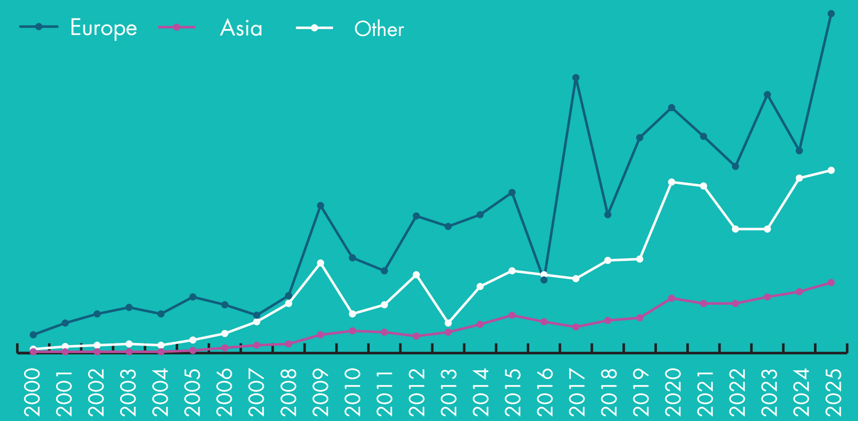
Provided by: CRU

Steel is a crucial element of offshore wind projects. It is used to build the tower, transition piece, offshore substation and, most importantly, the foundation. A monopile foundation is essentially a big steel tube driven into the seabed. Supporting a large turbine out at sea presents a challenge for material strength and durability, and steel plate provides an excellent response to that challenge.

Plate is a steel product defined as flat-rolled steel of more than 4.75 mm thickness. Offshore wind typically requires thicker plates than other applications, even as much as 150 mm. The sector has developed rapidly to become the key demand growth driver for this niche steel in Europe. Similar dynamics are now emerging in Asia and North America.

From the steel mills' perspective, offshore wind is a big deal. CRU calculates that 15-20% of European demand for reversing mill plate comes from wind. We expect this

Wind share of regional mile plate demand (%)



Source: CRU

to exceed 25% within five years, driven by offshore wind. In Asia, a plate market around ten times larger than Europe, the plate demand from wind is smaller but rising.

If we look at the relationship from the other end, steel is also a big deal for the offshore wind sector, with 25% of CAPEX coming from foundation and tower[1]. There is a huge mutual dependency between steel producers and offshore wind developers. In that context, the following key challenges can be highlighted:

- **Security of supply:** Amid competing demands, there is a need to ensure that the right amount of the right steel can be secured at the right time. The world market is complex and always changing, subject to multiple forces. Business intelligence to support managing that complexity is vital.
- **Supply chain carbon footprint:** Strategies to decarbonise supply chains are widespread and have a particular resonance within renewable energy. Offshore wind will be a strong future source of demand for low-CO2 steel. But steel is a "hard-to-abate" sector with enormous technological and commercial challenges to decarbonise. CRU's Emissions Analysis Tool shows that on average liquid steel emits almost 2t CO2/t.
- **Managing price risk:** Offshore wind requires large volumes of steel over long time periods. But steel prices are volatile; for example, steel plate prices in Germany increased by over 120% between July 2020 and July 2021. Many companies in the wind supply chain are choosing to manage this price risk by indexing their commercial contracts to CRU's *steel prices.*

Find out more:
https://www2.crugroup.com/l/707643/2021-07-01/zvs6y

1 IRENA (2016), The Power to Change: Solar and Wind Cost Reduction Potential to 2025.

wind, where projects like the EU's MAREWIND initiative aim to identify solutions for next-generation offshore wind materials and coatings to increase resilience, corrosion/erosion protection and recyclability.

Industry consortiums have also been formed in 2021, with public-sector backing, to enable blade recycling: DecomBlades project is a cross-sector consortium which seeks to accelerate commercialisation of composite recycling for wind turbines; while the Circular Economy for Thermosets Epoxy Composites (CETEC) initiative aims to deliver a solution for disassembly of blade thermoset composites into fibre and epoxy, which will then be "chemcycled" into base components for manufacture of new blades.

Improving project circularity, extending wind turbine lifecycles for greater economy and innovation for refined materials and commercial recycling processes will all be necessary components of improving offshore wind sustainability. Progress in these areas will require strong public-private partnerships, academic/R&D investment and cross-sector coordination.

Conclusion

While those in the industry are bullish about offshore wind's capacity to innovate and deliver competitive costs, the unprecedented scale of deployment required over the next three decades will require political will as much as favourable economics and sustainable expansion of the industrial supply chain.

The price volatility of oil and gas markets during the pandemic has only accentuated the strategic considerations for energy independence, which can be supported by offshore wind as an indigenous natural resource. Governments must go a step further and avoid the risk of stranded assets by curbing spending and support for carbon-intensive generation, which would otherwise lock in expensive and polluting fossil fuels for decades to come. Meanwhile, an evolving set of mechanisms offer market levers to disincentivise fossil fuel offtake and generation, from carbon border adjustment mechanisms to portfolio standards.

The UNFCCC Climate Action Pathway for Oceans and Coastal Zones outlines several milestones to 2050 for offshore wind to deliver its mitigation potential: concrete national capacity targets, concerted environmental impact assessments, integrated and sustainable ocean planning, accelerating allocation of seabed, and more[9]. A wave of commitment from policymakers, industrial consumers, public funders and other communities will be needed to achieve these milestones, phase out fossil fuels and clear a path for offshore wind.

Above all, national policymakers must recognise the role of offshore wind in their long-term energy system planning in this COP26 year and within the next decade, reflected in new or updated NDCs, country climate strategies and decarbonisation plans.

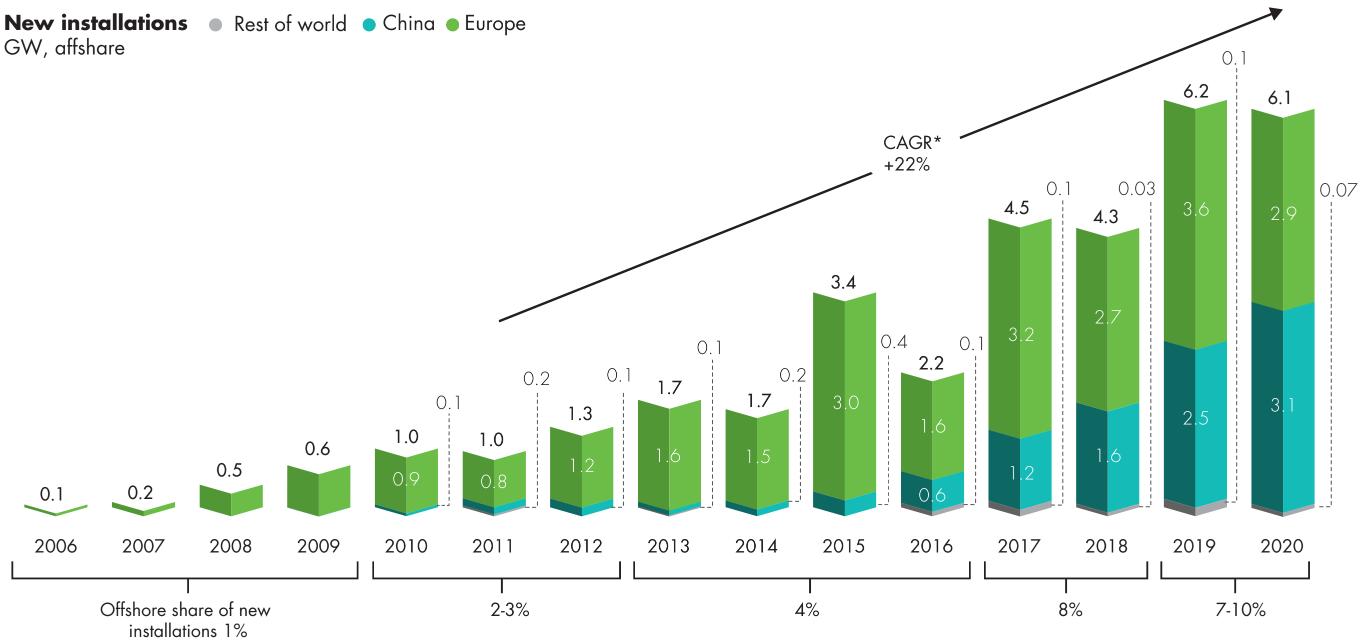
9 https://unfccc.int/climate-action/marrakech-partnership/reporting-tracking/pathways/oceans-and-coastal-zones-climate-action-pathway

MARKET STATUS 2020

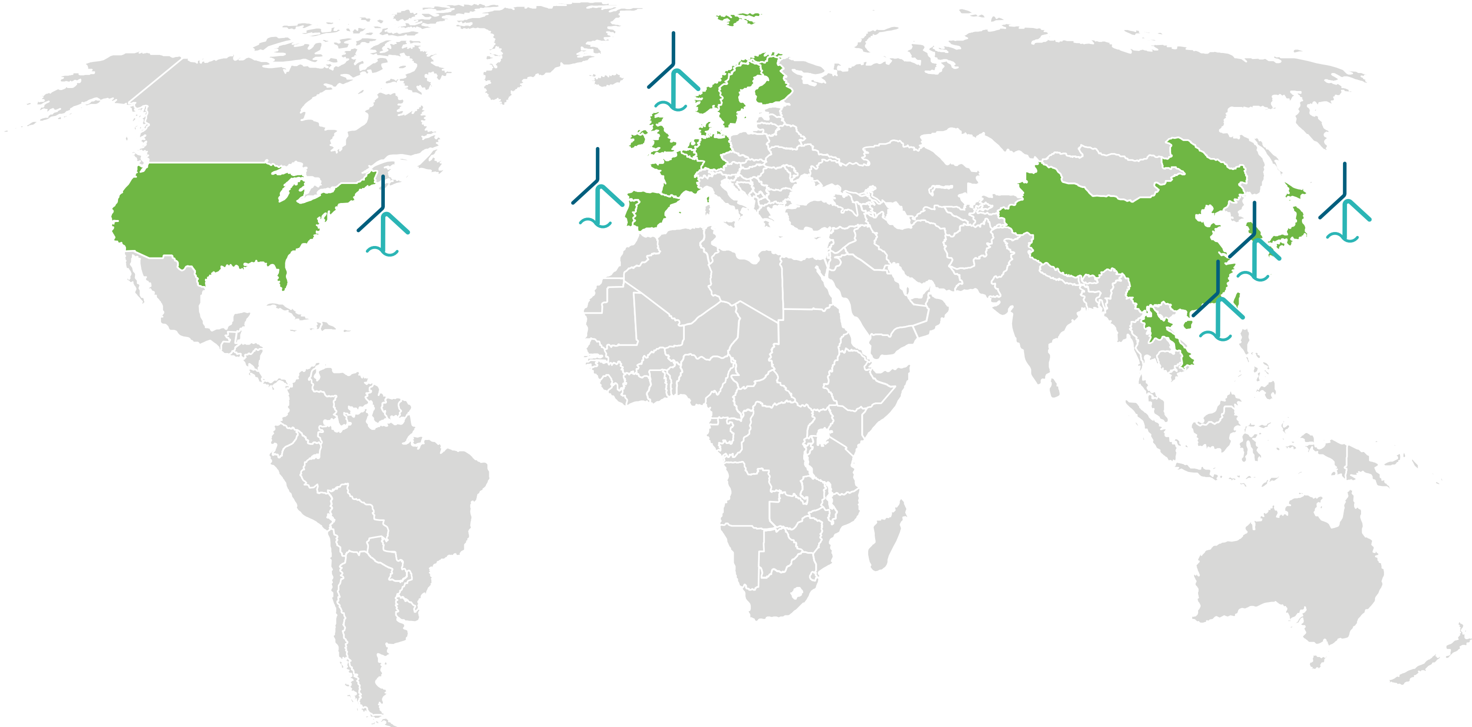
Offshore wind annual installations

- The global offshore wind industry had its second-best year ever in 2020 despite the impact of COVID-19.
- China led the world in new installations for the third year in a row with more than 3 GW of offshore wind grid connected in 2020.
- Steady growth in Europe accounted for the majority of remaining new capacity, led by the Netherlands, which installed nearly 1.5 GW of new offshore wind in 2020, followed by Belgium (706 MW).
- The UK and Germany installed 483 MW and 237 MW respectively, making them the No.4 and No.5 markets in new installations in 2020. The slowdown of growth in the UK was due to the gap between the execution of projects in the Contracts for Difference (CfD) 1 and CfD 2 rounds. In Germany, the slowdown was primarily caused by unfavourable market conditions and a lower volume of short-term offshore wind projects in the pipeline.
- Outside of China and Europe, two other countries recorded new offshore wind installations in 2020: South Korea (60 MW) and the US (12 MW).
- Last year, only 1,005 MW of offshore wind capacity was awarded worldwide through auctioning, of which 759 MW was from the Netherlands and the remainder from China. A consortium of Shell and Eneco won the right to build the 759 MW Hollandse Kust North project in the Netherlands. The project is the third so called "zero-priced" bid, meaning that the project will receive only the wholesale price of electricity and no additional support or payment.
- Although awarded offshore wind capacity was relatively low compared to 2019, more than 7 GW of offshore wind auction/ tenders were launched in 2020, of which 5.5 GW is through state-issued solicitations in New Jersey, New York and Rhode Island in the US. The rest of the capacity is from Denmark (800-1000 MW) and Japan - the East Asian country's first auction for both floating and bottom-fixed offshore wind.
- The offshore wind market has grown from 2.2 GW in 2016 to 6.1 GW 2020, bringing offshore's share of new wind installations from 4% to 7%, which is 3% lower than 2019. This is primarily due to the strong growth spurt of onshore wind in 2020.

New installations GW, affshare



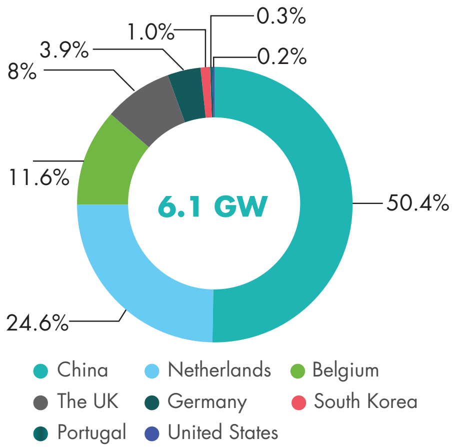
** Compound Annual Growth Rate*
Source: GWEC Market Intelligence, July 2021



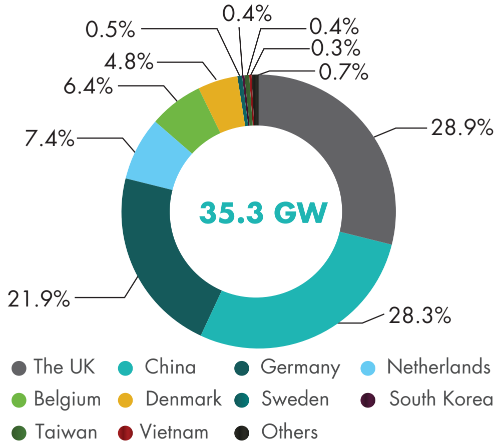
FLOATING WIND

- 16.83 MW floating wind installed in 2020, of which 16.8 MW is from Portugal and 0.03 MW from Spain;
- As of 2020, a total of 73.33 MW net floating wind was installed globally, of which 32 MW is located in the UK, 25 MW in Portugal, 12 MW in Japan, 2.3MW in Norway and 2 MW in France.

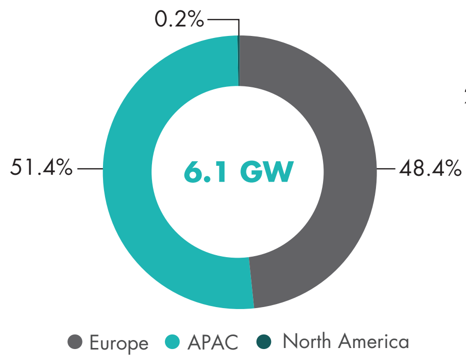
New offshore wind installations by country



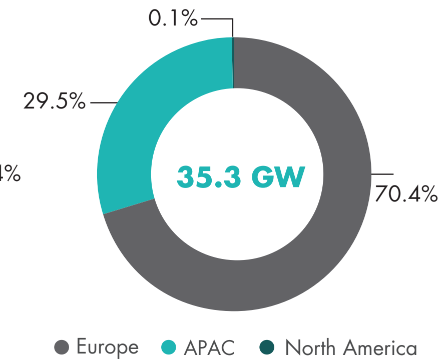
Total offshore wind installations by country



New offshore wind installations by region



Total offshore wind installations by region



Offshore wind cumulative installations

- The global offshore market grew on average by 22% each year in the past decade, bringing total installations to 35.3 GW, which accounted for 5% of total global wind capacity as of the end of 2020.
- Europe remains the largest offshore market as of the end of 2020, making up 70% of total global offshore wind installations, which is 5% lower than the previous year.
- Cumulative installations in Asia passed the milestone of 10 GW by the end of 2020, making it the second largest regional offshore market. China currently has a strong lead in offshore wind activities, followed by South Korea, Taiwan, Vietnam and Japan.
- North America has only 42 MW of offshore wind in operation as of last year, but deployment in the US is expected to accelerate from 2023.
- The UK remains in the top spot globally in terms of cumulative offshore wind capacity as of the end of 2020, while China has now overtaken Germany to become the world's second largest offshore wind market.

MARKET OUTLOOK 2030

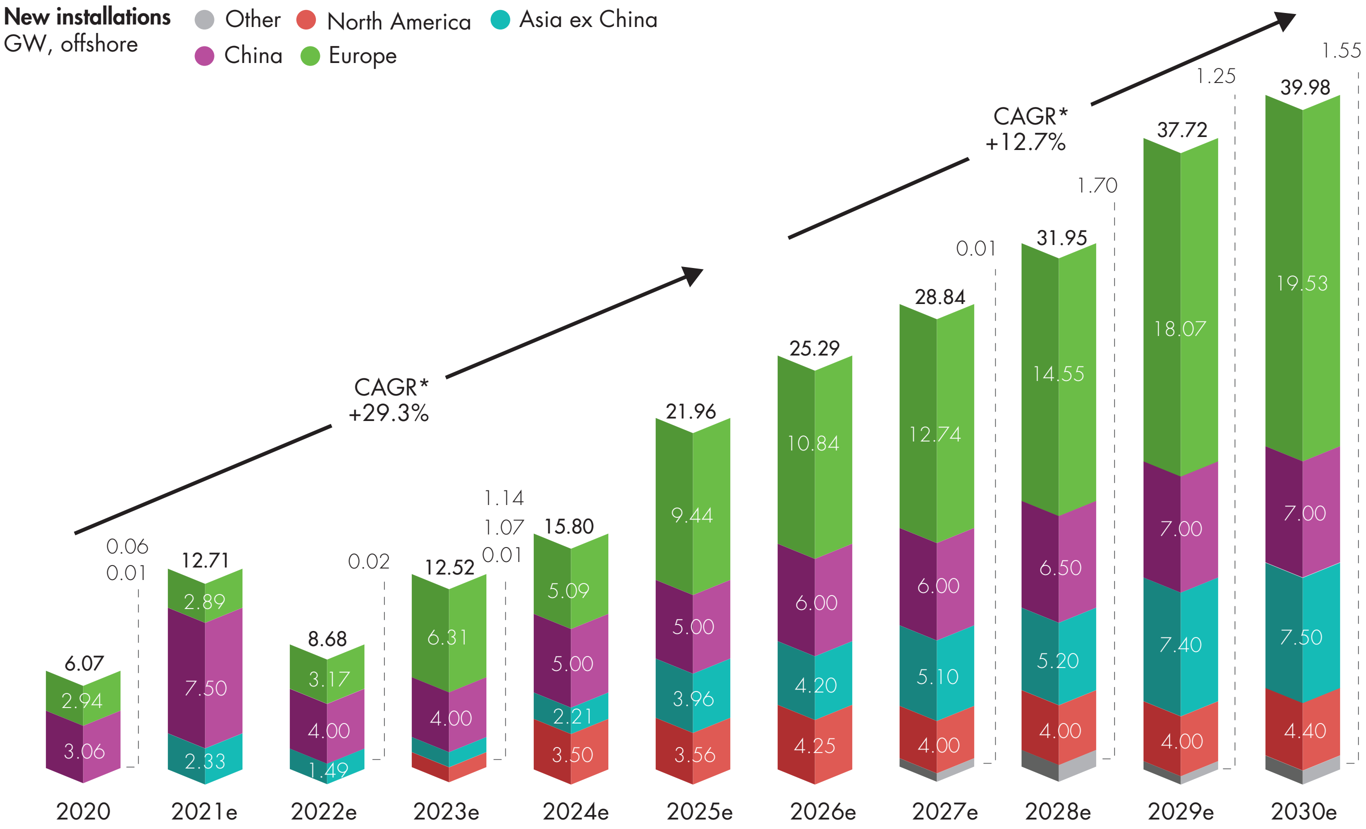
Offshore Market Outlook to 2030

The global offshore wind market outlook to 2030 has grown even more promising over the past 12 months as: 1) governments across the world continue to raise their ambition levels, 2) the sharp drop of offshore wind LCOE made it one of the most competitive energy sources, 3) progress continued in commercialisation and industrialisation for floating wind, 4) offshore wind increasingly played a unique role in facilitating cross industry cooperation and decarbonisation, such as oil and gas sector transition to renewables and Power-to-X.

With a compound average annual growth rate of nearly 30% until 2025 and 12.7% up to the end of the decade, new annual installations are expected to sail past the milestones of 20 GW in 2025 and potentially 40 GW in 2030.

GWEC Market Intelligence expects that over 235 GW of new offshore wind capacity will be added over the next decade, bringing total offshore

Global offshore wind growth to 2030



**CAGR = Compound Annual Growth Rate*
Source: GWEC Market Intelligence, July 2021

wind capacity to 270 GW by 2030. 30% of this new volume will be installed in the first half of the decade (2021-2025), with the remaining to be connected in the latter half (2026-2030). The volume of annual offshore wind installations is expected to more than triple, from 6.1 GW in 2020 to 23.1 GW in 2025, bringing its share of global new installations from today's 6.5% to 20% by 2025.

Europe retains its status as the largest regional offshore wind market as of the end of 2020, but new installations outside Europe, predominantly in Asia, already surpassed Europe last year for the first time. This situation is likely to remain through to 2030, although annual installations in Europe may pass the milestone of 10 GW in 2026. In the near term (2021-2023), the majority of growth outside Europe will come from Asia – primarily China, Taiwan and Vietnam, with contributions from the US.Japan and South Korea will grow in importance from 2024 onward.

Our near-term offshore wind market outlook was built using a bottom-up approach and is based on GWEC Market Intelligence's global offshore wind project database, which covers projects currently under construction, global auction results and announced offshore wind tenders worldwide. For the medium-term market outlook, aside from existing project pipelines, a top-down approach has also been used, which takes into account existing policy, support schemes, offshore wind auction plans and medium/long-term national and regional level offshore wind targets.

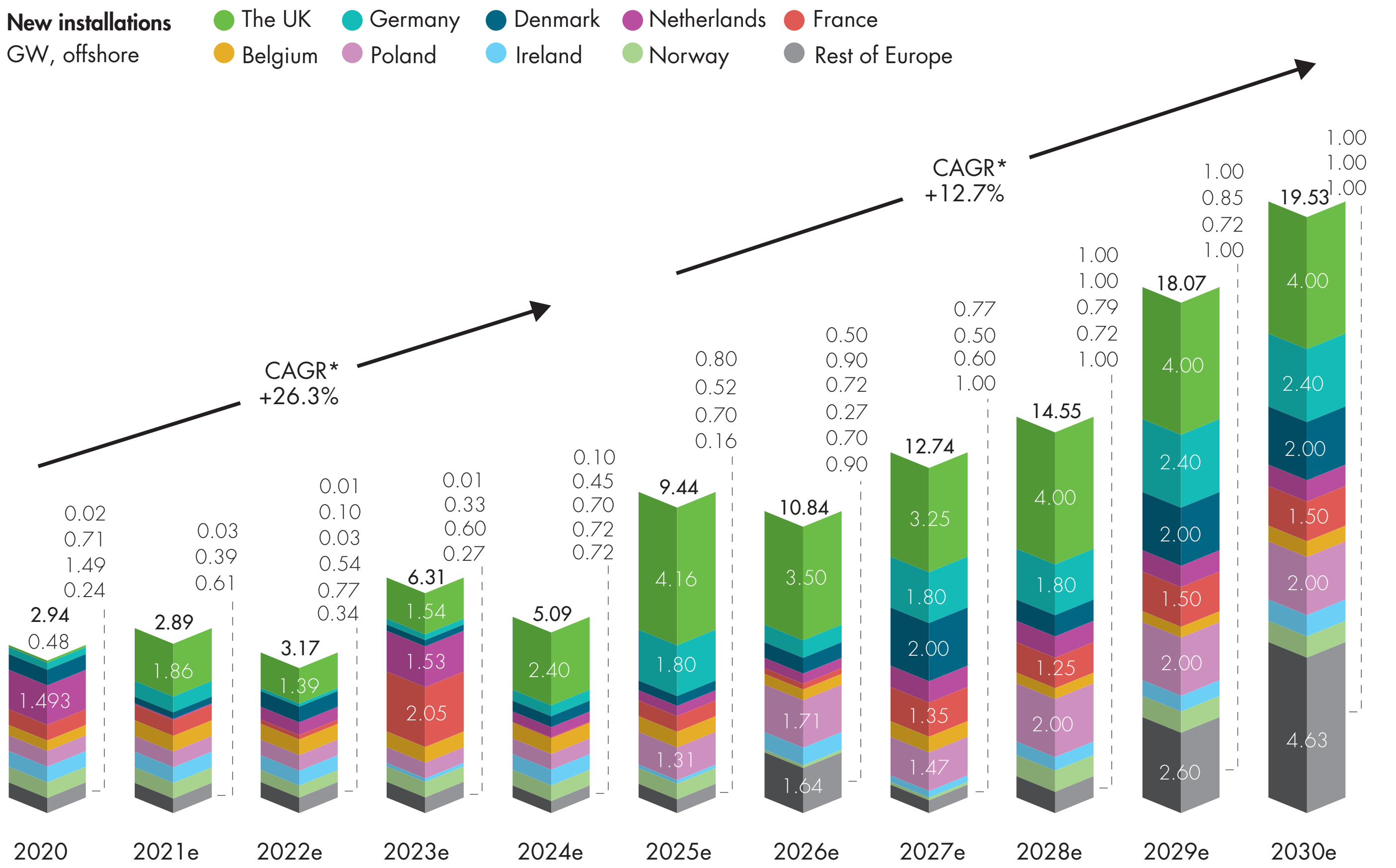
Europe

The world's first offshore wind project Vindeby was installed in Denmark in 1991, which makes Europe the birthplace of the offshore wind industry. Through close collaboration among European countries and experienced stakeholders in the past three decades, a robust offshore wind supply chain has been built in countries neighbouring the North Sea and Baltic Sea. As of today, offshore wind has not only established itself as a cost-competitive power generation of choice for governments in European continent, but also created nearly 100 thousand of jobs and boosted the local economic growth.

In the past decade (2011-2020), the European offshore wind market enjoyed double-digit annual growth (12%), making it the world's largest regional market in total offshore wind installations as at the end of 2020.

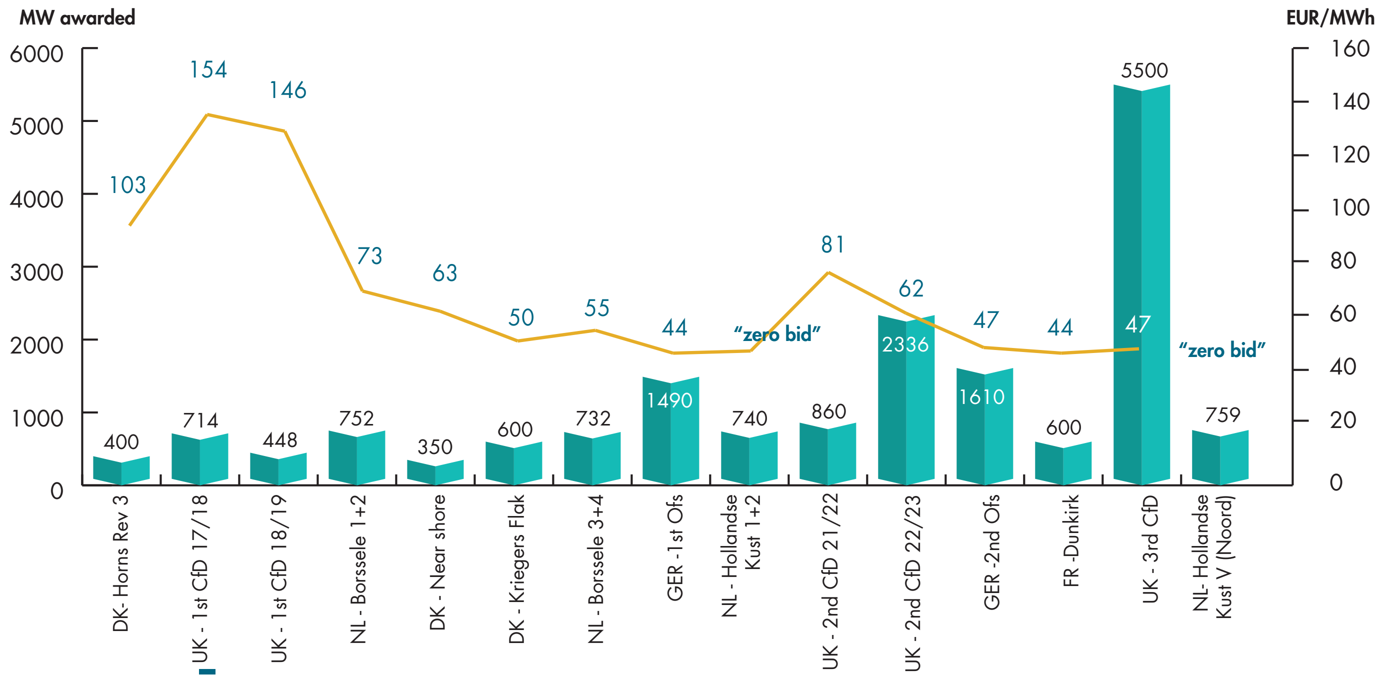
Looking at potential growth, GWEC Market Intelligence believes that Europe will maintain double digital growth rate in this decade (2021-2030), as offshore wind has become

Global offshore wind growth to 2030 in Europe



*CAGR = Compound Annual Growth Rate
Source: GWEC Market Intelligence, July 2021

European executed offshore tenders / auctions 2015-2020
Awarded capacity (GW), average winning bid (EUR/ MWh)*



**Tenders above 100MW capacity and no innovation auctions, tenders in order of execution from 2015 to end of 2020*
Source: GWEC Market Intelligence, GWEC Global Auction Database Q1 2021

the most competitive electricity generation technology after onshore wind and solar PV - but with considerable advantages in terms being able to deploy at scale, making it a key energy source to help Europe to meet its Nationally Determined Contributions (NDCs) and achieve the 2050 net zero target.

Last November, the European Commission presented its offshore renewable energy strategy as part of the EU Green Deal. It sets a target of 300 GW of offshore wind by 2050 for the EU, which makes offshore wind a crucial pillar in Europe's power mix and a core part of its net zero implementation strategy.

According to GWEC Market Intelligence's Q3 2021 global offshore wind market outlook, 2021 and 2022 are expected to be relatively slow years for Europe, with new installations staying the same level as that in the past four years (2017-2020), which is mainly due to the lower level of activities in Germany where no new offshore wind capacity is predicted in 2021. However, the European offshore market is likely to bounce back in 2023 when utility scale projects will also come online in new markets like France, and new installations in Europe are likely to double in 2023 compared with 2020.

Considering more offshore wind capacity is likely to be built in established European markets like the UK, Germany and Denmark after 2025 and the fact that installations in new markets bordering the Baltic Sea will not take place before 2025, GWEC Market Intelligence expects that 73.8% of total predicted offshore wind capacity will be built in the second half of the decade. New installations in Europe are likely to exceed 10 GW in 2026 and then potentially approach 20 GW by 2030.

The UK

As the world's leader in offshore wind energy, the UK continues to tell a successful story in the past 12 months. In September 2020, Prime Minister Boris Johnson set out commitments to boost the government's previous 30 GW target to 40 GW and set a 1 GW by 2030 floating offshore wind target, as part of the Build Back Greener initiative. Two months later, the UK government announced support for up to 12 GW of renewable energy projects in the fourth round of the CfD scheme, which is expected to open in December 2021. The Round 4 CfD auction will divide renewable technologies into three so-called 'pots'. Pot 1 is reserved for established technologies such as onshore wind and solar PV, Pot 2 for less-established technologies including floating offshore wind, advanced conversion technologies, and tidal stream, Pot 3 is only for offshore wind. In February 2021, the Crown Estate announced that six proposed new offshore wind projects, totalling 7.98 GW, had been selected through a competitive seabed tender process, as part of its Round 4 leasing programme and expected to enter into agreement for lease with successful bidders in Spring 2022. In addition, the 10 GW ScotWind offshore seabed leasing round that launched last June, closed on 16 July 2021. As the first round of seabed leasing for offshore windfarms in Scottish waters for a decade, it will play a major role in allowing Scotland achieve its net-zero emissions target by 2045.

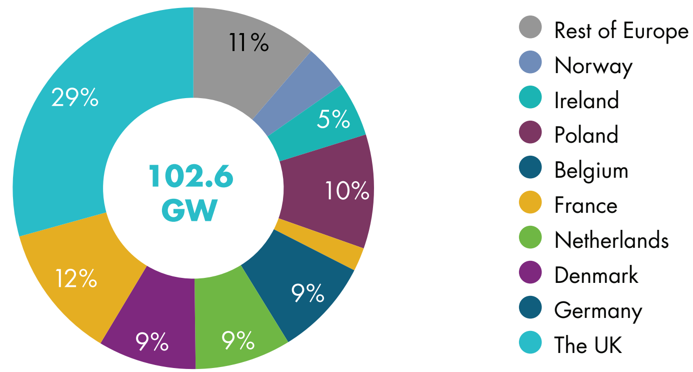
Germany

The country lost its title as the world's second largest offshore wind market in total installations to China in 2020 as it has been struggling with unfavourable market conditions and a lack of mid-term visibility. The positive sign is that in March 2021 the European Commission approved, under EU State aid rules, a German operating aid scheme to further develop offshore wind energy generation in the country. The new scheme will increase the target for installed offshore wind capacity from 15 GW to 20 GW by 2030 and set a target of 40 GW of installed offshore capacity by 2040. However, to reach the targets and to build a sound project pipeline, Germany's Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrography) will have to speed up to open up more offshore wind tenders.

Denmark

Last summer, the Danish government approved two "energy islands," one in the North Sea and one in the Baltic Sea (with a combined capacity of 5 GW planned by 2030). In February 2021, Denmark reached

Total added between 2021 and 2030
GW, offshore



an agreement on the location of an energy hub in the North Sea and a local consortium comprising pension funds announced it was ready to finance the project. The initial surveys of the seabed where the Energy Island will be built in the North Sea kicked off in April 2021. In June, the Danish Energy Agency also gave the green light to Energinet to start preliminary offshore investigations at the areas in the Baltic Sea where the planned energy island will be built. In addition, progress was made at the two 1 GW level offshore wind farms, Thor and Hesselø, in 2021. The Danish Energy Agency has published the final tender conditions for Thor and pre-qualified a total of six consortia and companies to participate in the tender.

France

Although France has only 2 MW of offshore wind power installed as of 2020, the Multiannual Energy Programme (Programmation pluriannuelle de l'énergie (PPE)), that came into force in April 2020 stipulates that France will tender up to 8.75 GW of offshore wind capacity from 2020 to 2028 and will grow operating offshore wind capacity to between 5.2 GW and 6.2 GW in the same period. The 2023 operating capacity target is 2.4 GW. From 2024 onward, France will tender 1 GW

Case study: Mastering design review for fixed offshore wind

Provided by: Bureau Veritas

For countries that border shallow water, installing offshore wind farms can be a key path to producing clean electricity. However, operators must be certain that these complex structures can safely withstand harsh offshore conditions. This means taking an in-depth approach to design review for all aspects of wind turbines, from blades to towers to jackets.

Fixed offshore wind is now a mature sector, with commercial projects reaching completion around the world. Among the largest offshore wind farms currently under construction is the Moray East project in the UK. Located 22 km off the coast of Moray Firth, and consisting of 100 fixed-bottom turbines, this wind farm is set to meet 40% of Scotland's energy needs.

Bureau Veritas was called on to provide key certification services for this project, ensuring the structural integrity of the Moray East wind turbines. Each of the 100 turbines rests on a tower supported by a three-legged jacket resting on the seabed. Bureau Veritas' task was to verify the calculations for asset fatigue and integrity provided by the wind turbine designer for all turbine components.

Evaluating the impact of harsh offshore conditions

To do this, our experts first performed a site conditions assessment, evaluating the effects of different environmental conditions on the wind turbines. We evaluated the impact of strong winds, powerful waves and major weather events on principal and support structures, towers, work platforms, secondary structures, anodes and more.

Based on this, Bureau Veritas could perform independent calculations to assess turbine strength and fatigue. Our experts chose representative structural aspects of the wind turbines and evaluated them using proprietary digital modeling tools. The calculations included: integrated load analysis; substructure design analysis; ultimate strength analysis; time domain fatigue analysis; and an assessment of fatigue and service limit states. We were also able to calculate potential cumulative damage on areas vulnerable to fatigue and corrosion, thereby assessing turbine lifecycle.

Overall, Bureau Veritas' millions of hours of computations created more than 10,000 scenarios using a representative pool of possible loads. In less than two months, our experts conducted design review, performed all necessary calculations, worked with the designer to resolve discrepancies and certified the project's components.

The Moray East project is expected to be operational by the end of 2021. By providing design review and performing key calculations, Bureau Veritas is helping ensure the safety and longevity of this innovative project.

Find out more:
https://group.bureauveritas.com/

per year of either fixed-bottom or floating wind capacity, depending on the cost. In May 2021, France launched a tendering procedure for a commercial floating offshore wind project to the south of Brittany with a capacity of up to 270 MW.

Poland

Poland's Council of Ministers adopted a draft bill last September supporting the development of offshore wind energy in the Baltic Sea. It would allow for 5.9 GW of capacity to be offered via CfDs by the end of June 2021. The second phase of development will include two auctions, the first in 2025 and the second in 2027, both for 2.5 GW of capacity, bringing Poland's total offshore wind capacity either operational or under development to 10.9 GW by 2027. In January 2021, Poland's Senate passed the Offshore Act, which was later signed into law by Poland's President Andrzej Duda. As of 30 June, the Polish Energy Regulatory Office (ERO) has awarded a Contract for Difference (CfD) to seven offshore wind projects, totalling 5.9 GW, exactly the same as it planned. In addition, Poland is also one of countries that signed the Baltic Sea Offshore Wind Declaration last September. The country aims to become the leader in offshore wind development in the Baltic Sea, with a target of 28 GW offshore wind by 2050.

Norway

Norway opened up for full-scale floating and bottom fixed offshore wind development, totalling up to 4.5 GW, in June 2020 and allowed developers to apply for project licenses from January 2021. According to the Ministry of Petroleum and Energy, the floating wind award process will start by the year end. The government is proposing to award at least three areas for up to 500 MW each at Utsira Nord area. The government plan is to launch the auction for areas in Sørlige Nordsjø II in the first quarter of 2022.

Ireland

The government adopted a Climate Action Plan in July 2019, which will require renewable energy, at least 3.5 GW of offshore wind, to provide 70% of its electricity generation by 2030. The 2030 offshore target was later increased to 5 GW. Last year, the Irish government designed seven offshore wind projects to be fast-tracked through a new Marine Planning Bill that was just passed in July 2021 and it is expected to speed up the permitting for offshore wind site investigation licences.

Sweden

No offshore wind project has been built in Sweden since 2013, but new proposed legislation released in May 2021 that will make the Swedish TSO, Svenska Kraftnät, responsible for offshore grid connection for future offshore wind farms, is expected to accelerate a long-awaited offshore wind build-out.

Asia

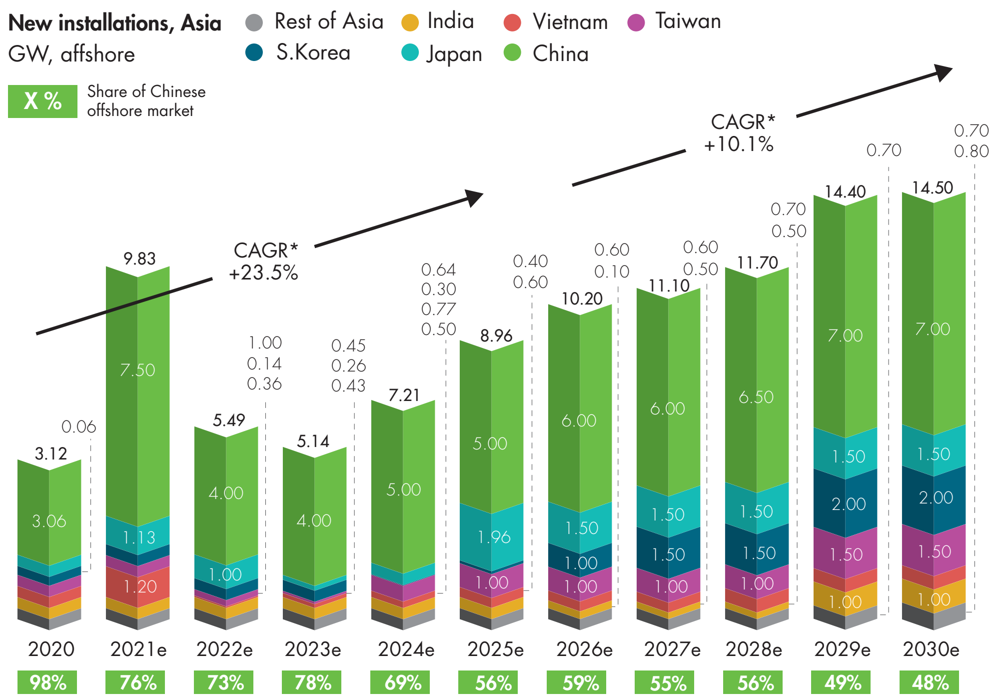
Asia built its first offshore wind project, totalling 1.3 MW, in Japan in 2003, but the regional offshore market was not ready to take off in earnest until 2014, when the Chinese National Energy Administration released the National Offshore Wind Development Plan (2014-2016). Annual installations in Asia region passed the milestone of 1.5 GW in 2018 when China also surpassed the UK as the world's top market in new installations. Last year, Asia replaced Europe as the leading regional offshore wind market in new installations for the first time.

GWEC Market Intelligence's latest market outlook predicts that China will continue to install the lion's share of offshore in Asia in the first half of this decade. Taiwan is expected to be the largest offshore market in Asia after China in new installations in the same period.

However, the market will become more diversified from 2025 onward, when more large-scale offshore wind projects are set to be commissioned in Japan, South Korea and Vietnam.

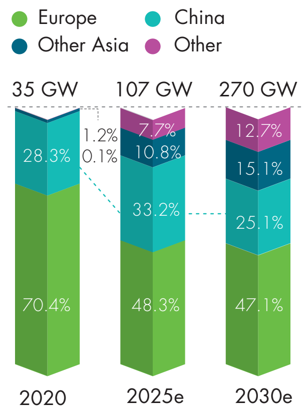
GWEC Market Intelligence forecasts that China's market share in this region is likely to drop from 76% in 2021 to 56% in 2026. This decline is expected to continue, to reach 48% toward end of this decade when new capacity is also likely to be built in emerging markets such as India and the Philippines.

Global offshore wind growth to 2030 in Asia



** CAGR = Compound Annual Growth Rate*
Source: GWEC Market Intelligence, July 2021

Total installations
Percentage and GW, offshore



Source: GWEC Market Intelligence, July 2021

In total, 63% of the predicted offshore wind for this region is to be built in the second half of the decade. New installations in the region are likely to exceed 10 GW in 2026 and then reach a level of nearly 15 GW by 2030. The top five markets in this region for new installations in this decade will be China, Taiwan, South Korea, Japan and Vietnam.

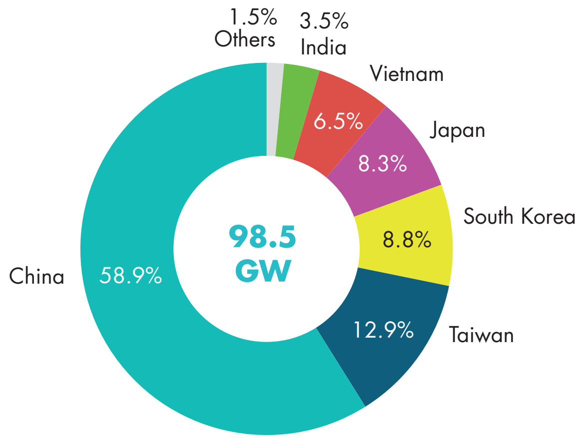
China is so far the most mature offshore wind market in the region with a domestic supply chain and infrastructure quickly built up in the past five years. The rest of the markets are still at the early stage of development and most of them face the challenge of developing a local supply chain and building the necessary competencies and work forces. However, the early experience of Taiwan has proven that collaboration with European partners across markets in this region is essential for success. Other Asian markets such as Japan and South Korea are now following suit.

GWEC Market Intelligence believes that Europe will remain the largest regional offshore wind market in terms of total offshore wind installations through to 2030. Nevertheless, the gap of the global market share between the two regions is likely to narrow from today's 40% to just 7% in 2030.

China

Last year, China grid connected more than 3 GW of offshore wind, overtaking Germany as the world's No. 2 offshore market in cumulative installations. New capacity is likely to be more than double this year as Chinese offshore wind industry undergoes a rush to bring projects online before the end of 2021 deadline in order to capitalise on the 0.85 RMB/kWh (or 0.11EUR/kWh) FiT for offshore wind. If this happens as expected, China will surpass the UK as the world's largest offshore market in total installations. However, new installations in China are expected to decline sharply from 2022, when support from central government will

Total added between 2021 and 2030
GW, offshore



be terminated. The pace of offshore wind growth in China thereafter will depend on whether support provided by provincial governments will be available and whether the offshore wind industry can reach price parity with competing power sources before 2025.

Taiwan

Although no offshore wind projects were commissioned in 2020 due to the impact of COVID-19, Taiwan is still positioned to become the second-largest offshore wind market in this region. Previously the government pledged to connect 5.5 GW of new offshore wind by 2025 and another 10 GW by 2035, but the target for 2026-2035 was upgraded by 50% in May 2021 when the government released draft regulations for the Round 3 auctions. This upgrade not only provides the visibility and certainty needed to help build a local offshore wind industry and supply chain, but would also allow Taiwan to exceed the 2030 targets set by South Korea and Japan.

South Korea

To reach the "Renewable Energy 3020" target of 20% renewables in the power mix by 2030, South Korea is planning to bring its offshore wind capacity currently 133 MW, to 12 GW by the end of this decade. In order to make this happen, an agreement to develop an 8.2 GW offshore wind complex in South Jeolla was signed by more than 30 public and private entities based in South Korea in February 2021. Three months later, President Moon Jae-in announced that the Korean government will invest in 6 GW of floating offshore wind in the coast of Ulsan by 2030.

Japan

Offshore wind development in Japan has been jeopardised by a lack of ambitious targets and a cumbersome permitting and licensing framework, but great progress has been made in the past two years. The country's first ever auctions for floating and fixed bottom offshore wind were launched in 2020, after the offshore wind zones were nominated by the government. At the end of last year, following a major cost reduction study commissioned by GWEC and JWPA and a series of industry-government dialogues, the Japanese government also approved the "Offshore Wind Industry Vision" targeting 10 GW of offshore wind by 2030 and 30-45 GW by 2040. This government-industry deal has been welcomed by the local and international offshore wind industry, as it brings in volume, scale, jobs and long-term visibility.

Vietnam

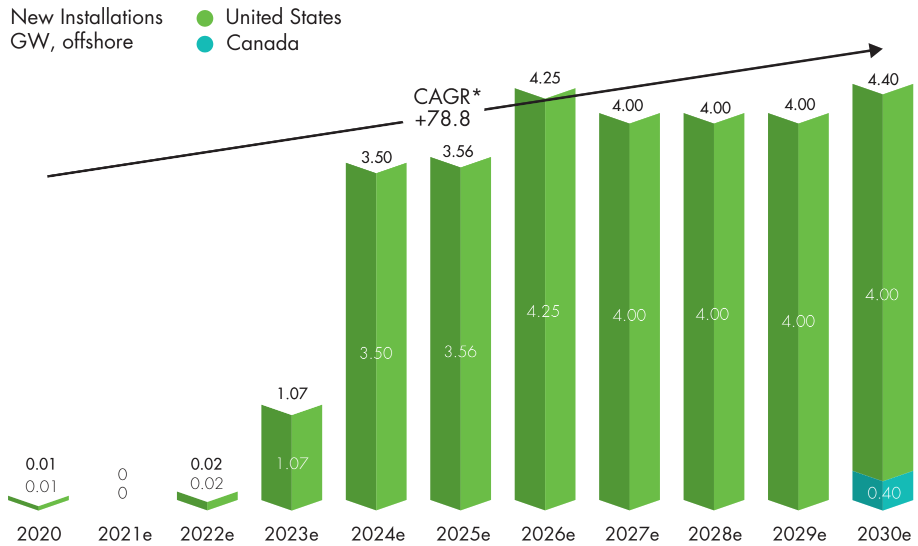
Similar to Taiwan, no offshore wind turbine was grid-connected last year due to COVID-19 disruption, but more than 1.5 GW of offshore wind projects are under construction at present, of which 1.2 GW are expected to come online before the current FiT expiry in November 2021. GWEC Market Intelligence predicts that new installations are expected to fall from 2022, but the Vietnamese offshore wind market is likely to bounce back once the offshore target is confirmed in the government's final Power Development Plan VIII (PDP8) and when the upcoming offshore wind auction scheme is clear for developers and investors.

North America

North America commissioned its first commercial offshore wind project, the 30 MW Block Island project, in Rhode Island in December 2016. The 12 MW Dominion Virginia demonstration project installed last year brings the total offshore wind capacity spinning in the region to 42 MW, making it the only region with commercial offshore wind projects outside of Europe and Asia.

Based on GWEC Market Intelligence's global offshore wind project database, no utility-scale offshore wind projects will come online in North America until 2023. In total, 28.8 GW of offshore wind is predicted to be built in this region in this decade, of which 99% is expected to come from the United States and only 400 MW is projected from Canada.

Offshore wind growth to 2030 in North America



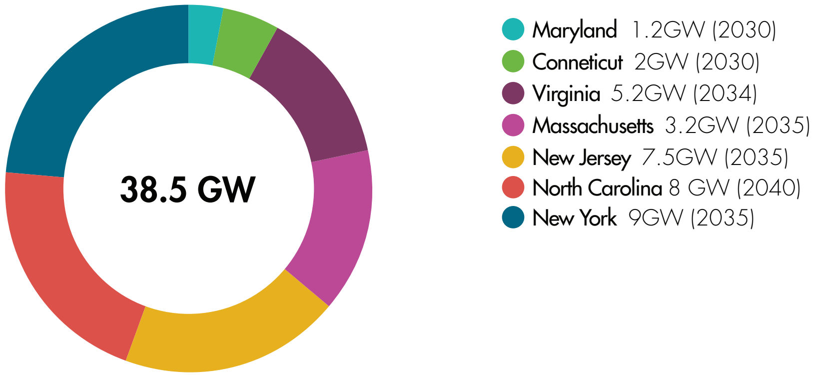
** CAGR = Compound Annual Growth Rate*
Source: GWEC Market Intelligence, July 2021

United States

The US had only 42 MW of offshore wind projects in operation at the end of 2020, but the level of offshore wind development activity remains impressively high. Although the permitting process, especially the final approval from BOEM for the Construction and Operations Plan (COP), slowed project development during the Trump Administration, 2021 has so far become an unprecedented year for US offshore wind. First, the Biden Administration announced the ambitious 30 GW by 2030 offshore wind target in March; second, the 800 MW Vineyard Wind 1 project received the final major federal approval from BOEM in May, which truly represents the start of the US offshore wind industry; third, DOE and BOEM plan to advance new lease sales and complete review of at least 16 COPs by 2025, representing more than 19 GW of offshore wind capacity to be installed off the U.S. coasts; fourth, an offshore target was announced in North Carolina in June and existing targets have also been increased in Massachusetts and Virginia, bringing the total state-level offshore wind development targets up to 38.5 GW.

GWEC Market Intelligence predicts a total of 28.4 GW of offshore wind could be built in the US by the end of this decade, which is 25% higher than what was predicted for this market a year ago. However, we keep our forecast for Canada unchanged compared with last year.

Offshore wind development targets in the US



Transforming livelihoods for a sustainable future

The monumental scale of investment brought by 380 GW of offshore wind deployed worldwide by 2030, as outlined by IRENA in its 1.5°C scenario, will translate into long-term economic benefits for coastal communities and countries. As capital-intensive and resource-intensive infrastructure projects, offshore wind will generate a diverse value chain of job opportunities, many of which will be locally based and sustainable as the sector pipeline continues to grow.

Analysis by GWEC Market Intelligence has found that installing an additional 70 GW of offshore wind from 2021-2025 would equate to the creation of more than 1.2 million direct jobs in a dynamic global supply chain[10]. This calculation is based on global studies by IRENA which have found that the job requirement for a 500 MW offshore wind project translates to 17.29 jobs per MW, over the 25-year lifetime of the project.[11] These jobs would encompass a variety of technical, professional and hard/soft skills, from project planning to manufacturing to transport and O&M.

A growing body of evidence reflects the strong linkage between offshore wind deployment and productive employment. A recent report by the Economic Council of the Labour Movement in Denmark and the United Federation of Danish Workers found that the permanent employment effects of offshore wind farms were among the highest of jobs in the green economy, compared to

10 One job is defined as one calendar year of full-time employment (260 working days) for one person. This assumes an 8-hour workday, 5-day working week and 52 working weeks in a year, in line with a standard calculation of one FTE year based on one individual working 2,080 hours in one year. See: https://gwec.net/wind-can-power-over-3-3-million-jobs-over-the-next-five-years/

11 Data originally provided by IRENA in person-days; jobs were determined by dividing the person-day figure by 260, the typical number of working days in a year. See: https://www.irena.org/publications/2018/May/Leveraging-Local-Capacity-for-Offshore-Wind

replacing oil and gas-fired boilers and other forms of employment.[12]

Offshore wind adds unique value in revitalising coastal communities that are often far from urban economic centres. Around 40% of the world's population lives within 100 km of a coastline. Industrial development and activity in these areas can contribute to a thriving local economy, spurring the creation of indirect and induced jobs. A study by NYSERDA found that two-thirds of offshore wind jobs would be localised and fulfilled by US-based workers.[13] For countries relying on imported offshore wind content, there would still be a need for domestic mobilisation of workers for installation, grid connection, O&M and decommissioning activities in the offshore wind project lifetime.

There is a relatively low-barrier workforce transition pathway to offshore wind for the offshore oil and gas, marine engineering and ancillary sectors which face labour dislocation in the energy transition *(***see: Expanding a safe, skilled and capable workforce for offshore wind**). Offshore wind can generate jobs in steel manufacturing for foundations, substations and installation vessels, sub-sea cables and offshore transport. All these areas can leverage the capabilities of workers accustomed to offshore environments, particularly when coupled with public sector programmes for targeted transition training and reskilling.

The socioeconomic benefits from offshore wind extend beyond job creation to savings in public healthcare costs, cleaner air, lower water consumption as fossil fuel generation is replaced and more[14]. But for offshore wind to continue delivering these benefits, it must maintain a culture of health and safety as it expands. The sector's "license to operate" is based on a strong track record of safe and reliable delivery, continued learning and performance improvement, as well as protection of its workers' welfare. As a sector transforming the livelihoods of millions, offshore wind has a responsibility to create a legacy of safety and security.

12 https://www.groennejob.dk/nyheder-fra-groenne-job/groenne-job
13 https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/Master-Plan/US-job-creation-in-offshore-wind.pdf
14 https://www.imf.org/external/pubs/ft/fandd/2019/12/the-true-cost-of-reducing-greenhouse-gas-emissions-gillingham.htm

TAKING OFFSHORE WIND GLOBAL

Part 1: Evolving challenges and opportunities

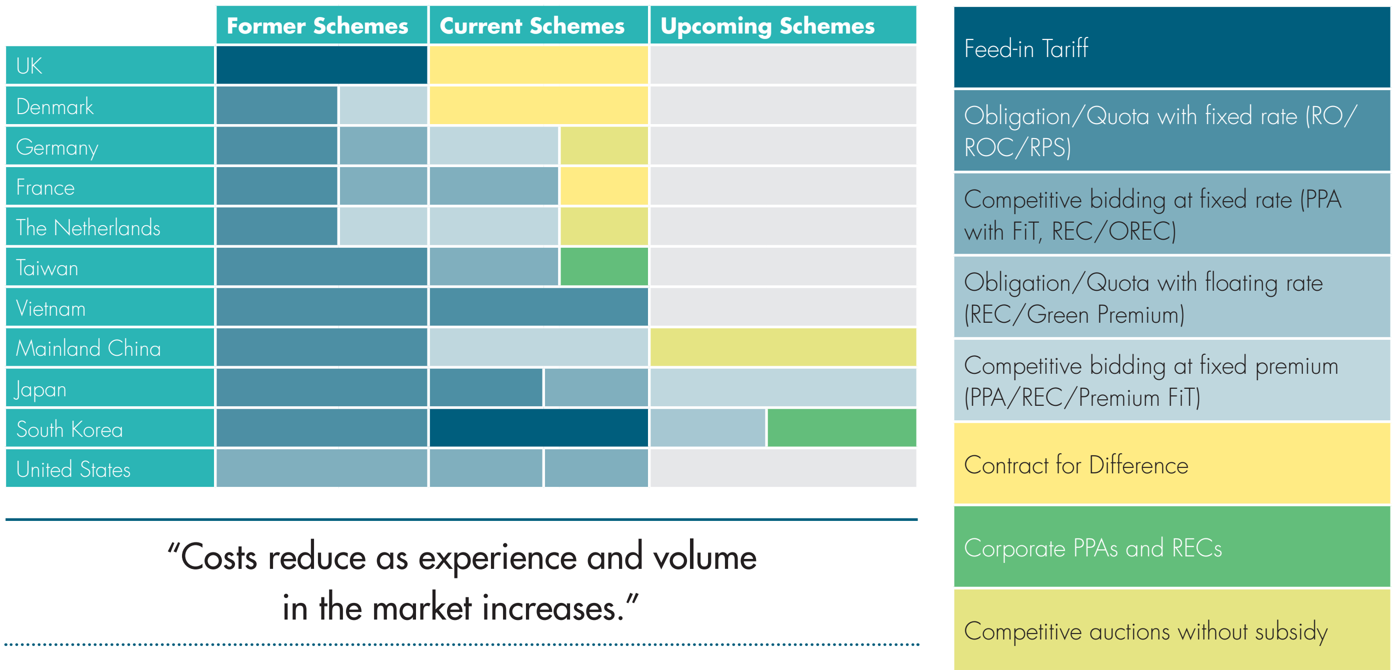
Support schemes and transitions to auctions

One of the critical factors in determining the growth of offshore wind in a new or early-stage market is the support scheme for procurement. In markets where offshore wind has not yet been established at commercial scale, and lacks a domesticated supply chain, market experience and investor confidence, the costs for project development, CAPEX and OPEX are still relatively high.

This in turn requires a form of remuneration support to compensate developers, investors and indeed actors across the value chain, and ensure projects can close financing. As markets become more established after the first few GW of offshore wind are connected, learning curves set in and smoother routes to market are established. Costs for offshore wind reduce – not necessarily over time, but as experience and volume in the market increases.

Revenue stabilisation and risk mitigation are among the benefits of a well-designed and robust support scheme for offshore wind. This is due to offshore wind's relatively larger time and capital investment requirements compared to other renewable energy technologies, which sharpens the focus on bankability conditions, as well as significant dependencies on enabling infrastructure such as grids, ports, manufacturing and workforce capacity. Certainty and transparency

Support schemes in key offshore wind markets



Source: GWEC Market Intelligence; NREL, Comparing Offshore Wind. Energy Procurement and Project Revenue Sources Across U.S. States (2020). This graphic has been simplified for legibility, and is not an exhaustive summary of all former, current or upcoming schemes in these markets

> "Costs reduce as experience and volume in the market increases."

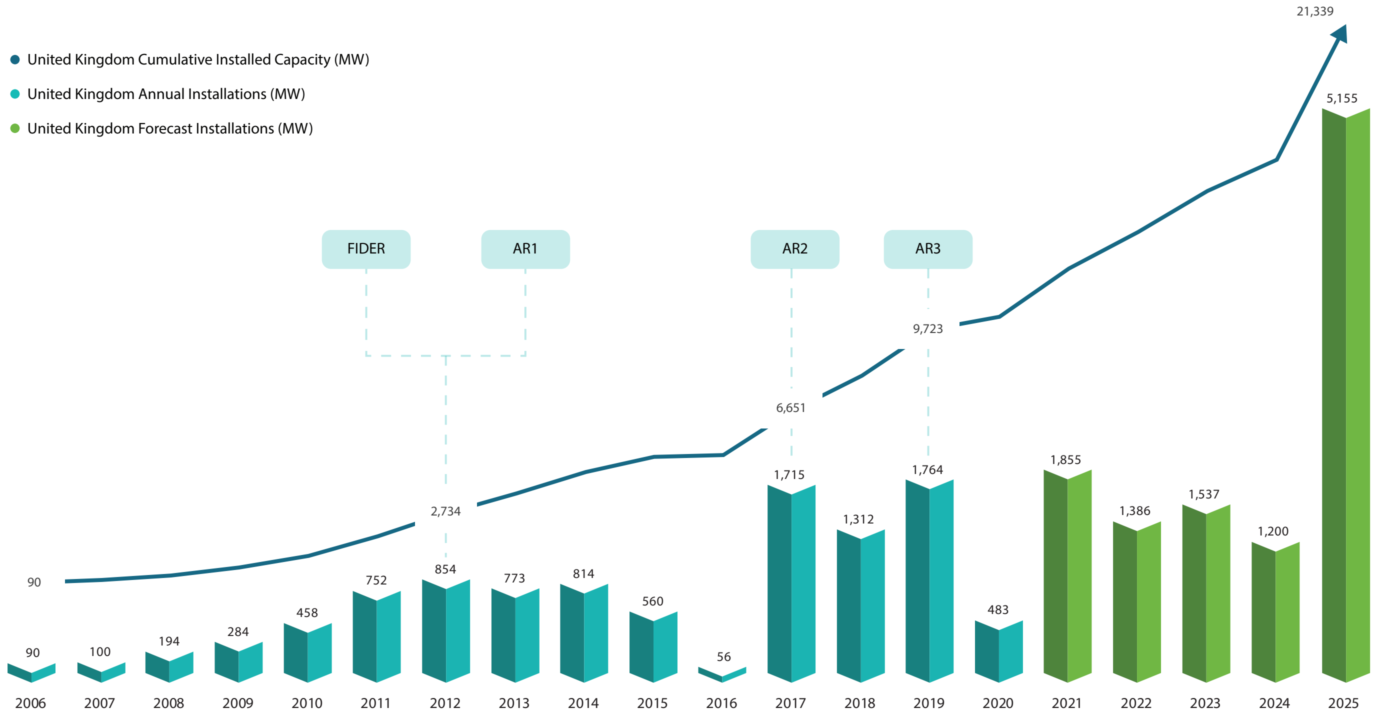
of remuneration enhances bankability for foreign investors, as new markets frequently depend on cost and availability of international finance to support the first batch of offshore wind projects.

IRENA data reflects that LCOE for offshore wind declined by 48% over the last decade, and the global weighted-average decreased by 9% in 2020 alone, driven by installations in China and Europe.[15] Competitive bidding schemes in mature offshore wind markets are even delivering LCOE levels which out-compete the costs of new coal and fossil fuel generation. This trend will continue, albeit at a slower pace, as the offshore wind sector continues to mature. Emerging markets should ensure that support schemes encourage the steady deployment and cost reduction required to reap the long-term socioeconomic and energy system benefits attached to offshore wind.

Revenue support schemes should be designed to encourage investment and confidence in a new or early-stage market, with a long-term aim to move towards cost reduction and efficiency, such as through competitive tenders and supply chain development. Markets like Germany, the Netherlands, Mainland China and Taiwan began with FiTs to minimise risk to developers and investors. Once sufficient volume was underway, they eventually moved to competitive schemes or procurement frameworks with greater price exposure to wholesale markets.

Support can be awarded either through an administrative process, such as in the first wave of projects in Taiwan, or through a competitive process, wherein the lowest-price bids receive a fixed or floating rate of support. Clarity on the procedures, criteria and remuneration mechanism should be provided by governments, with consultation undertaken directly with industry to optimise support scheme design and maximise buy-in.

UK annual installations and cumulative capacity



Credit: GWEC and RCG, "Vietnam's Future Transition to Offshore Wind Auctions: International Best Practices and Lessons Learned," 2021.

15 https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020

Often these consultation processes will highlight further considerations, such as an optimal volume to go to tender to achieve cost-competitiveness, required lead time for implementation and feasibility of local content requirements. Imposing overly strict local content rules at an early stage is detrimental to investment, as the costs of supply chain investment in a market with limited capacity and experience can weaken the economics of a project.[16]

Key to the design of a successful support scheme is transparency and visibility of when and how to transition to a more price-competitive scheme. For instance, the UK transitioned from a Renewables Obligation scheme which granted RECs for generation of renewable energy to a CfD-based auction framework in 2014. The UK was one of the first group of countries to implement auctions for offshore wind. In this transition, it introduced a grace period and two-year interim procurement phase under its Final Investment Decision enabling for Renewables (FIDeR) programme in 2012. This programme focused on simplified technical and competency criteria, instead of a least-cost approach, to ensure offshore wind investment continued in the transition. This enabled the UK to foster and sustain an active pipeline of offshore wind projects through the transition phase and subsequent CfD-based competitive tender rounds (termed Allocation Rounds), positioning it as the world's leading offshore wind market today with more than 21 GW of installed capacity.

In addition to remuneration support, investment incentives can also be provided as fiscal mechanisms such as tax credits, rebates or reliefs. For instance, in the US, tax incentives are provided in the offshore wind sector in the form of the Investment Tax Credit (ITC) and the Production Tax Credit (PTC), with the former incentivising CAPEX and the latter incentivising generation of energy (similar to a premium).

As established markets achieve cost-competitiveness and stable project pipelines, governments seek to reduce revenue support. This has led to transitions to schemes with remuneration at a premium determined by performance of wholesale electricity prices. In Germany and the Netherlands, such competitive tenders have resulted in winning bids which require no price support (''zero-subsidy'' bids) – this is made possible due to government-funded site development and transmission infrastructure, and is not economic in most new markets.

It is also important to note that schemes which put the onus on operators taking full wholesale market price risk are sub-optimal in the view of GWEC and its member associations, as this means basing long-term investment decisions on markets which will be impacted by increasing levels of variability from large-scale renewable energy sources (and hence susceptible to ''price cannibalisation''). Schemes which do not provide some form of long-term price visibility have been shown to strongly increase financing costs and hence the final cost to the consumer.[17]

Corporate PPAs (CPPAs), or direct PPAs secured bilaterally between the project owner and a corporate offtaker, are also emerging as a model for procurement without government-mandated revenue support. CPPAs have already been deployed in Germany, the UK and Taiwan, are common in the onshore wind sector in the US and are being eyed in South Korea. Where a bilateral market is available, CPPAs can support project financing decisions by offering higher remuneration than in a regulated auction; however, they are more common in established markets where offshore wind costs have already been reduced through stable support schemes.

16 https://gwec.net/vietnams-future-transition-to-offshore-wind-auctions-international-best-practices-and-lessons-learned/
17 Prol, Steininger and Zilberman, "The cannibalization effect of wind and solar in the California wholesale electricity market," Energy Economics, 2019; Aurora Energy Research, "The New Economics of Offshore Wind," 2018; Cornwall Insight, "Wholesale Power Price Cannibalisation," 2018.

UK

- The Renewables Obligation (RO/ROC), a subsidy scheme for large renewable electricity projects applied in 2002, supported deployment of 5 GW offshore wind installation until March 2017.
- Thereafter, UK has employed a CfD scheme, introduced in 2013 under the Electricity Market Reform, which: 1) Provides direct protection from volatile wholesale prices to consumers and developers and 2) Incentivises the upfront investment costs for offshore project developers.
- This CfD scheme, amended in November 2020 ahead of Allocation Round 4 (AR4), introduced a separate definition and administrative strike price for floating offshore wind projects and changes to Supply Chain Plans and the CfD contract.

Denmark

- Denmark financed RE projects through the PSO (Public Service Obligation) tariff. During the liberalisation of the Danish electricity sector (2000-2002), a guaranteed price with balancing subsidy for the first 10 years from the grid connection and premium FiT with balancing subsidy until 20 years was provided. This was followed by: 1) Feed-in-premium for up to 22,000 full load hours, with balancing subsidy for the entire life through the competitive tendering process 2) FiT for up to 50,000 full load hours (i.e. ~11-12 years of operation), wherein connection to the grid was an additional subsidy given to offshore wind farms and paid by consumers.
- In 2016 an agreement established that the PSO tariff would be phased out from 2017-2022 and projects would be financed through national budget.
- In November 2019, Denmark chose the CfD model to award the Thor offshore wind project with a 20-year PPA.
- In March 2021, the European Commission approved a two-way CfD premium-based Danish aid scheme to procure renewable electricity through a competitive tender organised in 2021-2024. The 1.2 GW Hesselø offshore wind project (tender delayed as of June 2021) will be the second project in Denmark, after Thor, under such a scheme.

Germany

- The German Renewable Energy Act (EEG) that came into force in April 2000 provided greater funding support to operators through two FiT funding models: Basic Model and Acceleration Model. It remained applicable for wind farms commissioned by December 2020. The EEG has been modified several times since then and remained applicable as the guideline for wind farms. Following the EEG Reform (EEG 2017) in 2017 and the Offshore Wind Act (WindSeeG), the tariff-based auction was made compulsory for offshore wind projects for cost reduction purposes.
- While guaranteed support schemes shifted to an auction-based mechanism in 2017, Germany had two zero-subsidy bids until 2018. No schedule for offshore wind project allocation was provided during 2019-2020.
- In March 2021, European Commission approved modified 'WindSeeG', a support scheme applicable until 2026. It is based on centralised auction model wherein the state pre-selects and awards specific sites for offshore wind in competitive tenders. Payments are granted for 20 years in the form of a premium on top of the market price, that will be set on the basis of the lowest bid in open and transparent competitive tenders.
- This scheme will increase the target for installed offshore wind capacity from 15 GW to 20 GW by 2030 with a goal of 40 GW by 2040. German Federal Network Agency (Bundesnetzagentur) has also opened tenders for three new offshore wind sites of ~ 958 MW in February 2021.

The Netherlands

- During 2003-2007, MEP subsidy (Milieukwaliteit Elektriciteitsproductie subsidie) was implemented through two policy instruments: FiT and a reduced ecotax
- Although the MEP FiT was effective, it cost too much for the government without leading to decrease the amount of FiT support in five years (2003-2007). Thus, it was replaced with Sustainable Energy Incentive Scheme (SDE: Feed-in Premium) for the period of 2008-2011 intending to develop at least 450 MW of offshore wind project before 2011. With lead-time between the submission of three application in 2009 and the realization of a project, the Dutch government supposed projects expensive despite there was sufficient budget hence, it did not lead to installation of new capacities until 2011.
- In 2011, the Netherlands established a tendering scheme with subsidies (premium FiT) under the Dutch Sustainable Energy Incentive Scheme (SDE+), targeting 4.5 GW offshore wind power capacity by 2023; it secured its two first offshore wind projects at Borssele sites in 2016.
- Soon after the target announcement, a prerequisite target of '40% cost reduction over the period 2015-2019' was achieved in first phase tenders during 2017, following the German precedent of zero-subsidy bids at Hollandse Kuts.
- In the Offshore Wind Energy Roadmap, about 11 GW offshore wind capacity is planned to be installed by 2030 through competitive tenders up to Q4 2025.

Taiwan

- For the implementation of targets set in its "Thousand Wind Turbines Promotion Project", Taiwan offered a "Demonstration Incentive Program" grant scheme designed to award two offshore wind farm projects in 2012. A guaranteed PPA with the FiT mechanism was provided since 2013 with gradual reduction in FiT rates.
- To capture cost reductions, a competitive bidding/auction process with lower FiT rates was introduced in 2018, followed by the government's announcement of 7.6% lower FiT rates for offshore wind in 2020. At that time, the offshore wind target was increased to 5.5 GW by 2025, initial 3.5 GW out of 5.5 GW allocated through FiT and remaining 2 GW allocated through the Competitive Bidding to drive down the price.
- For offshore wind projects signing 20-year PPAs in 2021, Taiwan has further reduced its FiT by 8.5%, compared with 2020 rates.
- The Bureau of Energy plans to tender total 15 GW offshore wind capacity in Round 3 for installation by 2035, across three tendering rounds from 2022 to 2024.

Vietnam

- Vietnam offers a FiT scheme for renewable energy-based power procurement including offshore wind projects under National Power Development Plan (PDP) 7. Several support measures promote the development of renewable energies, including incentives on the corporate income tax, the import tax, the land use fee, and project escrow.
- In September 2018, the government set a 20-year FiT at US$9.8c/kWh for offshore wind projects to be commissioned before 1 November 2021, which has applied primarily to intertidal/nearshore projects.
- The government has also announced its vision for a competitive power market with direct PPA pilot scheme operating from 2021 to 2023.
- Since the draft PDP8 was released in March 2021, with true offshore wind targets by 2030 and 2045 included for the first time, the government has not stated the procurement mechanism for offshore wind once the current intertidal/nearshore FiT expires in November 2021. There is the prospect for a transition to competitive auctions in the future.

Mainland China

- The Renewable Energy Law was released in 2006, as the foundation for policy of offshore wind power planning and development, economic incentive policies, grid connection policy and technical standards.
- China's first round of concession bidding started in 2010. In 2014, FiTs were introduced for offshore wind farms (CNY 0.85/kWh for offshore projects, CNY 0.75/kWh for intertidal projects).
- Following the new regulation released in 2018, offshore projects approved in 2019 and 2020 will go to competitive auction, with the price cap set at CNY 0.80/kWh and CNY 0.75/kWh respectively.
- At the end of 2021, the central government's offshore wind subsidy will be phased out. However, subsidies provided by provincial governments are encouraged to provide continuity of support. Guangdong province will subsidise offshore wind projects at incrementally reducing rates from CNY 1500/kW in 2022 to CNY 500/kW in 2024, but projects must be approved by 2018 and commissioned between 2022 and 2024.
- As coastal provinces release their Five-Year Plans to 2025, there will be more visibility around local support schemes for financing.

Japan

- Following the approval of the Renewable Energy Bill in 2011, Japan introduced a FiT for wind energy in June 2012. At the time, offshore wind was priced the same as onshore, although that has since changed. In March 2014, the Ministry of Economy Trade and Industry (METI) announced new wind tariffs for 2014/15 (¥22/kWh (€ 0.17/kWh) for onshore and ¥36/kWh (€0.28/kWh) for offshore) for 20 years. Although the purchase prices were high, complex permitting, and approvals made wind energy development a daunting process in Japan.
- In November 2018, Japan introduced competitive bids for pre-identified promotion zones in a new national framework for offshore wind projects. Under the Act, developers will compete not just on tariff, but also on the suitability of their occupancy plans in promotion zones.
- In March 2020, METI announced FiT for fiscal year 2020 auctions of fixed bottom offshore wind power and floating offshore wind at 36 JPY/kWh, to further boost investor interest.
- Approval of Offshore Wind Industry Vision in December 2020 led Japan to set high offshore wind installation targets of 10 GW by 2030 and 30-45 GW by 2040. These targets will be counted based on approved projects under FiT through transparent auctions targeting cost reduction to JPY 8-9/kWh by 2030 to 2035.

South Korea

- Initially, the government provided a FiT scheme. It was replaced by the Renewable Energy Portfolio Standard (RPS) scheme introduced in 2012 obliging energy suppliers to supply annual estimated percentage of energy from offshore wind at fixed price or purchase RECs corresponding to any shortfall in such RPS obligation. Currently, the mandatory RPS quota stands at 9% in 2021 and will go up to 10% in 2022 and beyond 2023.
- Under the 3rd Basic Plan for Energy 2019-2040 announced in June 2019, government is contemplating to rationalise the energy pricing model by adopting green pricing or implementing corporate PPA.
- Ministry of Trade, Industry and Energy announced the introduction of a Korean RE100 system in January 2021. Its key elements for renewable power procurement including offshore wind generation are: Third-party PPAs (Electric Utility Act Enforcement Decree Amendment will allow renewable power generators, Korea Electric Power Corporation, and electricity consumers to enter into PPAs); Green Premium and REC purchase.

United States

- The Internal Revenue Service (IRS) administers incentives for private investment for renewable energy technologies including offshore wind energy. Incentives are tax credits and financing mechanisms such as tax-exempt bonds, loan guarantee programs, and low-interest loans.
- Tax Credits which can be claimed are 1) Renewable Electricity Production Tax Credit (PTC) allows owners and developers to claim estimated allowable cents/kWh for a period of 10 years, it has been extended for renewable facilities beginning the construction by the end of 2021; 2) Business Energy ITC is one-time credit for owners and developers of offshore wind facilities commencing construction prior to 2026 are eligible for a 30% tax credit.
- Since 2018, states-issued competitive solicitations have been driving offshore wind market in US; most of the state's authority enter into contracts to buy Offshore Wind Renewable Energy Certificates (ORECs) and sell it to utilities and other load serving entities (LSEs), which are required to purchase clean energy credits; authorities in other states like Massachusetts, Rhode Island, and Connecticut enter into direct PPAs with utilities also allowing RECs.
- In May 2021, the federal government set an ambitious 30 GW target for offshore wind by 2030. Solicitations are expected to continue for long-term in most of the States, considering their proposed solicitation schedule and offshore wind targets up to 2035.

France

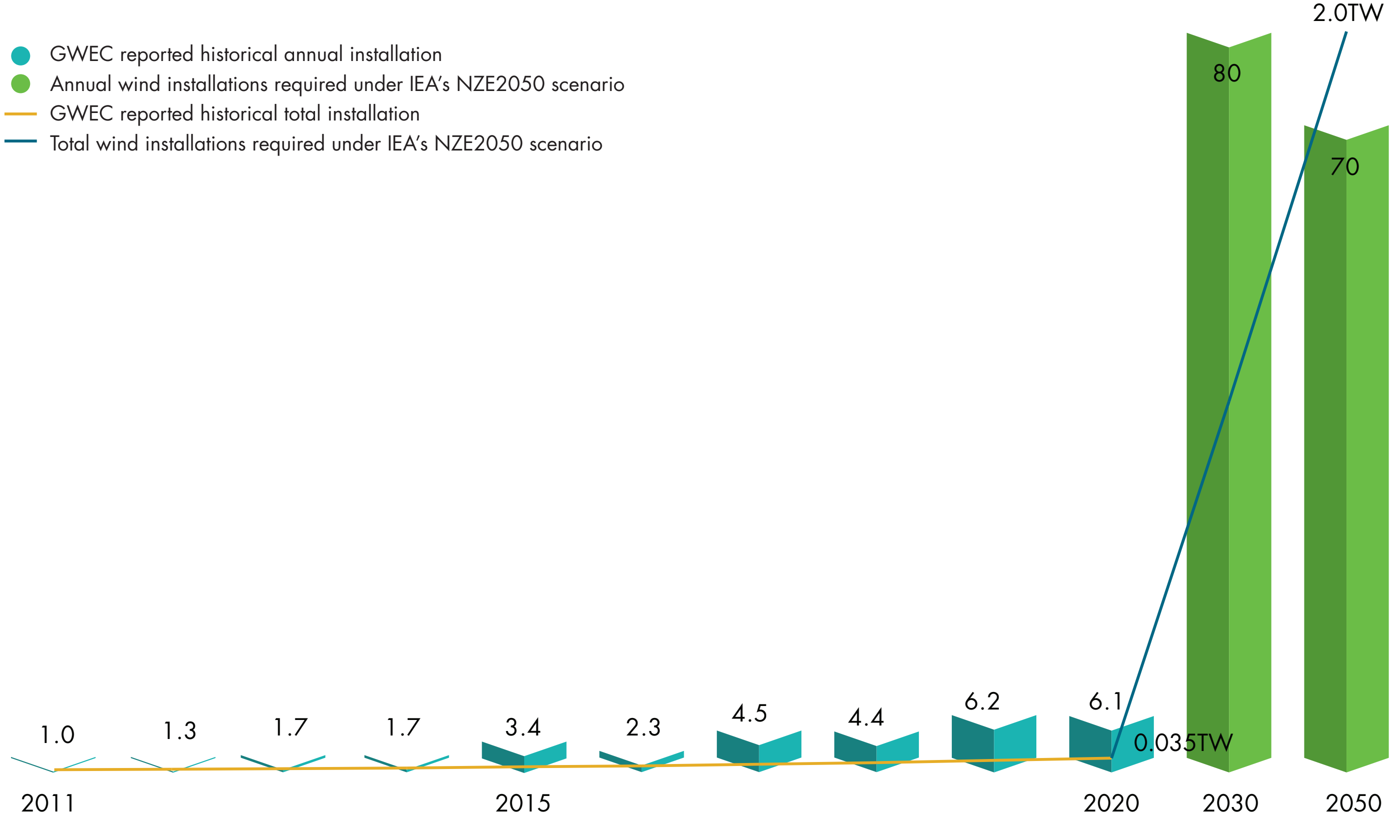
- France has been awarding offshore wind energy projects through competitive tenders since 2011.
- First two offshore wind tenders organised in 2011 and 2013, under EU Commission's State Aid Guidelines of 1 April 2008, a FiT scheme was provided. A limited number of categories of installations generating renewable energies, including some floating wind installations, can now fall under the FiT without a tender process.
- Further, a new 20-year CfD/feed-in premium support scheme, complément de remuneration, aiming to provide certainty created in 2015 is used wherein EDF is obliged to enter into PPA set at fixed reference tariff by the winning tenderer and market price difference is then reimbursed to EDF by the State through a tax on energy consumption called CSPE 48.

With input from: Michael Stephenson, Associate Director, RCG

Streamlined project permitting to support offshore wind growth

Offshore wind projects require a 360° techno-environmental review on impacts to the marine ecosystem, socioeconomic impacts and other dimensions. While this process is necessary, it can be time-consuming and costly. Circuitous and complex consenting processes or delayed approvals increase project risks. Therefore, a cohesive permitting process must be in place to support and accelerate offshore wind development. Streamlining permitting and consenting for offshore wind will be needed to get close to the annual offshore wind installations envisioned in the IEA's net zero by 2050 roadmap, and to reap the wider socioeconomic, environmental and system benefits of offshore wind.

Permitting plays a critical role in accelerating annual installations to reach net zero



Source: GWEC Market Intelligence; IEA Net Zero by 2050 Scenario (May 2021)

Case study: How can lidar support all phases of an offshore wind project?

Provided by: Vaisala

While the offshore wind market continues its exponential growth, offshore wind farms present new challenges—and new opportunities.

As turbines grow taller and offshore sites become more expansive, finding new ways to obtain precise wind data and maximize the potential of offshore wind farms is increasingly critical. Lidar technology is quickly becoming a proven and comprehensive measurement solution for every stage of an offshore project.

During development, an accurate performance and production estimate requires the most precise measurements possible to reduce uncertainty. For a recent Wind Resource Assessment (WRA) campaign, wpd deployed a WindCube Scan to ensure greater measurement heights and confirm wind speeds with on-site measurements, achieving its goals of increased wind data certainty while keeping the campaign highly efficient and cost-effective. Scanning lidar also supports dual lidar to provide even more comprehensive insights by observing offshore sites from multiple positions, further increasing measurement accuracy.

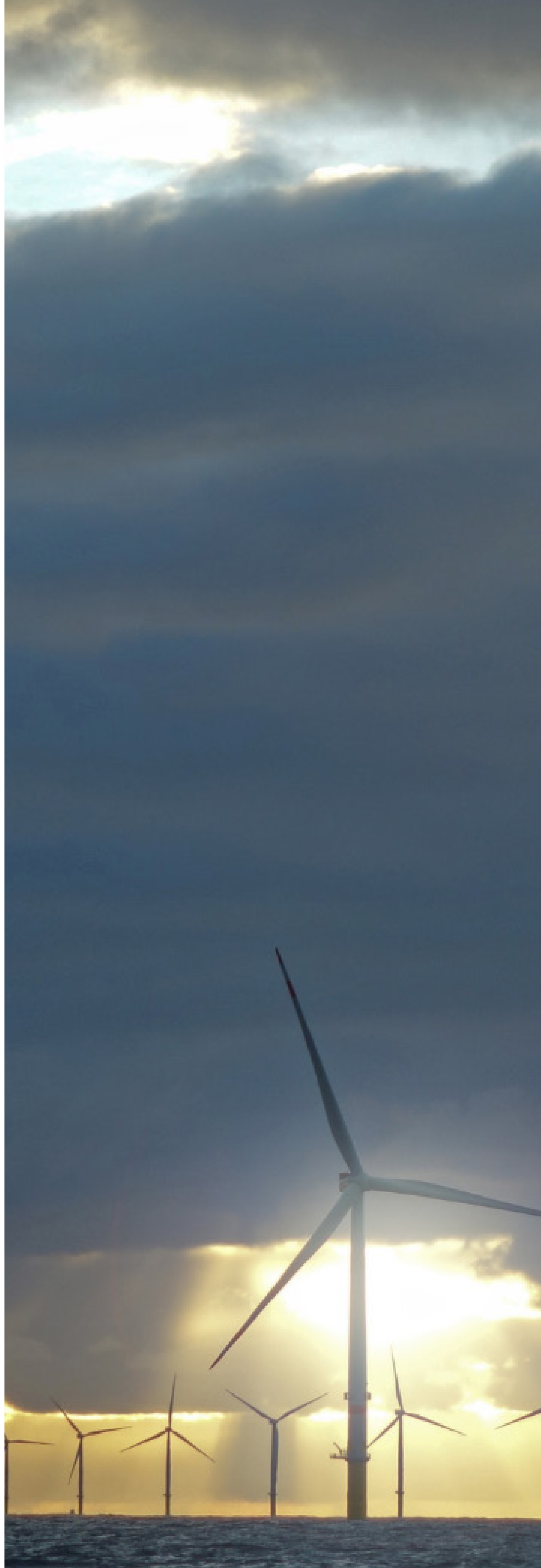
WindCube Offshore and Floating Lidar Systems (FLS) can also facilitate WRA. AKROCEAN has revealed the FLS could go from port to assessment site in just a week, speeding the process of project permitting. Moreover, as exhibited by Mainstream Renewable Power, on-site fixed offshore lidar measurements improve project bankability by reducing extrapolation uncertainty.

Before commissioning, contractual power curve verification is crucial. Siemens Gamesa Renewable Energy uses WindCube Nacelle in place of met masts because of the faster and more accurate calculations the nacelle-mounted lidar provides. WindCube Nacelle ensures correct and IEC-compliant Power Performance Testing (PPT), and WindCube Insights - Analytics software streamlines simplified and transparent PPT reporting and analysis. WindCube Nacelle can also aid during operations: When SSE Renewables wanted to carry out blade erosion repairs, they leveraged lidar to determine the impact of the repairs on turbine performance.

In operation, one or several WindCube Offshore systems are used permanently at the wind farm to provide continuous quality wind data to monitor production and identify potential losses or perform diagnosis. Wind lidar is also increasingly used for R&D purposes, which now include wake loss, blockage effect and boundary layer studies, active turbine and wind farm control and short-term forecasting.

Lidars are comprehensive, compatible, and simple to deploy and repurpose throughout the lifecycle of an offshore project. With the right tools, offshore wind farms are not just technically feasible but financially sound.

Find out more:
http://www.windcubelidar.com/



Global views on the offshore wind permitting process

In most European countries, offshore wind project development is now possible within around eight years, mainly because of the transition from an "open-door" model to a "one-stop shop" model. Under the former model, the developer takes responsibility for initiating site selection and verification, applying for all permits and approvals, and establishing the project at the end. However, lessons learned in the initial stage of offshore wind buildout have led Denmark, Germany, the UK and the Netherlands – where more than 60% of global offshore wind installations are based – to transition to the more simplified "one-stop shop" model. This model reduces administrative procedures for developers, making government agencies responsible for site selection in either a zonal or site-specific approach, pre-site investigations, licensing, Environmental Impact Assessment (EIA), grid connection to decommissioning.

China is the world's leading offshore wind market today by cumulative installations. It took more than a decade for the learning process to yield a robust industry and supply chain. An initial 1 GW concession program, consisting of four offshore wind projects in Jiangsu province, was launched in 2010, but project development was delayed primarily due to conflict between various government bodies including the oceanic administration, maritime administration and other functions like the military, fishery and natural reserves. The market did not take off until the National Offshore Wind Development Plan (2014-2016) and offshore wind FiT were released by National Energy Administration (NEA) in 2014. Most importantly, the Management Measures for Offshore Wind Power Development and Construction was jointly released by the NEA and State Oceanic Administration (SOA) in 2016, aligning permitting and development guidelines between various government bodies and stakeholders.

As an emerging offshore wind market, the US has demonstrated how project consenting and permitting can slow down or speed up project development and domestic supply chain and infrastructure establishment. Although a slow project permitting process was widely recognised as a challenge under the previous federal administration, under the Biden administration there is a determined political agenda and active engagements with relevant authorities and stakeholders. This has advanced the US as a market which is meeting critical permitting milestones.

Offshore wind farm development still takes more than ten years in emerging markets like Japan and South Korea, due to complex and time-intensive permitting procedures. Both countries have made bold offshore wind targets (10 GW by 2030 in Japan and 12 GW by 2030 in South Korea), but without a sensible permitting environment in place to ensure smooth and expeditious project timelines, those targets will be challenging to meet.

Case Study: Denmark's "one-stop shop" for timely project permitting

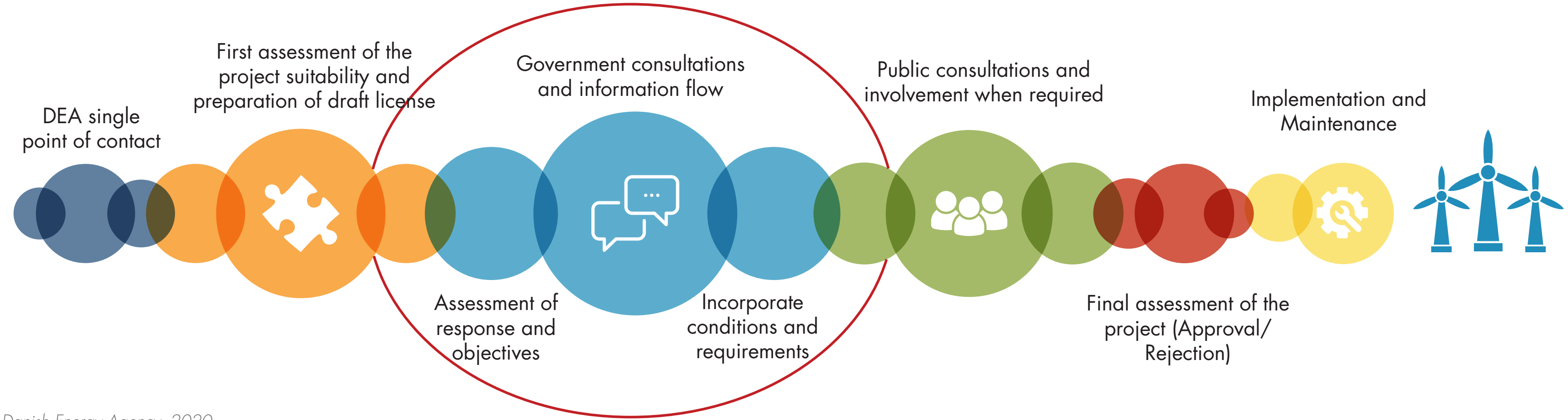
Long-term planning, as well as a stable and supportive policy framework, have been fundamental to the success of Danish offshore wind development. The concept of a single point of access, or a "one-stop shop", for project permitting not only speeds up the consenting process, but also reduces uncertainties and delays.

The Act on Promotion of Renewable Energy defines the rules, requirements and procedures for issuing licenses for offshore wind development. According to the Act, the Danish Energy Agency (DEA) has the mandate to both plan and issue permits for offshore wind projects within territorial waters and Denmark's Exclusive Economic Zone (EEZ). The three licenses required to establish an offshore wind farm are granted by the DEA, which serves as a "one-stop shop" for the project developer:

- License to carry out preliminary investigations, granted after the developer submits a project description and plan of activities to carry out on the offshore site.
- License to establish the offshore wind turbines, granted if preliminary investigations show that the project is compatible with the relevant interests at sea.
- License to exploit wind power for a certain number of years, and an approval for electricity production.

According to the DEA, the "one-stop shop" model ensures a smooth and administratively lean process in consenting offshore wind farms. The licenses required are prepared and granted by the DEA through an iterative process involving contributions from the relevant authorities. The DEA conveys relevant project specific knowledge to the other authorities in order to mitigate conflicting interests. Once the concession has been granted, the DEA will continue to operate as a single point of contact if the developer needs assistance on issues related to the granted licences and procedures.

Roles of DEA in offshore wind permitting process in Denmark



Source: Danish Energy Agency, 2020

Case Study: The US shows that a determined political agenda can advance project permitting

The Biden administration has elevated strategic attention to offshore wind deployment with a 30 GW federal target by 2030, in addition to a broader net zero by 2050 goal. Similar to China, it has been a learning process for government bodies in the US to enhance inter-agency coordination and streamline procedures, in addition to increasing the human resource required for technical and environmental review.

The Outer Continental Shelf (OCS) Renewable Energy Program announced by the Department of Interior (DOI) in 2009 provides a framework for issuing leases, easements and rights-of way for OCS activities that support production and transmission of energy from sources. These responsibilities are implemented through the Bureau of Ocean Energy Management (BOEM). BOEM has outlined a four-phase leasing process based on competitive or non-competitive auctions to regulate the overall offshore wind project permitting process.

In recent years, permitting was raised as a prominent hurdle for developers to meet construction timelines and benefit from the PTC and ITC tax credit schemes. The 12 MW Virginia offshore wind project installed in 2020 underwent an eight-year permitting process to ensure compliance with federal laws, state environmental and coastal management plans. The first large-scale 800 MW Vineyard project, awarded through a lease auction in 2018, had been paused for 1.5 years due to challenges from the Construction and Operation Plan (COP) and environmental impact review. It could not receive the green light for construction until the new administration streamlined the federal permitting process in 2021.

According to GWEC Market Intelligence, 28 GW of offshore wind could be built in the US by 2030 with up to 15 GW fixed-bottom offshore wind capacity already awarded through state-level solicitations or having secured offtake and another 9.2 GW of competitive solicitations (in Rhode Island, New Jersey, Massachusetts, Connecticut and

Maryland) lined up to 2028. To meet the scale of interest and targeted growth, BOEM has established 14 Intergovernmental Renewable Energy Task Forces as of May 2021 to help inform its planning and leasing process and plug critical data gaps.

There are also new permitting deadlines: BOEM plans to review at least 16 COPs by 2025, including the environmental review the 2.3 GW Vineyard Wind South wind project and up to 10 additional projects in 2021. These steps and improved engagements between relevant authorities and stakeholders have turned the US into a good example of an action-oriented administration resolving permitting hurdles to foster offshore wind growth.

Phases of BOEM's Offshore Wind Energy Project Authorization Process

Planning and Analysis

- BOEM publishes call for information and nominations
- BOEM identifies priority Wind Energy Areas (WEAs) offshore, WEAs are locations that appear most suitable for wind energy development, or
- Processes unsolicited application for lease
- BOEM may prepare an environmental assessment for lease issuance and site assessment activities

Leasing

- BOEM determines whether competitive interest exists
- If competitive interest exists, BOEM notifies the public and developers of its intent to lease through sale notices before holding a lease sale
- If competitive interest does not Exist, BOEM negotiates a lease (note: issuance may be combined with plan approval)

Site Assessment

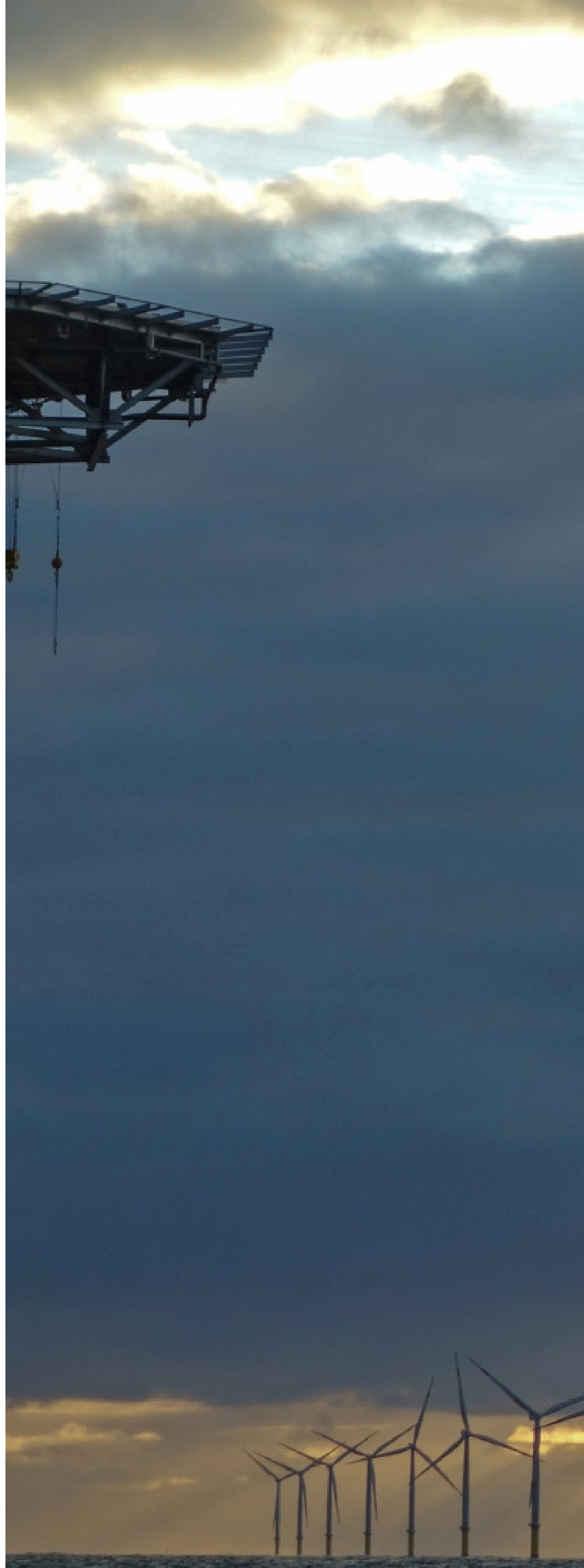
- Lease conducts site characterization studies
- Lease submits site assessment plan (SAP)
- BOEM conducts environmental and technical reviews of SAP, eventually deciding to approve, with modification, or disapprove the SAP
- If approved, lease assesses site (usually with meteorological towers and bodys)

Construction and Operations

- Lease may conduct additional site characterization
- Lease submits construction and operations plan (COP)
- BOEM conducts environmental and technical reviews of COP, eventually deciding to approve, with modification, or disapprove the COP
- If approved, lease builds wind facility

Inter government Task Force Engagement

Source: BOEM, 2021

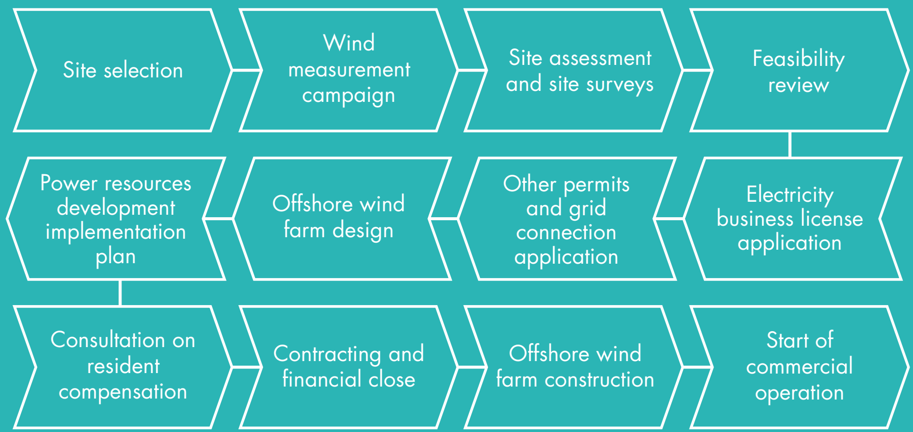


Case Study: South Korea's fragmented and lengthy permitting process delays project development

In October 2020, South Korea declared its carbon neutrality by 2050 goal. In support of this goal, and a key plank of the country's Renewable Energy 3020 Implementation Plan from 2018, is a target to install 12 GW of offshore wind capacity by 2030. By 2030, South Korea is expected to emerge as East Asia's hottest floating offshore wind market, housing some of the world's biggest floating offshore wind farms.

South Korea has granted permits for offshore wind project development via an 'open-door' model. The project developer takes responsibility for site selection, site verification, preparing and submitting applications for all approvals and permissions, as well as managing consultation with local authorities, residents and stakeholders. Developers are generally granted a four-year exclusivity period which begins when the permits to install the meteorological measurements equipment is granted.

Offshore wind project development process in South Korea



Source: Aegir, COWI, Pondera, "Accelerating offshore wind through partnerships," 2021.

As of March 2021, 42 projects totalling 7.7 GW have acquired an Electric Business License (EBL). The EBL is the first permit applied for after a successful wind measurement campaign and is therefore a good indicator of early project development. There is 140 MW operational in the country today, and most projects are developed over periods of 8-11 years from EBL to COD. Generally, offshore wind project development is a fragmented and lengthy process in South Korea, lacking a mediation forum for resolving challenges and grievances from various stakeholders, uncertainties regarding grid connection and disparity in central and local authorities' goals.

Currently, permit applications must be submitted to multiple ministries, resulting in delays and development uncertainties. In July 2020, the Ministry of Trade, Industry and Energy (MOTIE), Ministry of Oceans and Fisheries (MOF) and Ministry of Environment (MOE) jointly issued an 'Offshore Wind Collaboration Plan' with local residents and the fishing industry. This plan called for a new "one-stop shop" permitting organisation but is facing implementation delays due to lack of inter-agency alignment and continued opposition from local fisheries and diver groups.

Despite strong political support for offshore wind and the financial clout of both domestic and foreign players, it remains challenging for South Korea to realise its ambitious offshore wind targets on time in view of its lengthy permitting and stakeholder consultation procedures.

Advancing offshore wind through a holistic MSP process

The ocean holds a wealth of solutions to address global challenges. Offshore wind is a vital ocean-based climate solution in the future energy mix, supporting the significant GHG emissions reduction needed to meet the Paris Agreement.

The ocean also plays an important role in reconciling the climate and nature crisis. The restoration and rehabilitation of so-called blue carbon ecosystems such as seagrass, mangroves, coral reefs and saltmarshes, can both recover ecosystem biodiversity and function while accounting for carbon sequestration and increasing climate resilience. A sustainable ocean economy can deliver on all 17 of the Sustainable Development Goals (SDGs), from food security and nutrition (Goals 2 and 3) to provision of decent work and livelihoods for millions (Goal 8).

However, the demand for ocean space is rising with the combination of both new and established users, from fishing, tourism, military and shipping, to offshore renewables like offshore wind and aquaculture. Over the next two decades, more ocean users will undoubtedly emerge, such as marine pharmaceuticals.

Ocean management tools, such as Marine Spatial Planning (MSP), can reconcile the decarbonisation agenda, the biodiversity agenda and the SDGs. MSP uses an evidence-based approach to improve coordination among marine stakeholders, while minimising cross-sector conflicts, tapping into synergies and encouraging science-based

> "In order for the ocean to deliver on its potential, a well-managed ocean will be increasingly essential."

decision-making harnessing local knowledge.

MSP is important for fair and sustainable integration of offshore wind into the existing context of traditional marine uses. Since 2009, MSP has guided offshore energy through site selection, streamlining development through mitigating litigation risks, as well as easing permitting processes. A lack of spatial planning can lead to delays to offshore wind deployment, incur additional costs and incite pushback from other Ocean users; to date, offshore wind has faced setbacks from the fishing industry in several nations, from France to South Korea.

Established economic sectors and sub-sectors of Ocean users

Sector	Sub-Sector
Marine living resources	Primary production
	Processing of fish products
	Distribution of fish products
Marine non-living resources	Oil and gas
	Other minerals
Marine renewable energy	Offshore wind energy
	Wave and tidal energy
Port activities	Cargo and warehousing
	Port and water projects
Shipbuilding and repair	Shipbuilding
	Equipment and machinery
Maritime transport	Passenger transport
	Freight transport
	Services for transport
Coastal tourism	Accommodation
	Transport
	Other expenditure

Source: European Commission (2021). The EU Blue Economy Report. 2021. Publications Office of the European Union. Luxembourg.

It is not simply a matter of allocating new sites. The private sector plays an important role in broader integrated ocean management: Public-private engagement in legitimate processes can be success factors for a thriving sustainable ocean economy.

The offshore wind ector already catalyses and supports MSP processes: establishing partnerships with the fishing industry; driving new approaches to co-existence with other marine users, such as aquaculture and seaweed mariculture; providing evidence, development scenarios and non-commercially sensitive data-sets to relevant authorities; and enabling well-informed, future-looking and science-based plans. The offshore wind sector is also developing nature-inclusive designs with the potential to enhance marine ecosystems, enabling positive co-existence between biodiversity and clean energy.

Engagement in MSP processes can help to further explore and capitalise on synergies, in turn supporting the socially and environmentally responsible engagement of the offshore wind sector. The UN Global Compact Practical Guidance for

the Offshore Renewable Sector provides additional best practices on responsible development of offshore wind.

With input from: Martha Selwyn, Manager, UN Global Compact Sustainable Ocean Business Action Platform

Grid challenges and innovations in offshore wind

As the number and size of offshore wind projects that are under development grow at unforeseen rates, offshore grids have become a topic of much interest. The emergence of new transmission technologies, such as superconductivity, gas-insulated assets, HVDC and Power-to-X, are paving the way to a holistic approach to offshore grid planning and buildout.

Transmission ownership models

There are mainly three models of ownership for offshore grids: developer-owned, Transmission System Operator (TSO)-owned, and third party-owned. Under the developer-owned model, the developer is responsible for the offshore transmission infrastructure planning, installation, operations and maintenance, whereas in the TSO-owned model, the system operator is responsible and typically makes it part of broader power system planning. The third party-owned model separates the developer from the transmission assets.

Mature European markets, such as Germany, the Netherlands and Belgium, have adopted the TSO-owned model, whereas in the US, Mainland China and Taiwan, the developer-owned model has been adopted. Denmark evolved from more than 20 years of the TSO-owned model to the developer-owned model in 2018, to further drive competition and lower costs. The UK has utilised the third party-owned model, wherein transmission assets are usually built by the developer, and by law, at commercial operation, the developer must sell the transmission asset to a Third-Party Offshore Transmission Owner (OFTO). There are advantages and disadvantages to each model, which vary based on the political and fiscal preferences of each market, but they all work.

Technology, cables and features

Offshore wind projects have predominantly utilised a single line connection, or radial connection, to transfer power to the onshore grid. If the radial connection fails, there is less power available for the system operator and financial losses for the developer. High voltage alternating current (HVAC) technology has been widely used in offshore grids. Some offshore projects located more than 100km to the coast have used a radial high-voltage direct current (HVDC) interlink to shore, such as Sylwin1 (2014), DolWin3 (2017) and Dogger Bank (2023, planned).

Both HVAC and HVDC are well-known and proven technologies. While HVAC has lower terminal station costs, more moderately sized offshore platforms (larger supply base) and shorter delivery times, it is limited in cable length and typically has higher power losses than HVDC. On the other hand, HVDC has no limitation in cable length, requires less cabling, has fewer power losses and offers superior operations and control features (e.g. black start capability, voltage and frequency stabilization), but it requires larger offshore platforms and longer lead times. HVDC is also less cost efficient for short distances.

Basic HVAC to HVDC technology comparison

Parameter	HVAC	HVDC
Cable Cost	HIGH	MEDIUM
Electrical Losses	MEDIUM	LOW
Practical Maximum Length (without mitigation)	~100 km	Theoretically Unlimited, Current Longest is about 600 km
System Reliability	HIGH	MEDIUM-HIGH
OSP/Converter Platform Cost	MEDIUM	HIGH
OSP/Converter Platform Weight	1,500-3,000 T	~12,000 T (Borwin Beta Germany)
Max Power Per Cable	~ 400 MW	Currently Western Link; transmits 2,200 MW
Onshore Footprint	MEDIUM	LARGE

Source: NYSERDA, 2021.

Floating offshore grid applications require a different high voltage dynamic cable technology, as the cable technology used for fixed-bottom applications are unable to flex and withstand a lifetime of constant movement without fatigue cracking.

The decision between HVAC and HVDC is highly project specific, with several factors to consider, such as export cable lengths, installed capacity, technology readiness, delivery times, economics, operations and regulations.[18]

Offshore grid challenges

The offshore wind industry is facing challenges around offshore transmission, including unexpected cable damages, incremental cost of offshore grids and delays due to lack of planning and coordination.

Cables represent up to 80% of construction claim payments, but only 10 to 20% of capital spending, according to GCube, a renewables

18 Offshore Wind Submarine Cabling Overview. Fisheries Technical Working Group, Final Report. NYSERDA, April 2021.

insurance supplier.[19] In 2021, Ørsted identified a cabling issue during an inspection at Race Bank Offshore Wind Farm, where unstabilised cables connecting its offshore wind turbines had been moving across the scour protection (rocks placed on the seabed around the turbine foundations to avoid seabed erosion), abrading its cable protection system. Ørsted is now planning to place a cover around the damaged cables and stabilise them against the rocks, potentially saving hundreds of millions of dollars over the project lifetime. The first offshore wind projects had a layer of rocks on top of the cable to help stabilise them against ocean movement. The new solution, without this layer of rocks, was introduced a few years back and has been adopted by most operational projects worldwide.[20]

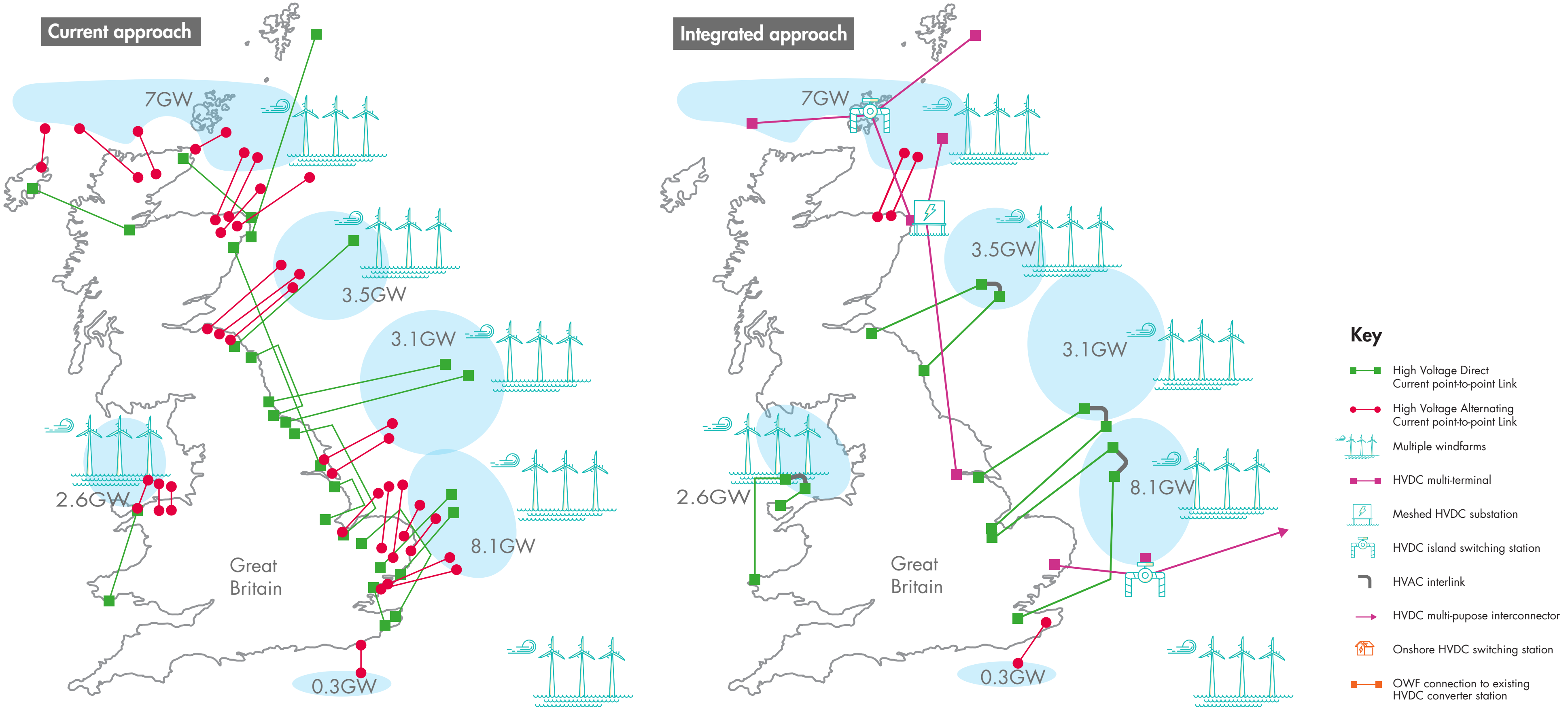
Another offshore grid challenge is around a lack of centralised planning and coordination, which leads to incremental transmission costs, project development and interconnection delays. These risks are particularly high in a developer-owned model, where transmission costs can escalate quickly over time as opposed to a TSO-planned and owned approach. These costs stem from the limited number and options of landing sites, cable spacing and crisscrossing with other infrastructure, impact on fisheries, local community and environment, congested transmission systems (existing grids were not designed for massive influx of offshore wind power), and in turn can lead to curtailments, higher onshore upgrade costs and other adverse outcomes.[21] The industry has also seen delays of more than 12 months in grid connections, such as in Germany.[22]

In Europe, ENTSO-E, the association for European TSOs, supports the planning of the future offshore grid by assessing the benefits of over 43 offshore projects all over Europe, including offshore interconnectors, innovative projects such as the North Sea Wind Power Hub and offshore storage solutions such as iLand.[23] Furthermore, seven European TSOs have signed a Memorandum of Understanding for the launch of Eurobar, an initiative for interconnecting offshore wind platforms across Europe.[24]

In the UK, National Grid estimates that the benefits of an integrated approach for all offshore projects to be delivered from 2025 would amount to nearly £6 billion between now and 2050, as well as significant environmental and social benefits (for example, the number of new electricity infrastructure assets, including cables and onshore landing points, could be reduced by around 50%).[25]

19 https://www.reutersevents.com/renewables/wind/growing-findings-offshore-cable-damage-hike-pressure-protection
20 https://www.bloomberg.com/news/articles/2021-06-14/orsted-readies-divers-to-fix-wind-power-cables-on-sea-floor
21 https://www.brattle.com/news-and-knowledge/news/planned-offshore-wind-transmission-system-for-new-york-could-provide-cost-savings-of-over-500-million-according-to-study-by-brattle-economists
22 https://www.offshorewind.biz/2012/06/25/germany-deals-with-further-grid-connection-delays/
23 https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2020/Foropinion/TYNDP2020_Highlights.pdf
24 https://www.offshorewind.biz/2021/04/15/european-tsos-form-eurobar-to-standardise-offshore-grids/
25 https://www.nationalgrideso.com/news/final-phase-1-report-our-offshore-coordination-project

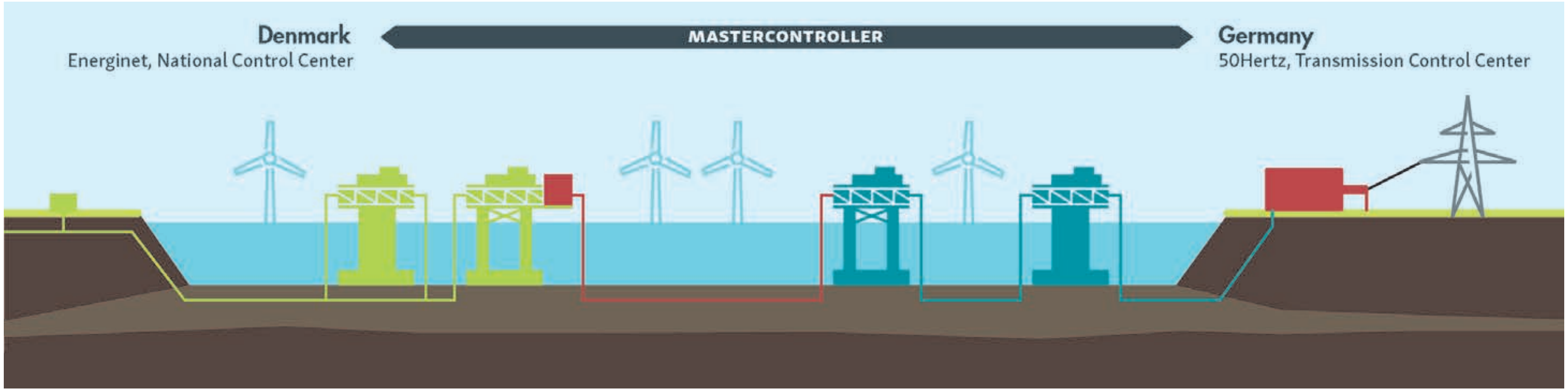
Current approach compared to the integrated approach for Great Britain network designs in 2030



Lines demonstrate the number of links, not the number of individual cables. Some of the links shown may be formed by a number of cables.

Source: NGESO, 2020.

Schematic representation of the Kriegers Flak Combined Grid Solution



Source: 50Hertz

In addition, the Kriegers Flak Combined Grid Solution project, completed in 2020, is the world's first project combining grid connections to offshore wind farms with an interconnector between Denmark and Germany.[26]

There are many other offshore grid challenges, but making offshore HVDC systems interoperable, flexible, modular, scalable, reliable and resilient, remain some of the greatest. The EU-funded project 'PROgress on Meshed HVDC Offshore Transmission Networks' (PROMOTioN), completed in 2020, concluded there are no technological showstoppers for multi-terminal HVDC transmission networks, although significant standardisation work is required.

Offshore grid innovations

Many companies and research institutions are looking at the next frontier for offshore grids, from robotics and digital twin technology to superconducting.

With regards to subsea inspections, the industry has traditionally used divers and remotely operated underwater vehicles (ROV). With the advancement of new technologies such as simultaneous localisation and mapping (SLAM), increasingly autonomous ROV and machine learning, operators are offered with the capability to process video feeds in discrete frames, recognising structural key features, anomalies, automatically tagging and grading them according to predefined levels. This vastly expedites the process, removes people from hazardous environments and reduces vessel sizes.[27] For example, the Woods Hole Oceanographic Institution designed the torpedo-shaped REMUS ocean robot to map the seafloor around cables in order to collect detailed information such as gaps in the sediment protecting the cable.[28]

According to research institute MaREI, at University College Cork, current superconducting cable technology is not fit for large offshore wind

26 https://www.50hertz.com/en/Grid/Griddevelopement/Offshoreprojects/CombinedGridSolution; https://en.energinet.dk/Infrastructure-Projects/Projektliste/KriegersFlakCGS
27 https://www.zdnet.com/article/the-undersea-robots-driving-offshore-wind-generation/
28 https://www.whoi.edu/oceanus/feature/a-new-way-of-seeing-offshore-wind-power-cables/

applications. Superconductor cables are made of special materials that when cooled down to extremely low temperatures activate the superconductivity phenomenon. The primary challenge is to minimise heat ingress that reduces performance of the superconducting over the length of the pipes under deep-sea high-pressure conditions. Innovations around optimisation of the cooling system and manufacturing process are also needed to bring superconducting to offshore grid scales.[29]

As global economies reaffirm their renewable energy commitments with larger targets, robust and proactive planning and development of offshore grids will be needed to enable countries to reach their aims. This must include significant investment and R&D in some of the technological innovations reviewed above, from subsea cabling to remote O&M to superconductivity, as well as wide stakeholder collaboration to ensure environmentally sound buildout and industrial efficiency.

29 https://www.entsoe.eu/Technopedia/techsheets/high-temperature-superconductor-hts-cables

Offshore wind financing

A record-breaking period for offshore wind financing

Last year, what will eventually be the planet's largest offshore wind farm reached a significant milestone – financial close on the first two 1.2 GW phases of the 3.6 GW Dogger Bank Wind Farm off the east coast of England in a deal worth approximately US$8 billion. This marked the largest ever offshore wind farm project financing completed anywhere in the world. Significant investments such as this transaction have now become commonplace for the offshore wind industry.

There was also an abundance of financing activity in the sector as 2020 became a record year for offshore wind financing, despite the COVID-19 pandemic. Offshore wind financing in the first six months of 2020 totalled US$35 billion, up by a record 319% year-on-year, according to BloombergNEF, representing the most active half-year ever for final investment decisions, well above 2019's record full-year figure, a revised US$31.9 billion.

The first half of 2020 saw 28 investment commitments reach financial close for offshore wind farms, including the largest ever at the time, the 1.5 GW Hollandse Kust Zuid off the coast of the Netherlands at an estimated US$3.9 billion. Several other major deals followed as projects and financing 'ticket' sizes continue to increase, including the 1.1 GW Seagreen project in the UK at an estimated US$3.8 billion, and the Fecamp and Saint-Brieuc projects in France, together totalling 993 MW and US$5.4 billion.

According to WindEurope's latest analysis, total investments in 2020 for offshore wind across the region were approximately US$31 billion (including offshore transmission line infrastructure). Of this total investment figure, 58% represents non-recourse debt financing, while just 18% of the capital raised was on balance sheet financing using a corporate finance approach.

Over the last decade, from 2011 to 2020, the breakdown of financing approaches is as follows: corporate balance sheet financing of €47billion using a corporate finance approach; and €21.7 billion of non-recourse project financing broken down as €15.4 billion of debt and €6.3 billion of equity. In recent years, offshore wind investments increasingly lean on project finance due to the high capital requirements. [30]

Evolution of the offshore wind financing ecosystem

Fixed-bottom offshore wind technology has reached a point of maturation in Europe, with its rapid growth enabled by an expanding network of financial actors, along with favourable and increasingly attractive conditions relating to country political risk profiles, available liquidity and weighted cost of capital. The recognition of offshore wind as an infrastructure asset class

30 WindEurope, "Financing and investment trends," 2019.

has also helped unlock additional pools of equity and debt capital from corporate and institutional investors, including pension funds, insurance companies and sovereign wealth funds looking for de-risked and predictable yield investments.

In the early stages of the offshore wind industry, from 1991 to the mid-2000s, the traditional players in terms of equity financing were corporates, including utilities, energy companies and independent power producers (IPPs), while commercial banks were the key players in terms of supplying debt (on a non-recourse basis). The standard project finance debt ratios of 60% employed for the first offshore wind financings have increased to between 80% and 90% in many cases. In addition, the ecosystem of financial actors involved in offshore wind transactions has expanded.

As key equity investors in offshore wind, pension funds and insurance companies have typically sought partnerships with experienced project developers who guarantee full coverage of both technical and cost overrun risks during construction and initial operations. Teaming up with an experienced utility company capable of managing these risks has

The evolution of the offshore wind financing ecosystem

Type	Equity	Debt (non-recourse basis)
Traditional players	Corporates including utilities, IPPs (equity on balance sheet, e.g. Ørsted, Vattenfall, RWE)	Commercial banks (including club deals)
Non-traditional newcomers	Pension funds (e.g. PGGM, PensionDenmark, PKA)	Export Credit Agencies (Public debt sources like Denmark's EKF)
	Insurance funds (e.g. Allianz and Munich Re)	Multinational financing organisations (Public debt sources like EIB)
	Sovereign Wealth Funds (such as Masdar Capital, Norwegian Sovereign Wealth Fund)	State owned or state backed banks such as National development banks (public debt sources like KfW)
	Infrastructure funds (e.g. Copenhagen Infrastructure Partners, Macquarie, Global Infrastructure Partners)	Institutional investors (e.g. Denmark's pension fund PKA recently provided a €120 million subordinated loan in a hybrid debt structure for the North Sea Gemini project, backstopped by an ECA guarantee from Denmark's EKF)
	Private equity funds (e.g. Partners Group and BlackRock)	Green Bond finance (e.g. Ørsted in Taiwan)
	Green power corporate investors (direct investment in stakes like Colruyt group, Kirkbi or indirect via Corporate PPAs, e.g. Amazon & BASF)	
	Citizens equity for smaller projects (engage with local communities like nearshore projects in Denmark)	
	Oil and gas companies (primarily based in Europe, e.g. Shell, Equinor, BP, Total, ENI)	

Source: FTI Consulting, GWEC Market Intelligence, July 2021

been key to enlarging the pool of risk capital willing to invest in the sector. A growing number of sovereign wealth funds have also begun to enter the offshore wind sector on a similar basis.

The cost of offshore wind is highly sensitive to the cost of debt, making access to cheaper debt crucial for the sector's further development. The industry is increasingly reliant on commercial banks entering into project financing deals with additional financing support provided by multilateral banks and national finance institutions. Key players providing debt finance continue to be commercial banks, export credit agencies, state-owned banks and multilateral lenders.

Most recently, in March 2021, the European Investment Bank (EIB) has granted a US$412 million credit line to a consortium building a wind farm off the coast of Courseulles-sur-Mer in France. The financing will be guaranteed by the European Fund for Strategic Investments, the central pillar of the Investment Plan for Europe - reinforcing offshore wind's strategic importance for Europe and the EIB's position as the EU 'Climate Bank.'

The evolving trend to watch is the move to a 'zero-subsidy model' seen in the Netherlands and Germany, for example. This development, in terms of market design, signals that the underlying business fundamentals in selling power are changing as project developers will only receive the wholesale price of electricity. Under this wholesale market approach developers must bear the risk of electricity price volatility. This is uncharted territory for many in the offshore wind industry, bringing new opportunities but also a huge amount of uncertainty and financial risk, including the likely compression of internal rates of return that may make offshore wind projects less attractive to investors (**see: Support schemes**).

Exporting the European experience

We are now seeing experienced developers, utilities, financial investors, and equipment suppliers export their proven offshore wind financing approaches to new markets beyond Europe. Export Credit Agencies (ECAs) have played a crucial role in extending the industry beyond Europe, by offering guarantees of commercial bank loans to support the offshore wind industry's international expansion.

State-owned or state-backed banks also play a pivotal role in their support of domestic wind industry participants and infrastructure sector projects more generally, often offering loans and bank loan guarantees at lower rates than those offered by commercial banks. The participation of government-supported financing institutions has been instrumental in raising the confidence of private investors in offshore wind, not only by illustrating strong political support but also by lowering the cost and availability of conventional commercial bank debt.

Commercial banks have also provided a significant amount of non-recourse debt on a project finance basis as they are able to utilise a variety of flexible loan instruments to cover short to medium term financing of infrastructure projects. However, these banks typically have a low tolerance for risks that cannot be readily mitigated. But as offshore wind's expansion to new markets has been driven by the same European companies that established the European wind sector, significant risk premiums are not being attached to projects seeking financing in new markets in investment grade countries, such as the United States and Taiwan.

In the US market, an important role in wind project financing is played by tax equity investors due to the availability of lucrative production tax credits (PTCs). Availability of debt should not be an issue for US offshore wind projects. Most likely will be the use of 7-to-10-year term mini-perm structures with cash sweeps followed by re-financings to match the PPA tenors of 20-25 years. There may also be use of term loan B debt and project bonds depending upon the tenors and rates offered by commercial banks. In addition, the U.S. Congress has extended the availability of ITCs to offshore wind projects that begin construction before 2026. The stability and visibility offered by these federal tax credits helps to ensure mobilisation of sufficient tax equity investment and long-term debt to finance the expected expansion of the US offshore wind market.

Earlier this year, in a prime example of established offshore wind actors and models at work in a new market, Copenhagen Infrastructure Partners (CIP) of Denmark, announced that it had reached financial close on

the Changfang and Xidao 589 MW offshore wind project off the coast of Changhua County in Taiwan. The 589 MW offshore wind farm will be financed through a combination of equity and senior loans from a consortium of 25 international and Taiwanese banks and financial institutions, along with equity financing support from CIP's Funds I and II, Taiwan Life Insurance and TransGlobe Life Insurance, as well as with support from six export credit agencies. The total project financing raised from commercial banks and other financial institutions amounts to approximately US$3 billion (NT$ 90 billion).

Another Asian market not to be ignored in terms of offshore wind volume is Mainland China, where a unique approach to financing exists due to the country's specific economic and political environment. According to BloombergNEF, there were no fewer than 17 Chinese installations financed in 2020, led by the Guangdong Yudean Yangjiang Yangxi Shapaat 600 MW project which required financing of its US$1.8 billion project cost. GWEC notes that Mainland China expects to move to a subsidy-free merchant model as of 2022, following certain European markets such as the Netherlands down this route.

New markets, new risk profiles

Another question now is how these established project financing models will adapt as offshore wind development proceeds in new markets, where country risk profiles are higher. This transition into riskier markets, will represent an important new challenge for offshore wind deployment, where the availability of financing could turn from enabler to roadblock.

Available liquidity in the global financial sector doesn't flow as easily to markets with higher risk profiles, such as Brazil, Turkey, India and Vietnam. The risk profiles of first-generation projects in these countries will also be higher, likely requiring more equity to be deployed and in some cases even requiring on balance-sheet financing until projects are constructed and significantly de-risked. Support schemes such as the one provided by the Brazilian Development Bank (BNDES) to ignite onshore wind development in the country could be launched as a strategy, in Brazil and in other emerging markets for offshore wind.

Floating offshore wind, which is still at the pre-commercialisation stage of development in both Europe and Asia, is experiencing similar financing challenges to those faced in financing fixed-bottom offshore wind projects in new emerging market countries. As utility-scale floating wind is yet to be deployed on a commercial basis, it is likely to require either balance-sheet financing or more equity to be employed as a part of non-recourse project financing packages. According to Green Giraffe, the EIB, a couple of ECAs and a handful of commercial banks are prepared to consider lending to a floating wind project with the right "bankability" profile using more conservative debt ratios.

As the world transitions away from fossil fuels there is also a growing trend towards producing "green" hydrogen at massive offshore electrolysis facilities powered in some cases by equally massive offshore wind farms. Such innovative infrastructure projects may also face challenges in raising financing during their initial deployment period. For example, the recently announced AquaVentus initiative has set a goal of achieving 10 GW of electrolysis capacity in the North Sea by 2035. Despite the participation of experienced offshore wind investors, the initial process of financing such projects may encounter teething problems as the technology involved is increasingly complex and located farther offshore.

Role of financing in reaching net zero

As reflected in the ever-increasing financing activity in the sector, competition and innovation have helped bring costs down. Encouragingly, there is still more room for improve ment as IRENA's latest projections show average offshore wind LCOE falling by 55% by 2030 compared to 2018.

Financing is not seen to be a major roadblock to building new offshore wind projects as many organisations across the financing ecosystem are seeking to increase activity in the sector and there is sufficient liquidity available in global capital markets. This means that the financial sector is already positioned to enable the required offshore wind growth needed to achieve collective net zero commitments.

While there is sufficient liquidity in global financial markets, the focus must shift to issues around market design, especially relating to project permitting (**see: Permitting and consenting schemes**), grid connections and closer interaction between industry, the financial community and government. There are also uncertainties surrounding a transition to wholesale energy markets and its impact on financial returns. These issues must be carefully managed if the global community is to achieve deployment of offshore wind and capital at the rate required to reach global climate change mitigation goals.

Expanding a safe, skilled and capable workforce for offshore wind

The offshore wind industry is growing at an unprecedented rate. To manage this rapid growth and achieve a sustainable workforce, the industry must expand without compromising on safety.

This requires alignment and coordination on a global scale amongst policymakers, industry representative bodies, employers, supply chain and educators to ensure sufficient training capacity and expertise is available.

The narrative to date has focused purely on one mission: To create an injury-free working environment, the world's largest wind industry employers have supported the operationalisation of safety management by investing in systems and standards that can be deployed on a global level.

In 2021 and beyond the story will increasingly consider the job creation potential associated with propagating these systems into new markets. This means thousands more instructors and support staff to help us send out a technician workforce with the right skills and safety mindset to avoid injury on site.

Earlier this year, the Global Wind Organisation's (GWO) sister organisation G+ reported that in Europe, the offshore wind sector experienced fewer than 100 recordable injuries for the first time, decreasing the sector's Total Recordable Injury Rate (TRIR) to 3.75, representing a 32% year on year reduction. This underlines how standardised training in basic safety and technical skills for wind turbine technicians is contributing to the industry's safety performance.

With COP26 on the horizon, GWO and GWEC widened our focus with a new report, the Global Wind Workforce Outlook 2021-2025, which considered the true extent of the workforce capacity challenge ahead. The report concluded that by 2025, over 480,000 GWO-trained technicians will be required in construction, installation, operations and maintenance globally. The opportunity for training providers, colleges, universities, and other institutions is tremendous.

In Europe, training capacity is plentiful with employers enjoying choice and variety of standardised wind power-specific safety and technical training at more than 250 locations across the continent. Around 80,000 technicians have a valid GWO training record in Europe, many of whom are certified

Forecast capacity installations and number of people requiring new training for construction, installations and O&M globally (2021-2025)

Region	Onshore		Offshore	
	Installations (MW)	Training needs (# of people)	Installations (MW)	Training needs (# of people)
Europe, Middle East, Africa	92,500	60,057	34,300	44,412
Asia-Pacific (except China)	39,200	31,227	12,200	32,659
Americas (except USA)	26,800	15,660	-	-
China	194,500	149,256	34,500	70,099
USA	46,000	51,624	9,100	25,381
Total (global)	399,000	307,924	90,100	172,281
Total (global onshore and offshore)	**480,205**			

Credit: Global Wind Workforce Outlook: 2021-2025: Global Wind Organisation and Global Wind Energy Council. 2021.

beyond the suite of basic safety, in skills such as Advanced Rescue, Enhanced First Aid and Blade Repair.

Beyond Europe, there are a further 40,000 people with GWO certifications and there is already potential to double this number by the end of 2022 according to current estimates.

To take us beyond 2022 and the long-term target of nearly half-a-million trained technicians, we have a challenge to meet in terms of encouraging investment into institutions to train the workforce.

Training can be delivered in a variety of ways, but a rough estimate suggests that a 'typical' GWO-certified training centre will at a minimum require three instructors to manage a pipeline of 240 participants per year, or one instructor per 80 students.

This allows for a participant to instructor ratio of 4:1 during the more hazardous practical courses such as Working at Heights and Sea Survival, as opposed to classroom training for theory elements where a 12:1 ratio is permitted according to GWO standard.

To take this idea further, the Global Wind Workforce Outlook 2021-2025 indicates that a country such as the United States will require a GWO-trained workforce of more than 25,000 to meet its projected offshore installations by 2025. This equates to around 320 instructors. In China, where some 70,000 technicians will be needed, the instructor demand for offshore training is approaching 900 people.

For this reason, GWO instructor qualification training is a priority, but we must also help bridge the gap by encouraging greater knowledge-sharing with regional industry associations and policymakers. Our intention is to support all markets by helping them introduce a system that complements existing health and safety regimes. If we work together, sharing the twin goals of achieving safety and creating new jobs, we can achieve great things as a truly sustainable industry.

With input from: Ralph Savage, Director for Global Development and Stakeholder Relations, GWO

Japan

New direction for Asia's first offshore wind market

2020/21 has been a big year for the offshore wind sector in Japan. Despite the first projects being installed in 2003, the focus in Japan has remained on testing and demonstration, and only in 2021 has construction started on a first generation of commercial-scale offshore projects.

Japan fell behind thanks to a combination of complex geography and regulatory uncertainty. However, Prime Minister Yoshihide Suga's vow that Japan will achieve carbon neutrality by 2050, backed up by the largest national offshore wind target seen globally with a plan to deliver 10 GW by 2030 and 30-45 GW by 2040 means increasing sector confidence and growing investment.

The Government's Offshore Wind Industry Vision includes an agreed government-industry cost reduction pathway to bring down offshore wind costs to JPY 8-9/kWh (EUR 0.06-0.07/kWh) by 2030-35 and to deliver local content of 60% by 2040. Alongside industry commitments on cost and local content, the government is looking at central coordination of planning of projects to ensure efficient, fair and transparent auctions, master planning of the required electricity network, and support for skills growth needed in the industry.

GWEC and JWPA policy leadership

GWEC has been actively supporting offshore wind growth in Japan since 2018, with efforts stepping up in 2020. In partnership with the Japanese Wind Power Association, GWEC established a Japan Offshore Wind Taskforce to bring industry together. This Taskforce initiated coordination work to bring industry and government together to work on offshore wind acceleration, through the Public-Private Council for Strengthening the Industrial Competitiveness of Offshore Wind.

This Council aimed to ensure efficient cooperation and knowledge sharing, and to support work to deliver economic cost-competitiveness and socio-economic benefits. The Taskforce also produced a major Cost Reduction Study on Offshore Wind, produced by the Mitsubishi Research Institute and BVG Associates. This work played an important role in building government confidence in offshore wind's ability to bring down costs, and shaped agreement on future targets.

Increased sector confidence

The Japanese government launched the first offshore wind auction in June 2020 with 11 auction zones now known. These auctions stem from the Japanese *Act on Promoting the Utilization of Sea Areas for the Development of Marine Renewable Energy Power Generation Facilities.*

Japan's first floating wind farm auction began last June with the successful bid announced in June 2021. A consortium of six companies (Toda Corporation, ENEOS Corporation, Osaka Gas, Kansai Electric Power, INPEX, and Chubu Electric Power) bid successfully (as the only bidder) for the rights to develop a 16.8 MW floating project, consisting of 8 units of 2.1MW turbine on the spar-type floating foundation, offshore near Goto City in the Nagasaki Prefecture.

In November 2020, the auction process for Japan's first fixed bottom offshore wind auction opened, closing to bids at the end of May 2021. That auction covered four offshore wind zones, three zones are located off Akita Prefecture: Noshiro (Mitane Town and Oga City), Yurihonjo City North, and Yurihonjo City South and the fourth zone, Choshi City, is situated off Chiba Prefecture. The winner will be announced in November 2021.

In July 2021, Japan's METI chose three government-led central coordinated research projects, including Gann-u and Minami-Shiribeshi in Hokkaido prefecture, Sakata in Yamagata prefecture Hirono in Iwate prefecture. Wind resource measurement, seabed survey and environmental impact assessment for those three projects will be completed by the government before the auction.

In response to these and future auctions, many leading global players have now formed joint ventures with local Japanese companies and/

or set up local operations, with companies seeking to align and work on auction bids. Local players like Marubeni, J-Power, Kansai, TEPCO and Sumitomo are active in the market, and are seeking to bring their experience from investing in offshore wind in Europe back home to Japan.

Ørsted, Japan Wind Development Co. (JWD), and Eurus Energy are working in partnership to develop projects off the coast of Akita, with Ørsted also in partnership with TEPCO on other auction bids. Kyuden Mirai, a subsidiary of Kyushu Electric Power Co, has signed a partnership with RWE, MHI has also signed similar partnership with CIP, and Equinor is working with Electric Power Development (J-Power) and JERA. Spanish company Iberdrola reached an agreement with Macquarie's Green Investment Group (GIG) to acquire 100% of the Japanese offshore wind developer Acacia Renewables in 2020. In Q1 2021 Iberdrola also signed an agreement with Japanese oil company Cosmo Eco Power (COSMO) and engineering firm Hitz to jointly develop a 600 MW site in Aomori prefecture in readiness for the second round of expected capacity auctions.

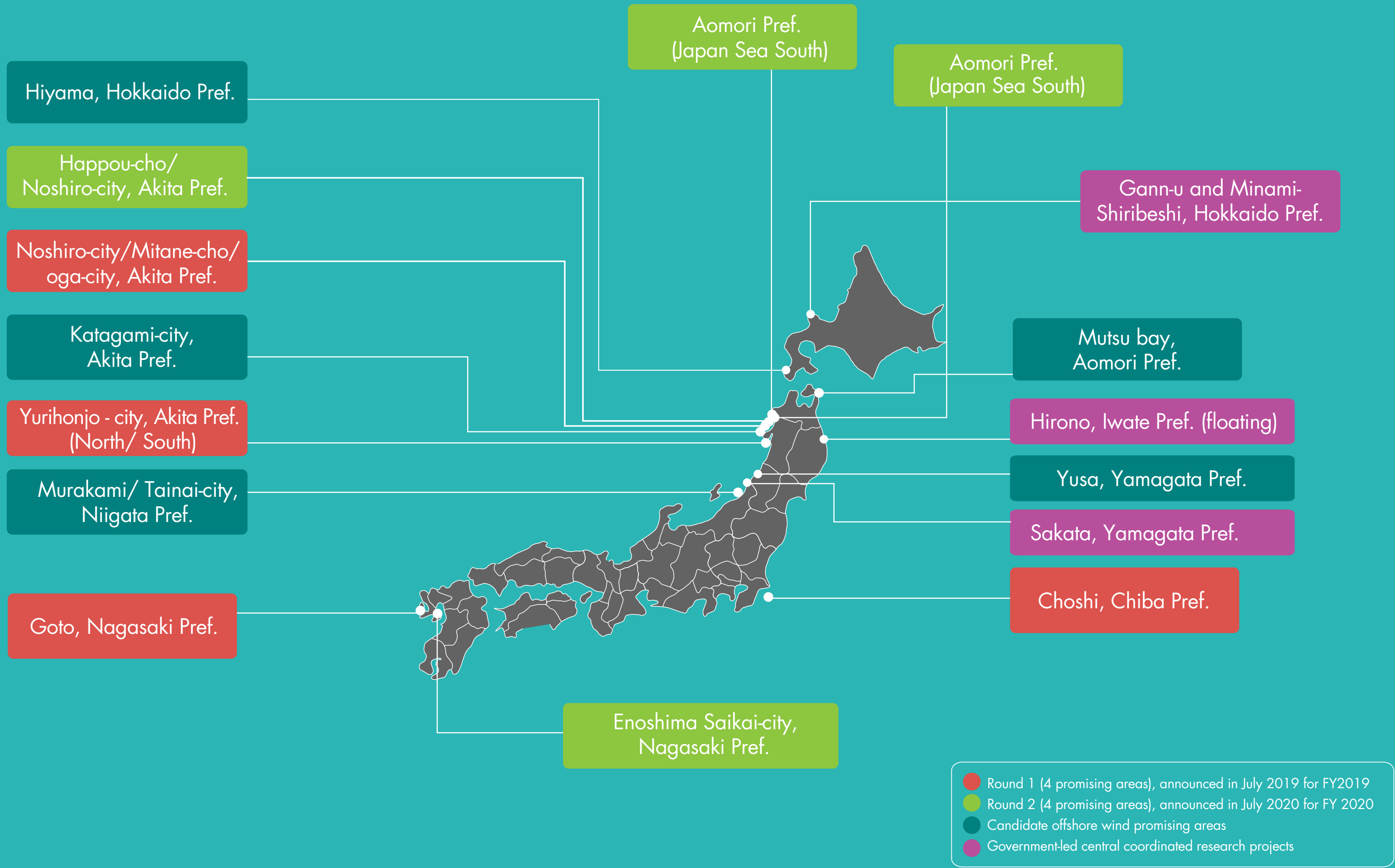
Progress in government auction rounds over the past 12 months is summarised in the table below.

Japanese offshore auction progress list

Stage of progess	Round1 (FY2019)		Round2 (FY2020)	
	Initial (July 2019)	Progress (July 2020)	Initial (July 2020)	Progess (November 2020)
Candidate zones	Japan Sea side North, Aomori Japan Sea side South, Aomori Mutsu bay, Aomori Happou-cho & Noshiro, Akita Kisakata, Akita Murakami & Tainai, Niigata Enoshima Saikai-city, Nagasaki		Hiyama, Hokkaido Mutsu bay, Aomori Kisakata, Akita-city, Akita Yusa, Yamagata Murakami & Tainai, Niigata	
Promising areas	Noshiro, Akita Yurihonjo, Akita Choshi, Chiba		Japan Sea side North, Aomori Japan Sea side South, Aomori Happou-cho & Noshiro, Akita Enoshima Saikai-city, Nagasaki	
Official promotion areas	Goto, Nagasaki	Noshiro, Akita Yurihonjo North, Akita Yurihonjo South, Akita Choshi, Chiba		
Areas with auction already launched		Goto, Nagasaki		Noshiro, Akita Yurihonjo North, Akita Yurihonjo South, Akita Choshi, Chiba

Source: JWPA, July 2021

Nominated offshore wind promising areas from Rounds 1, 2 and government-led central coordinated research projects in Japan



Source: METI, MLIT, JWPA, July 2021

Growing a Japanese supply chain

In May 2021, GE Renewable Energy and Toshiba announced a strategic partnership agreement to localize manufacturing of GE's Haliade-X offshore wind turbine at Toshiba's factory based in Yokohama city. After Mitsubishi Heavy Industries ended their 50/50 joint venture with Vestas, the two companies have now established a Japanese venture – MHI Vestas Japan Co. Ltd – to explore renewable hydrogen opportunities in Japan. In July 2021, JFE Engineering announced the plan to produce monopile and transition piece in new factories in Japan. Companies like Hitachi Zosen, Hitz and Marubeni are working on floating offshore wind platforms and foundation technologies more suited to the Japanese market.

Rapid change on the horizon

After many years of discussion and much engagement, Japan is now moving beyond research and demonstration with an auction program in place to drive delivery of new schemes. Local and international players are active in the market with growing confidence and investments being made. From the 65 MW in operation at the end of 2020, GWEC Market Intelligence forecasts that a total of 8.2 GW of offshore wind is likely to be operational in Japan by 2030, of which 2 GW is expected to be floating wind.

South Korea

South Korea pushing the reset button on offshore wind

Nearly a decade ago, South Korea adopted an ambitious Green Growth Strategy that aimed to reduce greenhouse gas emissions by 30% by 2020. This strategy marked the beginning of "green growth" as the direction of travel for South Korea's economic growth, sparking the interest of domestic industrial conglomerates (such as Samsung, Hyundai, Doosan and STX) in renewable energy project development and equipment supply.

Following a 2.0 MW STX direct drive offshore turbine and a 3.0 MW Doosan geared drive turbine installed in early 2010s for testing purpose, the 30 MW Tamra offshore wind farm came online off Geumdeung-ri in Jeju Island in 2016. However, the sector has been generally slow to take off, due to public opposition on environmental and livelihood (fishing) issues. Long permitting periods and a low initial feed-in tariff (prior to the introduction of the Renewable Portfolio Standard scheme) also dampened growth.

As a result, South Korea's initial foray into "green growth" and a clean energy transition saw little translation into action for the better part of the last decade.

Nonetheless, at the start of a new decade, the momentum for offshore wind in South Korea is picking up with the passage of President Moon Jae-in's Green New Deal and a groundswell of interest from an ambitious consortium of local and international wind energy developers. With floating offshore wind now ready for commercial deployment globally, South Korea has demonstrated clear ambition to lead scale up in Asia, using its fixed and floating resource.

Policy support stronger than ever

Growth in modern South Korea is built upon energy-intensive industries such as electronics, automotive and shipbuilding, many of which are difficult to decarbonise. As such, the nation is still embroiled in public debates over its commitment to coal, gas and nuclear power, imposing a drag on the transition to cleaner and more secure renewable energy sources.

Now, with President Moon in office and the re-election of the Democratic Party in 2020, South Korea can press ahead with its newly adopted Green New Deal. To boost the green sector, South Korea plans to invest a total of 12.9 trillion won (US$10.8 billion) in green buildings, urban forests and low-carbon energy production by 2022 and create 133,000 jobs in the process. Under this plan, South Korea has become the first group of countries in East Asia to pledge to reach net zero emissions by 2050.

Through its Third Energy Plan, released in June 2019, South Korea's "Renewable Energy 3020" target for 20% of total electricity consumption to come from renewable energy by 2030 (currently around 6%) and to increase that share to 30-35% by 2040. Given insufficient land available for onshore wind and low

solar radiation, attention has moved offshore. Over 12 GW of new offshore wind capacity needs to be installed to reach the country's goals. To make this happen, President Moon Jae-in oversaw the agreement to develop an 8.2 GW offshore wind complex in South Jeolla which was signed by more than 30 public and private entities based in South Korea in February 2021. In May 2021, the South Korean Government has also announced plans to build a 6 GW floating offshore wind farm off the coast of Ulsan by 2030.

Strong local industrial base dedicated to offshore wind

South Korea's industrial experience in steel, shipbuilding and logistics could translate to competencies in offshore engineering and supply chain efficiencies, smoothing the pathway to developing a localised offshore wind industry.

For instance, its marine and offshore industry will play a critical role fabricating offshore wind jacket foundations, with local shipyard company Samkang already delivering jacket foundations to the Changhua Demonstration project in Taiwan. South Korea also has the advantage of high R&D intensity in shipbuilding and cabling, allowing Samsung and Hyundai to build offshore wind installation vessels and local company LS Cable & System to manufacture offshore cables for markets in Europe and the US.

South Korea also has its own wind turbine manufacturers. Of these, Doosan has the longest track record in offshore wind with 96 MW installed. With its second production plant completed in Changwon in 2021, the company is expanding its product line up to an 8 MW platform from the current 3 MW and 5 MW models. In addition, local turbine suppliers Unison and Hyosung are seeking opportunities in offshore developments. Most recently, it was reported that Hyosung signed a joint venture with leading Chinese offshore turbine producer Shanghai Electric in South Korea with the goal of capitalizing opportunities in the offshore wind sector.

A strong local supply chain also exists for forging, with local companies Hyundai Forging, Hyunjin Materials, Kofco and Taewoong, as well as slewing bearings manufacturers Shilla and CS Bearing, already exporting products to overseas offshore markets.

International partnerships expected to accelerate offshore wind development

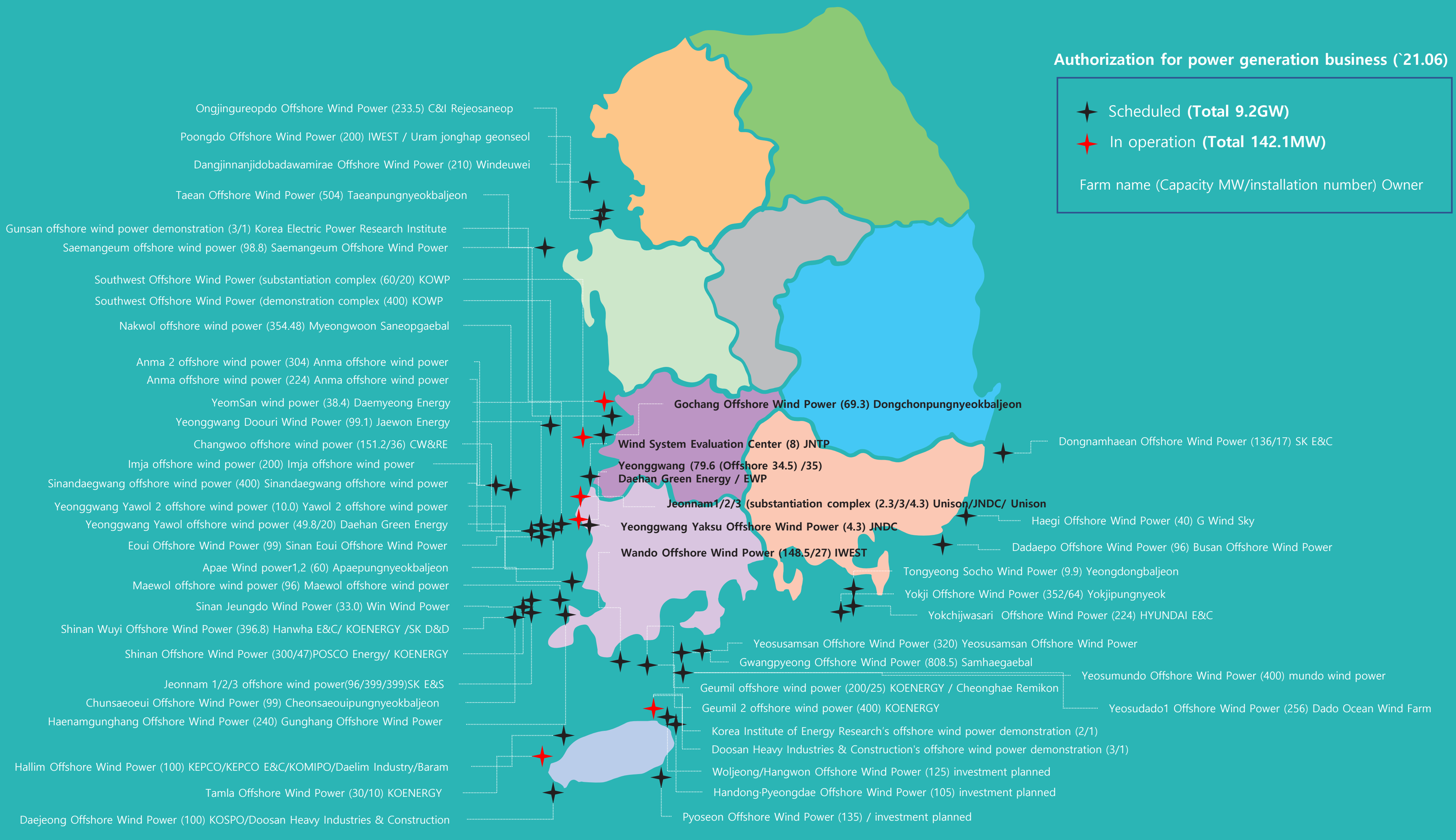
Leading international offshore players have recognised the potential for offshore wind (particularly floating offshore) in South Korea and are piling into the market.

Early last year, the port city of Ulsan signed a Memorandum of Understanding (MOU) with domestic and foreign partners and investors (including Royal Dutch Shell and CoensHexicon, South Korea's energy company SK E&S and Denmark's Copenhagen Infrastructure Partners, Macquarie's Green Investment Group (GIG) and Korea Floating Wind (KFWind)) to explore large-scale floating offshore wind development. In February 2020, Canadian power producer Northland Power acquired local wind developer Dado Ocean, which owns a portfolio of early-stage offshore wind projects in South Korea. In March, Ørsted signed an MOU with Korean POSCO Group to strengthen collaboration on offshore wind and renewable hydrogen in Korea and the latter will support the development of Ørsted's 1.6 GW offshore wind projects off the coast of Incheon City. Early this summer, Spanish utility Iberdrola also entered the South Korean renewable market (including offshore wind) by signing an MOU with Korean energy company GS Energy.

In addition to partnerships and acquisitions, large-scale floating projects are being developed by an international-local consortia. The 200 MW Donghae 1 floating offshore wind farm, nearly 60 kilometres offshore from Ulsan, is being developed by Equinor, the Korea National Oil Corporation (KNOC) and Korea East-West Power Corporation, for commissioning in 2024. In proximity to this project, Equinor recently commenced LiDAR installations to conduct metocean data measurements for a potential 800 MW floating offshore wind project.

By 2030, South Korea is expected to emerge as East Asia's hottest floating offshore wind market, with some of the world's biggest floating offshore wind farms, boosted by significant developer and investor appetite.

Status of offshore wind farm in Korea



Source : Korea Wind Energy Industry Association

Fulfilling the promise of South Korean offshore wind

As of the end of 2020, there are currently five operational offshore wind projects totalling 132.5 MW, including the latest and largest 60 MW demonstration Southwest Offshore Wind Project completed in January 2021 – the first phase of a massive 2.5 GW project. Over 45 offshore wind projects are in preliminary development (totalling 9.2 GW), as shown below.

Despite its slow start, South Korea's offshore wind sector is now benefiting from the financial clout coming from both state-owned and foreign investors and buoyed by its existing industrial infrastructure. GWEC Market Intelligence forecasts that a total of 8.7 GW of offshore wind is likely to be built in South Korea by 2030, of which 4.8 GW is expected to be floating wind.

However, South Korea remains a challenging market with respect to terrain complexity, turbulent wind conditions and strong incumbent energy and marine actors, particularly among the coal and fishing industries. Coupled with criticism that government rhetoric does not always match action, the market will need steadfast public steering and ambitious long-term targets to drive decarbonisation and diversify the power mix. Still, with sufficient government commitment and industry experience from neighbouring countries to smooth the learning curve, the future of South Korea's offshore wind sector looks bright indeed.

Vietnam

The long-awaited Power Development Plan VIII (PDP 8) - which outlines the strategies for the next decade of renewable energy development in Vietnam from 2021-2030 with a vision to 2045 - will be finalised at the end 2021. This plan could be one of the most significant pieces of legislation that enables the country to move into a green economy with better grid stability and a larger share of renewable energy generation. Offshore wind (OSW), for the first time, was introduced with a separate target in the PDP 8 draft release in February. With a modest target of 2-3 GW by 2030, and out to 21-36 GW by 2045, it signals the beginning of a true OSW development in Vietnam and urging the key industry stakeholders to prepare the ground to develop the first generation of OSW projects. With the final PDP 8 draft still under revision, the wind industry is asking for a more ambitious offshore wind target of 5 GW or even 10 GW by 2030. There is also an increase in activities among investors, developers and international agencies as different stakeholders look to join force and enter the blooming OSW market in Vietnam.

PDP 8 development and the need to increase offshore wind power in the future energy system

In the Draft PDP 8, non-hydro renewable energy is set to reach 30% of the total installed capacity by 2030, a two-fold increase from the 16% target previously indicated in PDP 7.[31] For wind power alone, Vietnam plans to develop an additional 15 GW of onshore and near-shore wind power, and 3 GW of OSW power by 2030. The total wind power capacity will be tripled from 6 GW in PDP 7 to 18 GW under the plan of Draft PDP 8 by 2030. The ratio of wind power capacity will account for 12% of the total installed capacity in 2025 and 13% of the total installed capacity in 2030.

The higher ambition for wind and renewable energy is in-line with the Politburo's Resolution No. 55-NQ/TW to diversify[32] the energy mix

31 https://www.globalcompliancenews.com/2021/03/13/vietnam-key-highlights-of-new-draft-of-national-power-development-plan-draft-pdp8-04032021-2
32 https://www.bakermckenzie.com/en/insight/publications/2020/02/vietnam-national-energy-development-strategy

and to ensure the country is ready for energy transition.

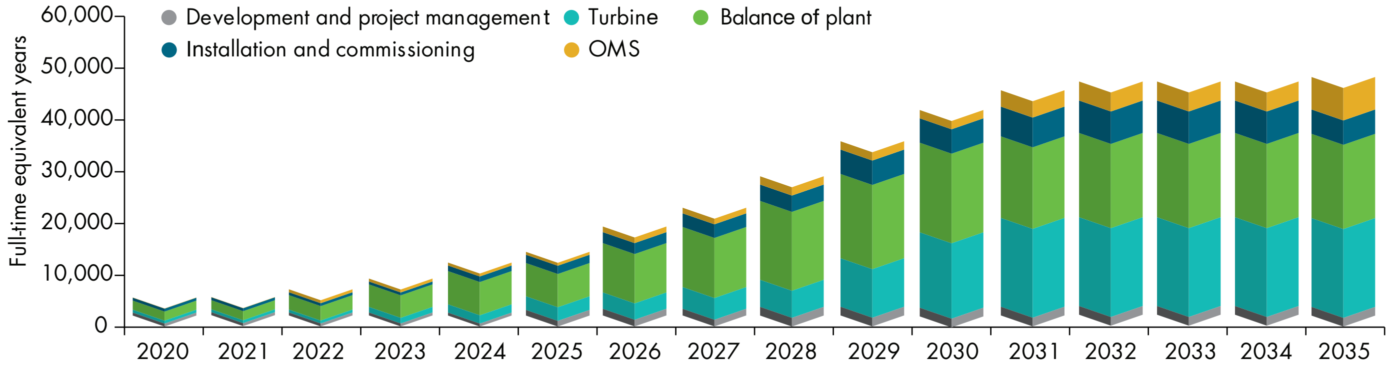
It is clear that renewable energy is the key to the future energy transition as the majority of European banks have divested from fossil fuel investment, and more will follow suit with the IEA's Net Zero Report which calls for global divestment from fossil-based projects. With the increasing prioritisation on renewable energy and enhancing grid infrastructure in the next decade, PDP 8 will pave the way for Vietnam to rely less on imported coal to meet the rapidly increasing electricity demand with lower carbon emissions.

Offshore wind roadmap: Prospects and outlook

Prior to the announcement of Draft PDP 8, the World Bank Group (WBG) and Danish Energy Agency (DEA) cooperated to develop an Offshore Wind Development Roadmap for Vietnam which outlines ways to tap on the country's huge offshore wind potential.

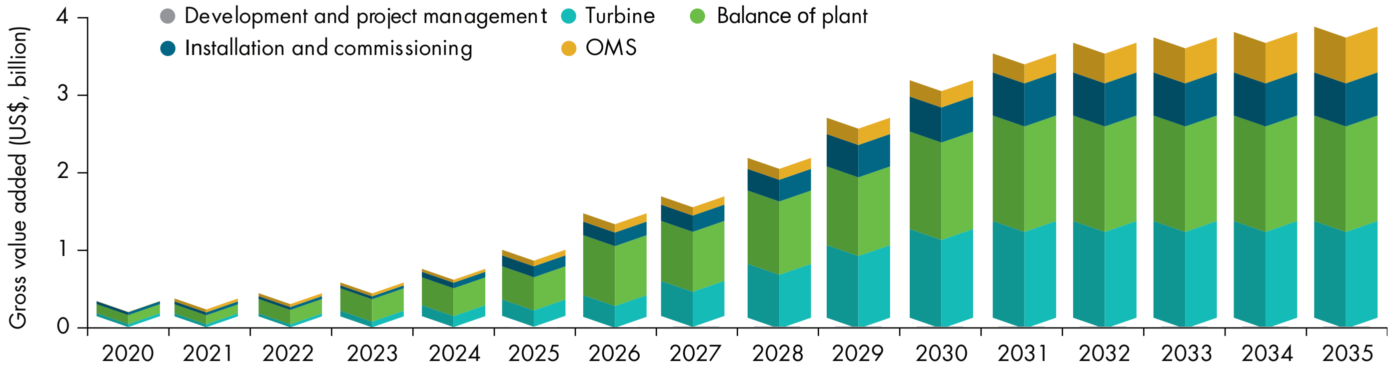
The WBG estimated that the offshore wind technical potential for Vietnam is 475 GW (261 GW for fixed foundation and 214 GW for floating foundation) and DEA's estimation indicated that

Vietnamese annual full-time equivalent years employment created by all vietnamese projects in the high growth scenario, split by cost element



Source: GWEC Market Intelligence, June 2020

Vietnamese annual gross value added created by all Vietnamese projects in the high growth scenario, split by cost element



Source: GWEC Market Intelligence, June 2020 after a constraints analysis, Vietnam will be left with a highly realisable technical potential of 160 GW.[33]

In the near term, under a high offshore wind growth scenario modelled by both WBG and DEA, a 10 GW target is achievable by 2030. A total capital investment of over US$500 million is needed to deliver the supply chain, in the area of turbine towers, blade manufacturing, foundation fabrication yard, subsea cables and installation vessels. In this scenario the cost of energy of the projects is expected to reduce to about US$70-80/MWh by 2030. All the local projects will provide about 45,000 full-time equivalent years (FTE) and a US$6.5 billion of gross value addition annually to Vietnam's economy by the 2030s.

Current offshore wind project development

Vietnam is currently experiencing a huge wave of capacity building activities, with Denmark, the UK, Germany, and USA investors actively investing in the offshore wind sector and international experts providing technical assistance to various governmental ministries across the whole supply chain. These are important precursors for a promising OSW market growth.

In 2020 alone, Vietnam has attracted significant foreign investment to develop two of the biggest OSW projects in Binh Thuan province. Some of these well-known developers are Enterprize Energy, Copenhagen Infrastructure Partners (CIP), Ørsted, Macquarie and Mainstream Renewable Power. Currently, there are approximately 20 OSW projects in different stages of construction, and GWEC estimates that around 1.2 GW will be in operation by the end of 2021.

In H1 of 2020, the announcement of the development of 3.4 GW Thang Long project by Enterprize Energy caught the international attention with its one-of-a-kind installation scale. As of April 2021, the offshore pre-survey operation has completed and the first 600 MW tranche of the project is expected to achieve commercial operation by the end of 2025. The remaining tranches will be developed on a rolling basis, subjected to grid availability. Similarly, in H2 of 2020, CIP has signed a memorandum of understanding (MoU) with Binh Thuan People's Committee to develop a 3.5 GW of OSW project. The estimated capital expenditure for this project amount to 8.5 billion Euro and is expected to generate significant number of green jobs and improve the incomes level for the province and the country. As of May 2021, the project is undergoing a site evaluation survey study.

Industry challenges: Supply chain bottlenecks, FiT expiry and auction design

For the initial stage of development, like any other new offshore wind market, Vietnam will face with a long list of financial, political, and technical challenges in the areas of marine spatial planning, permitting and procurement process, and local supply chain development, as well as building of ports, grid and other critical infrastructures.

On top of these common challenges, the approaching expiry of wind power feed-in tariff on 31st October 2021 will pose a great deal of uncertainty for the future wind projects. It is unclear what mechanism will be adopted by the government to support future wind projects and how it will impact the returns of the first-generation offshore wind projects mentioned earlier. The government is currently at the planning stage of designing an auction system for wind power, including offshore wind. However, with a highly complex supply chain and high-risk index, offshore wind auction design will not be an easy task. The wind industry is currently advocating for a transition phase to facilitate a smooth transition into an auction system. The aim is to provide sufficient time for the government to design a robust auction mechanism unique to the Vietnam market and to support and stabilise the development of the existing supply chain.

Another key challenge is the limited bankability of the offshore projects under international standards. Unlike solar and the onshore wind sector which can be financed domestically, the offshore wind sector requires much bigger project finance and hence the need for international financing to resolve the PPA bankability issues.

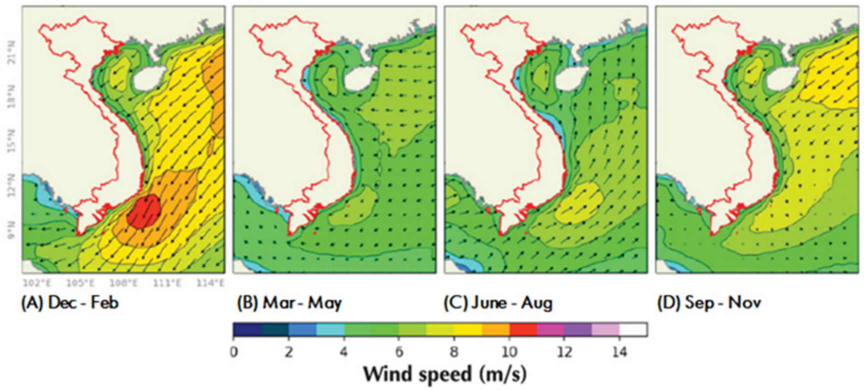
33 https://ens.dk/sites/ens.dk/files/Globalcooperation/d5_-_input_to_roadmap_for_offshore_wind_development_in_vietnam_full_report_english_final_2020-09-21.pdf

Unique benefits: High capacity factor and grid compatibility

The new range of global capacity factors is approximately 40 - 50%, with technology progression, it has the potential to reach 60% by 2050. With this, and a low hourly power generation variability, offshore wind will eventually match the capacity factors and efficiency of fossil fuel power plants.

Furthermore, as a country with hydropower contributing to 30% of the energy mix, offshore wind offers great complementarity with hydropower. The high wind speed period in Vietnam matches with its dry seasons (November-April) in which the hydro reservoir is at its lowest operation capacity. Similarly, the low wind speed period collides with the rainy season (May – October) when the hydro reservoir is being replenished and at its peak operation capacity.

Seasonal Average Surface Wind Speed within Five Years from 2007 to 2011



The US

The offshore wind technical resource potential in the United States exceeds 5,000 GW, but the total offshore wind installations in the country is only 42 MW after the 12 MW Dominion Virginia demo project was installed last year. Nevertheless, the US offshore wind market has picked up strong momentum in the past few years. Particularly, a recent series of federal and state commitments and announcements – from the Biden Administration's ambitious 30 GW by 2030 offshore wind target to Vineyard Wind's approval by the Bureau of Ocean Energy Management (BOEM), to the coasts opening off California and Gulf of Mexico, and to more states increasing or announcing their offshore wind targets, has made 2021 an unprecedented year for US offshore wind.

Ambitious target set by the New Administration

A series of milestones have been achieved since the inauguration of United States President Joe Biden. Following the Executive Order on 27 January to direct the Department of Interior (DOI) to speed up the offshore wind energy production, the Biden Administration set a national target of 30 GW of installed offshore wind capacity by 2030 in March 2021. According to the White House, the ambitious offshore wind target will support about 44,000 direct jobs and trigger more than USD 12 billion annual investment in projects on both U.S. coasts and achieving this target also will unlock a pathway to 110 GW by 2050 creating more jobs and further economic opportunity for the coast states.

Regulatory breakthrough at federal level

BOEM is responsible for managing development of offshore resources in federal waters in the US. In 2009, the DOI announced final regulations for the Outer Continental Shelf (OCS) Renewable Energy Program, which provides a framework for issuing leases, easements, and rights-of-way for OCS activities that support production and transmission of energy from sources other than oil and natural gas. Since the regulations

East Coast offshore wind project and lease areas

Source: BOEM, ACP, January 2021

were enacted, BOEM has issued 16 commercial and two non-competitive offshore wind energy leases on the Atlantic, from Cape Cod to Cape Hatteras, as of the end of 2019. Although, in total, those offshore wind leases could support more than 21 GW of generating capacity, project permitting, especially the final approval from BOEM for the Construction and Operations Plan (COP), has been reported as a major challenge for project development during the Trump's presidency.

However, a set of bold actions that will catalyse offshore wind development was announced since President Biden took over the White House. In January, DOI's BOEM and Bureau of Safety and Environmental Enforcement (BSEE) agreed to a framework for coordination in regulating renewable energy activities on the OCS. To position the domestic offshore wind industry to meet the 2030 target, BOEM plans to advance new lease sales and complete review of at least 16 COPs by 2025, representing more than 19 GW of offshore wind capacity to be installed off the U.S. coasts. To unlock the deployment potential, BOEM identified new priority wind energy areas in the New York Bight covering nearly 800,000 acres of shallow waters between Long Island and the New Jersey coast in March. Two months later, DOI, in cooperation of Department of Defence (DOD), identified an area that will support 3 GW of offshore wind off California's central coast region, northwest of Morro Bay. The processes for the northern and central coasts will then be merged in a Proposed Sale Notice (PSN) for one lease sale auction, targeted for mid-2022. In addition, the DOI is also advancing the Humboldt Call Area as a potential Wind Energy Area (WEA), located off northern California. In total, these initial areas could bring up to 4.6 GW of offshore wind including floating wind to the grid. In June, BOEM also issued the Request for Interest (RFI) in commercial leasing for wind power development on the Gulf of Mexico Outer Continental Shelf. The RFI will be focused on the western and central planning areas of the Gulf of Mexico offshore the states of Louisiana, Texas, Mississippi, and Alabama.

In December 2020, Vineyard Wind announced that it would temporarily withdraw is construction and operations plan for its 800 MW project off the coast of Massachusetts. With the Biden Administration taking office, Vineyard rescinded its withdrawal in early 2021. In May, DOI announced approval of the construction and operation plan of the Vineyard Wind project - the first large-scale offshore wind farm in the United States, truly representing the start of the US offshore wind development. Additionally, as of July 2021, BOEM has started a series of environmental reviews of offshore wind projects including Revolution Wind project, Ocean Wind project, Kitty Hawk offshore wind project and Dominion Energy's Coastal Virginia Offshore Wind project.

Strong momentum at the state level

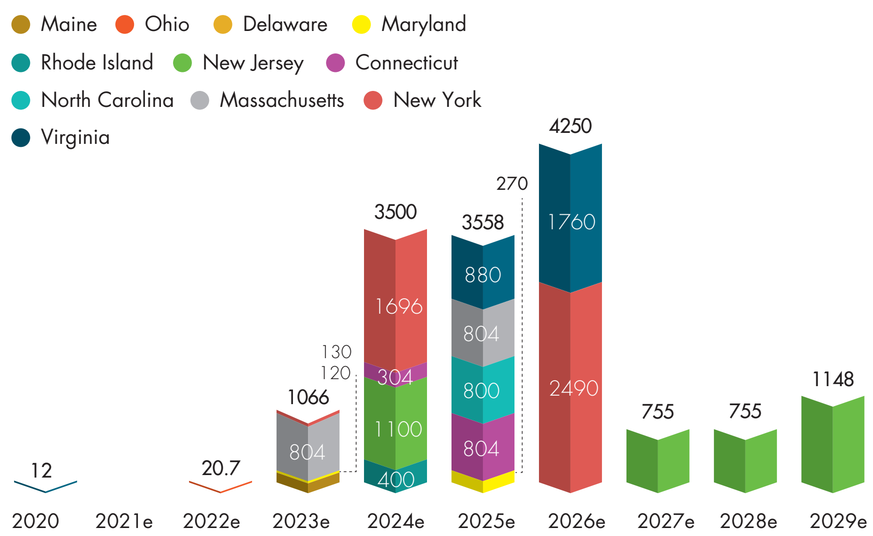
The East Coast cluster consisting of Maine, Connecticut, Rhode Island, Massachusetts, New York, New Jersey, Delaware, Maryland, Virginia and North Carolina is driving strong demand for offshore wind energy. 2021 saw an increase of existing offshore targets, first in Virginia and then Massachusetts. In June, Governor of North Carolina issued an executive order calling for the development of 2.8 GW of offshore wind power by 2030, and 8 GW by 2040. Those new targets bring the total announced offshore wind procurement targets on the state level, through either legislation, conditional targets or executive orders, from 28.1 GW in 2020 to 38.5 GW (see figure on page 32 in Global Market Outlook section).

In addition, progress has been made on the state-level solicitations. Although the coronavirus pandemic caused disruptions across the state, Maryland opened up its second round of applications for at least 400 MW offshore wind in Q1 2020. NYSERDA also launched its second offshore wind solicitation in July 2020, seeking up to 2.5 GW of offshore wind, which makes it the largest in the US history. New Jersey followed in September with a second solicitation, seeking up to 2,400 MW of offshore wind capacity. Rhode Island announced a competitive Request for Proposals (RfP) for up to 600 MW of new offshore wind power one month later. State-level solicitations continues to move on in 2021. Massachusetts issued its third RfP aiming at procuring at 400-1,600 MW of offshore wind capacity in May and the results are expected to be announced in late 2021.

Market ready to take off from 2023

According to GWEC Market Intelligence global offshore wind database, as of the end of H1 of 2021, the US offshore wind pipeline totalled more than 30 GW in both federal and state waters, of which 18 offshore wind projects have secured offtake or won state solicitations and announced an anticipated year of operation. Developers expect a total of 15 GW of offshore wind to be online between 2022 and 2029 (see figure on the right). Out of the 15 GW of offshore wind capacity, 28.7% is likely to be built in New York, followed by New Jersey (25.0%), Virginia (17.5%), Massachusetts (10.7%). With regards to project ownership, the situation is the same as last year and the majority of assets planned to be built in 2022-2029 are controlled by European developers including utilities such as Ørsted, Avangrid Renewables (a subsidiary of Spain's Iberdrola), and EDPR and oil and gas companies like Equinor and Shell. It

Expected annual offshore wind installation by state, 2020-2029



Note: This forecast is only based on projects with commission date announced. For the entire 2021-2030 US offshore wind forecast, please see the Market Outlook chapter.

Source: GWEC Market Intelligence, July 2021

is worth highlighting that oil giant BP acquired a 50% interest in Equinor's Empire Wind and Beacon Wind in September 2020 and the consortium was selected by NYSERDA as the winner of the state's second offshore wind solicitation in early 2021.

Compared to GWEC's US offshore wind outlook in last year's Global Offshore Wind Report, adjustments have been made for the commission date for projects expected to come online in the near-term. The primary reason for the change is due to the recent federal approval of the 800 MW Vineyard Wind project made the previous announced project commission schedule become realistic. Additionally, in GWEC's updated US offshore outlook we included the four projects that won the second offshore wind solicitations in both New York and New Jersey in 2021.

As of the end of H1 2021, offshore developers have selected or announced preferred turbine suppliers for eight offshore projects. Thanks to Dominion Energy's 2,640 MW project off the coast of Virginia, Siemens Gamesa remains as the largest winner with a 4,354 MW order backlog in the US, followed by GE Renewable Energy (2,024 MW). However, the latter increased its US offshore order backlog by 66 % after the project developer of Vineyard Wind switched its offshore wind turbine selection from MHI Vestas V164-9.5 MW to the GE Haliade-X wind turbine model. Due to the same reason, the order backlog of Vestas in the US dropped to only 21 MW. As of today, the most popular models selected for these projects are SGRE's SG14-222 DD (released by SGRE in May 2020) and GE's Haliade X- 12MW DD.

Challenges starting to be addressed to ensure growth

Slow project permitting processes, local supply chain, port infrastructure, grid and work force were highlighted as the key challenges by the leading European developers when they entered the US offshore wind market. To pave the road for the industry to take off in the US, however, achievements were made in the past 12 months in the following areas (aside from project permitting and consenting breakthrough already mentioned in the early section of this profile).

Local supply chain – Balance of plant

Partnerships with experienced European companies at all levels of the supply chain and in different states have been adopted as a strategy to maximise US offshore wind potential.

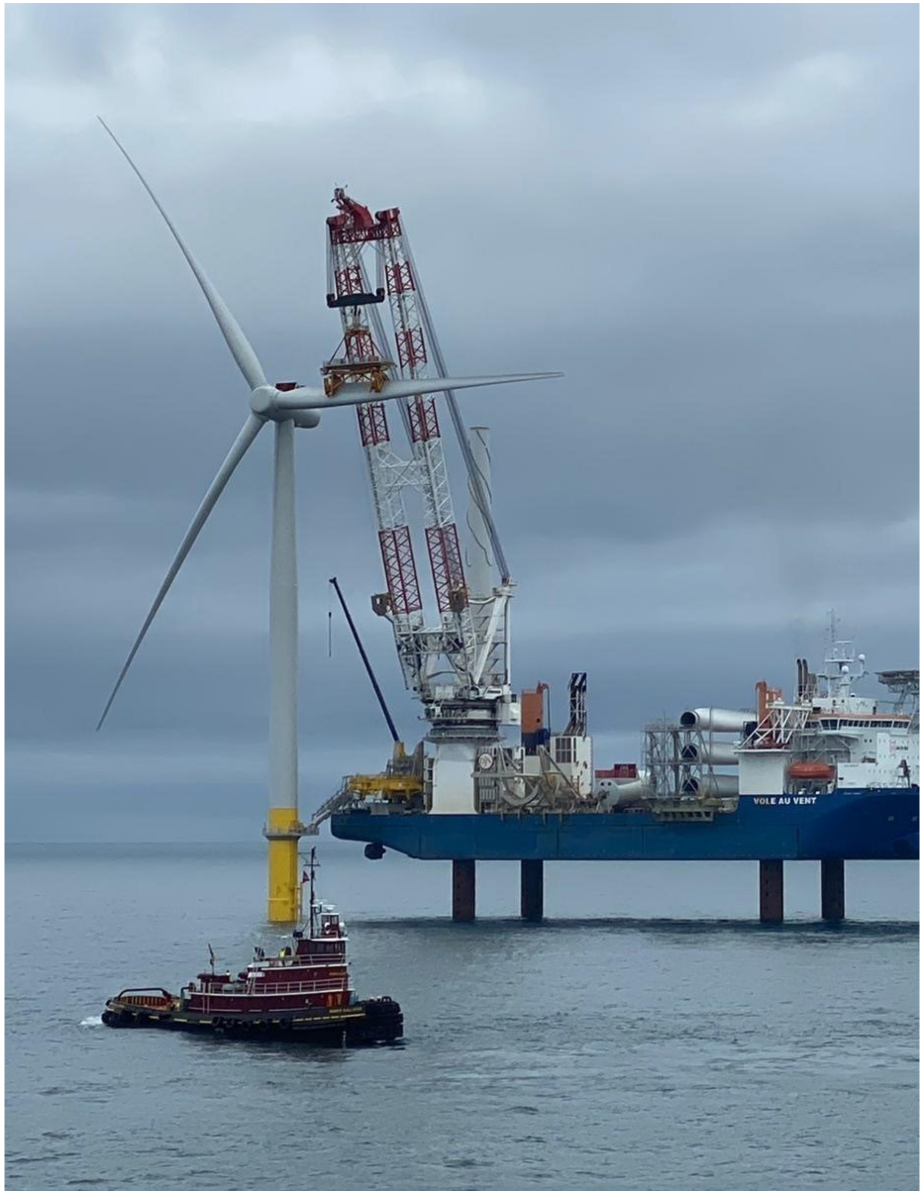
Last November, the US-based Burns & McDonnell formed a strategic alliance with leading European foundation supplier Bladt Industries to provide steel and other offshore wind components along the Eastern coast. Following the Memorandum of Understanding (MoU) signed last summer by Ørsted and EEW to work towards establishing a monopile fabrication facility in Paulsboro, New Jersey for the Ocean Wind project, the two Europeans companies together with local members of the building trades have broken ground for the EEW monopile manufacturing facility in April. In addition, the Danish developer together with the joint venture partner Eversource are establishing a manufacturing facility for offshore wind foundation components at ProvPort in Rhode Island, which will be used for their offshore wind projects in Rhode Island, Connecticut and New York. To support the local supply chain, Vineyard Wind has selected the US-based Southwire to design, manufacture, and install the onshore cables for Vineyard Wind 1 wind farm. Last but not at least, a US offshore wind supply chain study project was launched by state and federal authorities in May. The purpose of the project is to put together a Supply Chain Roadmap which will present the collective benefits of a domestic supply chain and facilitate the acceleration of the offshore wind industry in the United States.

Local supply chain – Vessels

Jones Act compliant offshore wind installation vessels are essential to getting projects built in the US. Although European wind turbine installation vessels (WTIV) were used for the first two US offshore wind projects, the situation is likely to change when Dominion Energy's Charydis, the first Jones Act compliant WTIV is delivered in 2023. Early this summer, Ørsted and Eversource agreed with the owner to charter this WTIV for the construction of two offshore wind farms Revolution Wind and Sunrise Wind in the US Northeast.

In response to the strong local demand, US companies MiNO Marine and 2nd Wind Marine also announced the plan last summer to start building two Jones Act compliant offshore wind construction support (feeder) vessels to transport wind turbine components from US ports to installation vessels at offshore wind construction sites. The same decision was made by Ampelmann and C-Job in 2021. Additionally, US based Great Lakes Dredge & Dock Corporation (GLDD) is developing the first US-flagged Jones Act compliant vessel for subsea rock installation.

To support the local growth, the Florida-headquartered Crowley Shipping also formed a new division focusing on the offshore wind sector in the United States early this year. Crowley Shipping expects its expansion in the offshore wind industry to be as a total lifecycle service provider, with tailored solutions in support of the entire project. In addition, Crowley has signed partnerships with US companies and a joint venture agreement with Danish ESVAGT to create a single-source terminal and supply chain management solution and to bolster purpose-built, Jones Act vessel in support of the emerging US offshore wind energy market respectively.



Infrastructure – Ports

To upgrade the country's ports to accommodate the upcoming surge in offshore wind projects, the US Department of Transportation's (DOT) Maritime Administration has announced a Notice of Funding Opportunity for port authorities and other applicants to apply for USD 230 million for port and intermodal infrastructure-related projects through the Port Infrastructure Development Program. Currently, offshore wind ports are under construction in the following states:

- New Jersey Wind Port, on the eastern shore of the Delaware River. Construction is planned in two phases with Phase 1 expected to begin in 2021 and Phase 2, targeted to begin in 2023. The Wind Port has the potential to create up to 1,500 manufacturing, assembly, and operations jobs.
- The city port's State Pier in New London, Connecticut. The proposed two-phase State Pier infrastructure improvement project will be used for wind turbine generator pre-assembly and staging to power Revolution Wind, Sunrise Wind, and South Fork Wind projects with a combined capacity of more than 1.7 GW.
- The South Brooklyn Marine Terminal (SBMT) and the Port of Albany, New York. Following the state's 2nd offshore wind solicitation that requires developers to includes a multi-port strategy and to partner with any of the eleven pre-qualified New York ports, the winners, Equinor and bp, agreed to partner with the State of New York to transform the South Brooklyn Marine Terminal (SBMT) and the Port of Albany into large-scale offshore wind working industrial facilities.
- Arthur Kill Terminal, Staten Island, New York. Agreement with investment funds has been signed for this offshore wind energy staging and assembly port, which is expected to begin operating in late 2025.
- The New Bedford Marine Commerce Terminal in Massachusetts. The state has signed lease agreements with Vineyard Wind and Mayflower Wind to use the terminal as the primary staging and deployment base for the construction and installation of their offshore wind projects.
- Tradepoint Atlantic's port facility in Baltimore County, Maryland. Ørsted and Tradepoint Atlantic completed the initial phase of Maryland's first offshore wind staging centre in March 2021 and are now beginning preparations for the second phase of the staging centre.

Infrastructure – Grid

In November 2020, the New Jersey BPU and the regional electricity grid operator PJM signed an agreement known as a State Agreement Approach (SAA) for solicitation of offshore wind transmission solutions, which set New Jersey on a path to become the first US state to fully align its offshore wind transmission goals with its regional grid operator's planning process. The US electric transmission project developer Anbaric Development Partners has decided to participate the solicitation with DNV GL as a partner. At the end of last year, the US Department of Energy (DOE) has launched a Request for Information (RFI) process regarding the research needs for integration of large-scale offshore wind energy generation into the transmission grid.

Workforce development

A trained and skilled workforce is one of the critical factors to build the local offshore industry and meet ambitious targets. Last September, the New Jersey Economic Development Authority (NJEDA) and the Board of Public Utilities (NJBPU) approved two MOUs to support offshore wind and other clean energy projects. Under the agreements, New Jersey's Clean Energy Program (NJCEP) will provide USD 4.5 million to support NJEDA-led workforce development projects to prepare more local workers for offshore wind jobs. In January 2021, The State University of New York (SUNY) and the New York State Energy Research and Development Authority (NYSERDA) have launched the Offshore Wind Training Institute (OWTI). Through a partnership between SUNY's Farmingdale State College and Stony Brook University, the USD 20 million investment will advance offshore wind training programs and the educational infrastructure needed to establish a workforce that can support the national offshore wind industry. In the same month, the new purpose-built Maryland Offshore Wind Training Center developed by ARCON Training Centre opens for business after receiving approval from the Global Wind Organization (GWO). Early this summer, Massachusetts government also announced USD 1.6 million in grant funding to eight organizations to support offshore wind workforce training programs.

With input from: American Clean Power Association

Taiwan

Taiwan is heating up as the second-largest offshore wind market in the Asia-Pacific region, after Mainland China. Ambitious capacity targets set by the Democratic Progressive Party (DPP) government have attracted eager interest from leading offshore wind developers and technology providers. Already, 128 MW of offshore capacity has been installed at Formosa 1, Taiwan's first commercial-scale offshore wind farm in Miaoli County, and a further 1.1 GW is expected to come online from the Changhua phase 1, Formosa II and Yulin offshore wind farms by the end of 2021.

New target showing the ambitions, but challenges remain

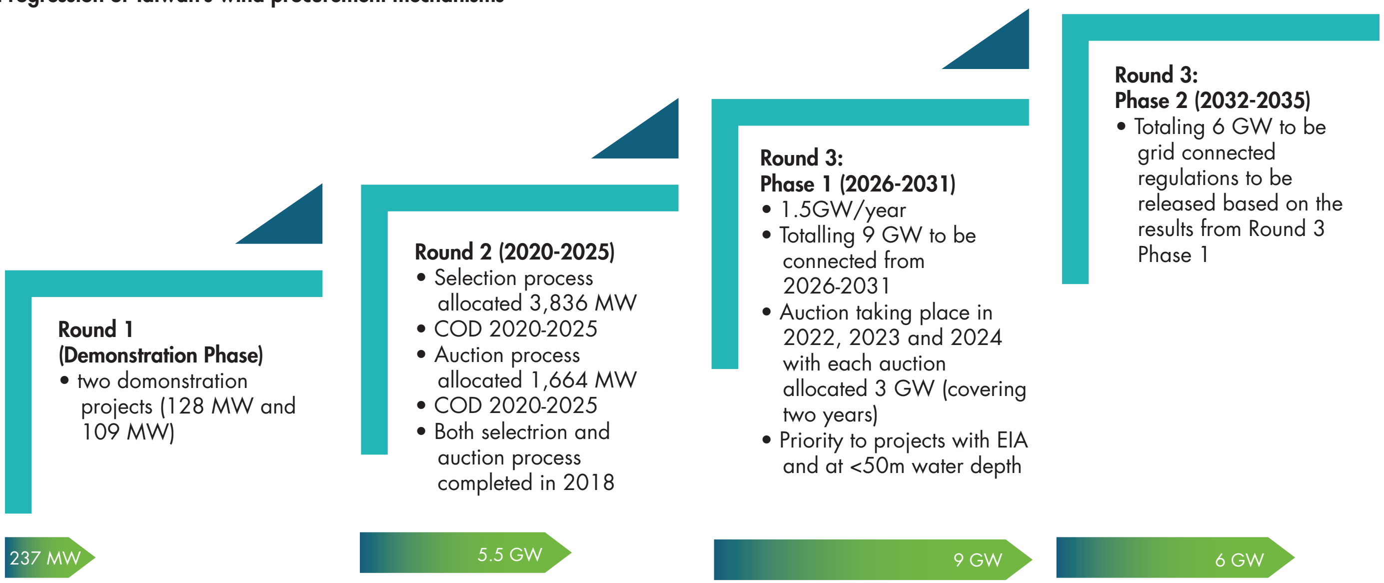
Offshore wind is a key component of Taiwan's green economy vision, which charts a nuclear-free pathway to generate 20% of electricity through renewable energy by 2025. The government is aiming to install 5.7 GW of offshore wind by 2025, and in May 2021 announced that it would increase its offshore wind ambitions to 15 GW over the 2026-2035 period from 10 GW announced in 2019. While the 5.7 GW tranche was procured across a selection round and auction, the next 15 GW (termed Round 3) will likely be conducted across two phases; the first phase (2026-2031) will prioritise projects at water depth of less than 50 metres.

Following government delays due to COVID-19, a draft version of the Round 3 framework, including how much volume will be allocated and when, is due to be published by middle of this year.

Critical to the steady progression of the market will be the government's localisation strategy, which aims to consolidate the entire supply chain in Taiwan, from turbine components to submarine cables to shipbuilding. The industry must balance growth with local content requirements that are expected to be higher in Round 3.

The Round 3 rules take some industry concerns into account by removing some items from the previous Round 2 requirements. It also introduced a mandatory and optional list, and reduced the volume of the items mandatory list from 100%

Progression of Taiwan's wind procurement mechanisms



to 60%. Despite these changes, the requirements in the Round 3 rules are still very challenging.

Apart from the strict Local Content Requirement (LCR), the Government is also introducing two factors: a price ceiling and a project cap. The Government is introducing a price ceiling in the auction at the avoidance cost[34] of Taipower. The government was inspired by the example of zero-subsidies auction in Europe, as well as the burgeoning Corporate PPA market. However, the price ceiling means a very aggressive cost reduction and would lead to another 11% of cost reduction based on the 2025 auction price, where LCR was not a requirement in the auction for that year. The price ceiling is giving developers a big challenge as market demand in the CPPA is not clear and the price ceiling can also deflate the CPPA price significantly. The lack of a long term stable PPA price can also lead to high risks for project financing.

The other factor is the project cap, where projects are limited to 500 MW (with the possibility to increase 100 MW). The goal of the Government is to encourage competition. However, with so many factors, LCR and project cap all together, the Government's cost reduction target could be very hard to achieve at the same time.

Development of the supply chain

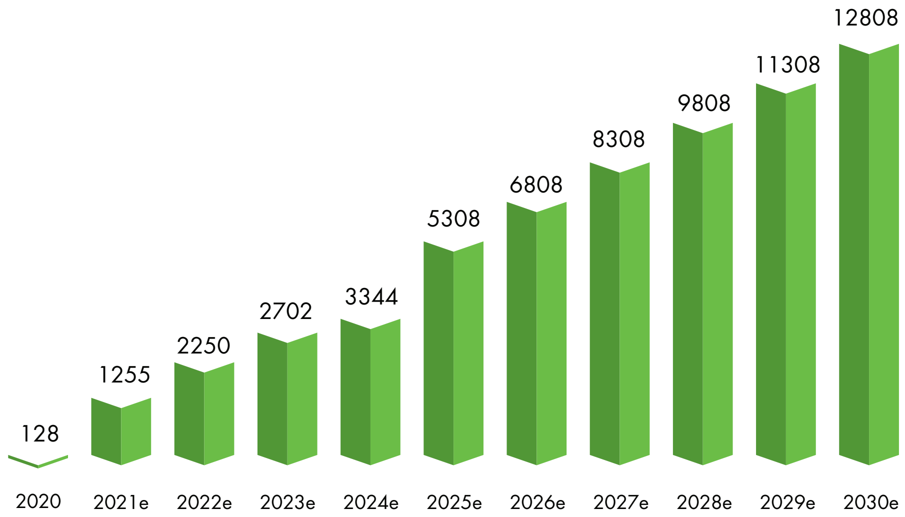
In 2020, positive signs have already been marked by announcements for an MHI Vestas-Tien Li blade manufacturing facility in Taichung, an SGRE nacelle production facility in Taichung and CDWE's work on the first Taiwan-built offshore wind installation vessel. But how flexible the localisation requirements are in the forthcoming Round 3 framework will be key to determining whether the nascent offshore wind industry can develop into a sustainable and competitive market.

Market outlook for cumulative installed offshore wind capacity in Taiwan

Within the next decade, Taiwan will achieve more than 12 GW of installed offshore wind capacity, becoming an experienced market with an established domestic supply chain. The sector is supported by a feed-in tariff, a four-year wind power promotion plan and a relatively open investment environment. Limited land space and high energy insecurity further compels Taiwan to look to coastal zones for power production.

Power sector reform is also on the horizon, with amendments in 2017 to the Electricity Business Act which mandated the unbundling of utility Taipower's generation, transmission and distribution business, and the liberalisation of the electricity market to enable multiple business models for direct procurement of renewable energy.

Cumulative installed offshore wind capacity forecast in Taiwan from 2020 to 2030



Source: GWEC Market Intelligence

34 Avoidance cost is the average price of coal fired power for Taipower.

Brazil

Offshore wind in the near future

Within the next decade we will see the first Brazilian offshore wind farm begin construction. This may seem like a very distant future, considering the increasingly efficient development timelines for offshore wind in European and some Asian countries, but Brazil is a market with its own specificities. It is important to understand that Brazil has one of the highest levels of renewable energy in its grid, around 49%, in contrast to the world average of 15%. These figures demonstrate a very different reality from other geographies: The country has vast renewable energy resources at its disposal for energy production. Given the abundance of resources, the country can afford to implement new technologies according to availability and, above all, competitiveness.

With the cost of offshore wind technology dropping, companies and the government have mobilised themselves to prepare for offshore wind farms on the Brazilian horizon. Today, there are more than 40 offshore wind projects under evaluation by IBAMA, the environmental assessment and authorisation body. In April 2020, EPE, the government energy research and planning company, released 'Roadmap Eólica Offshore', which shows that Brazil has about 700 GW of offshore wind potential to be explored. The report is a big step for Brazil because it deals with domestic challenges related to the environment, investments, technological development and infrastructure. Challenges and opportunities involve the creation and adaptation of a specialised offshore wind supply chain, development of a regulatory framework, connection to the grid and other items that will guide stakeholders seeking to develop the technology in the country.

In line with the EPE Roadmap, the World Bank Group-ESMAP report "Going Global: Expanding Offshore Wind to Emerging Markets" presents Brazil as an emerging market with strong potential for offshore wind. According to this report, Brazil has an offshore wind potential of around 1,200 GW, concentrated in the

northeast region of the country. The report also outlines Brazil's primary challenges linked to transmission expansion and grid infrastructure bottlenecks.

A competitive position in the energy mix

It is worth noting that the technology is considered by the Decennial Energy Plan - PDE 2029, a document developed by the Ministry of Mines Energy (MME), as a source that can contribute to the expansion of new installations into the national energy matrix. The document emphasises that Brazil will benefit from increased cost-competitiveness already seen in places like Europe.

The National Energy Plan – PNE 2050 shows that in the next 30 years the expansion of the energy sector will occur through renewable sources, primarily wind and solar. In this sense, the document confirms the importance of offshore wind for this expansion and states that the cost of production needs to be reduced by around 20% to become competitive in the market.

Competitiveness is directly related to the offshore wind industry's supply chain. Leading offshore wind companies are already active in the country, including manufacturers of turbines, blades and other components, such as GE Renewable Energy, Siemens Gamesa Renewable Energy, Acciona and others. These companies have already been operating in Brazil for over a decade for onshore wind, and will continue to drive innovation in the sector.

Resolving challenges through collaboration

Despite the great potential raised in the EPE Roadmap and other global studies, offshore wind will face challenges related to the definition and creation of a legal and regulatory framework, environmental issues and offshore installations, transmission and consolidation of the national supply chain. These challenges need to be faced head-on by investors, companies and the government in order to support the development and competitiveness of the technology in the Brazilian context.

These are the most important themes at the centre of ABEEólica's Offshore Wind Working Group, which addresses issues related to the creation of a regulatory framework and review of the draft offshore wind Law 576/2021. Technical topics such as measurement criteria, transmission and areas of interference have also been addressed by the group. The group is also focused on creating an Investor's Guide, which aims to support domestic and international investors in comprehending the current status of the regulatory environment, stakeholder ecosystem and the panorama of capacity-building in the sector.

ABEEólica will continue to work to meet the local challenges to scaling offshore wind; in addition to those mentioned above are the creation of the enabling environment for foreign direct investment and workforce training in the sector. In the coming years, Brazil will have to concentrate its efforts to face these challenges, and the role of ABEEólica and local/international partners will be substantial to foster collaborative discussions to drive Brazil's energy transition and its deployment of offshore wind.

With input from: Elbia Gannoum, CEO, ABEEólica

India

The offshore wind market in India has been under exploration since 2010. Nodal agency National Institute of Wind Energy (NIWE) initiated a call in 2010 to aggregate technical inputs for offshore wind technology. The Facilitating Offshore Wind in India (FOWIND) 2014-2018 project, led by GWEC and funded by the EU Delegation to India, focused on pre-feasibility studies off the coasts of Gujarat and Tamil Nadu.

With growing interest, the Government of India announced the National Offshore Wind Energy Policy in 2015 and another EU-funded project, First Offshore Wind Project of India (FOWPI) 2016-2019, was initiated for capacity-building. These projects paved the way to launch a 1 GW Expression of Interest (EOI) for Gujarat in 2018, which received interest from nearly 35 key players.

However, the EOI has not progressed any further due to high CAPEX and lack of government support schemes. Taking note of this, the Ministry of New and Renewable Energy (MNRE) applied for €800 million viability gap funding (VGF) to the Ministry of Finance in 2019 to support the construction of India's first 1 GW offshore wind project in Gujarat. Also in 2019, the draft Offshore Wind Energy Lease Rules were made available for comment.

Offshore wind's role in India's long-term energy transition goals

Building on a number of factors, including its Nationally Determined Contributions (NDCs), surging energy demand increasing at 6-7% year-on-year over the next decade, 24x7 Power for All and power sector decarbonisation, the government has set one of the world's largest renewable energy targets of 450 GW by 2030. This includes targets of 5 GW of offshore wind by 2022, which was later scaled up to 30 GW by 2030.

Deployment of large-scale offshore wind is envisaged to fulfil a power supply gap over the next decade. Using mesoscale satellite data, NIWE estimates 36 GW of offshore potential off the Gujarat coast and 35 GW off the Tamil Nadu coast. An estimation done by World Bank-ESMAP suggests offshore wind technical potential of 195 GW (112 GW fixed and 83 GW floating) within India's EEZ. Offshore wind is seen as a response to growing power demand, competition over land availability on land and a system balancing technology. However, no offshore wind project has commenced in India to date.

Plans to push for project development

The FOWIND studies facilitated the identification of 16 potential zones with a concept design for demonstration projects of indicative capacity 150-504 MW in Tamil Nadu and Gujarat. They found net capacity factors ranging from 26.9-32% in Gujarat and 30-38.1% in Tamil Nadu for 4-10 MW turbine ratings. While the final tender for 1 GW project at Pipavav, Gulf of Khambhat, Gujarat is in the pipeline, industry interest has shifted to the stronger wind resource and geotechnical conditions in Tamil Nadu.

The MNRE is pursuing an offshore wind measurement campaign for at least 10 GW of valid and accurate

Demonstration projects of indicative capacity of 150-504 MW in Gujarat and Tamil Nadu

Category	Gujarat	Tamil Nadu
LiDAR (Light Detection and Ranging)	One LiDAR commissioned at Zone B in Nov 2017; Two are Proposed for Zone A & B	No LiDAR installed; Three LiDAR proposed for Zone A1, B and C1
Avg. Wind Speed	~7.63 m/a @100m HH as per 6-month LiDAR Data- Zone B	NIWE's 100 m guyed mast installed at Rameshwaram shows 8.62 m/s average wind speed @100m HH and WPD of 603 W/m2 @50 m a.g.l.
Geotechnical Condition	Extensive weak clay or soft soil layers (~9m) found in Zone A & B; challenging and costly for foundation design and need customization	Better than Gujarat site – soil profiles for Zone A indicate significant spatial variation in the southern Tamil Nadu offshore region; ranging from weak/loose sands/clays to strong cemented sand to depth
Infrastructure and Logistics	Pipavav port is larger and lively with high vessel availability and storage facility in the region but need to be optimised for offshore wind	Ports are relatively smaller in size; need significant modification efforts for readiness for offshore wind farm installation
Coastal Area	Rich in biodiversity and has fishing communities up to 10 km off the coast; Rapid EIA study is complete; however, detailed EIA study is required	Strong tradition of fishing communities at the coastal area; precise geopolitical, EIA and social acceptance studies are required
Tender or other activity	EoI invited for Zone B nearest to Pipavav port in Gulf of Khambhat- Rapid EIA study, Geotechnical and geophysical analysis are done. Tender for a LiDAR in Zone A1 has been conducted.	Tender for three LiDARs in Zone A1, B and C1 hae been conducted; no project tender yet, but plan is to award first project of 300-500 MW capacity in Zone B; 75 acres of land in Dhanuskodi site is allocated to NIWE for establishing first National Offshore Research & Testing Facility 2019-29

on-site data for feasible offshore wind siting. NIWE's plan to have five LiDARs (Light Detection and Ranging) installed by the end of 2021 would gather precise bankable data critical to developing offshore wind projects of up to 7.4 GW indicative installable capacity. NIWE has already floated tenders for design, fabrication, delivery and installation of the support structures for four offshore LiDARs. These interventions are likely to enhance the robustness of estimates for commercially viable offshore wind in India.

Since India already has comparatively cheaper onshore wind and solar energy, the MNRE is seeking feasible cost interventions from stakeholders for offshore wind. The structures for offshore wind PPAs and auction designs are being examined by government authorities, and the MNRE, NIWE and the Danish Energy Agency have entered into a partnership for financial modelling of offshore wind farms in India (FIMOI) 2019-2021. A World Bank Group roadmap study on offshore wind in India is also forthcoming.

Opportunities ahead

The offshore wind sites identified off Gujarat and Tamil Nadu will require technology and business model customisation alongside institutional resource. In April 2021, GWEC India published a statement of recommendations for offshore wind development in India, including the need for the government to frame a visionary policy towards long-term cost reduction and energy security, implement seabed leasing legislation and provide clarity on the bidding process and timelines for tenders. In addition, expanding the offshore wind measurement campaign will yield LiDAR data to identify the potential zones for bankable offshore wind projects.

A first step may be targeting a feasible scale of demonstration project, along with a support scheme framework, which can demonstrate offshore wind capacity factors, technology optimisation and initial costs. Additionally, state-level roadmaps in Tamil Nadu and Gujarat with offshore wind targets can foster development progress.

These challenges will require regular engagement between GWEC India, decision-makers at federal, state and local levels of government, civil society institutions and local stakeholder communities, in order to align the offshore wind development strategy and strengthen collective understanding of the socioeconomic benefits associated with offshore wind. The true potential for the offshore wind market in India is recognised as enormous, but urgently requires increased government-industry coordination and techno-economic studies to be realised in this decade.

World Bank Group – Offshore Wind Development Program

Background

The World Bank Group's (WBG) Offshore Wind Development Program was launched in March 2019.

The Program's objective is to accelerate the deployment of offshore wind in emerging markets. It provides this support to the public and private sector by undertaking:

1. Knowledge generation, dissemination and exchange
2. Market development activities including roadmaps and informing regulations
3. Preparation of projects, supportive infrastructure, investment plans, and competitions

WBG works closely with GWEC, which provides market insights, support for events, workshops, training, peer reviews and more to the Program.

Knowledge Creation

In late 2019 the Program published its first report "Going Global: Expanding Offshore Wind to Emerging Markets". This was followed in 2020 by 56 maps of the offshore wind technical resource potential for WBG client countries and regions, which have been published on the GWEC website in a library of technical resource maps for nearly 100 countries globally. This resource assessment work estimated that 115 of the world's countries have a technically extractable offshore wind potential of over 71,000 GW.

Further knowledge studies are in preparation:

- "Key Factors for Successful Development of Offshore Wind in Emerging Markets": This report, together with a series of learning materials, covers the essential elements that comprise a successful offshore wind market. It provides lessons learnt and good practices appropriate for a developing country setting.
- Environmental & Social Framework for Offshore Wind Spatial Planning (FOWSOP): This framework enables WBG client governments to plan a country-scale spatial assessment of environmental and social aspects associated with offshore wind, in order to lower environmental and social risks and so improve project bankability.
- "The Role of Concessional Climate Finance in Accelerating Offshore Wind Development in Emerging Markets": This study demonstrates how concessional finance could be used to reduce the tariff required by initial projects in emerging markets. It establishes the role and need for climate financing to accelerate offshore wind deployment.

Virtual Study Tour

In 2020 GWEC delivered a virtual study tour on behalf of WBG. The event was held over three days and provided a mixt of live study tours, masterclasses, meet-the-expert sessions and networking with over 20 hours of content.

The event welcomed over 400 delegates from 24 countries. By holding the event online, it was possible to surpass the successful 2019 event in terms of number of attendees and countries, while also achieving greater geographical coverage and increasing the breadth and depth of technical materials.

Countries Engaged

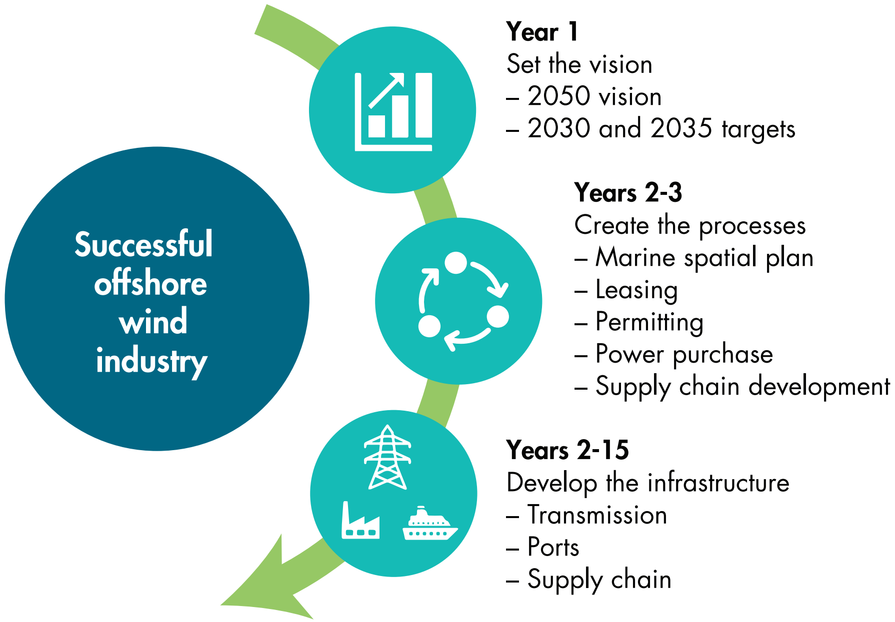
The WBG program has provided direct assistance in 10 countries to date:

Country	Progress to date
Vietnam	Roadmap completed and published in June 2021. High and low growth scenarios together with 20 recommendations. Ongoing technical assistance to support market development.
Sri Lanka	Roadmap started November 2020. Focus on development is in the Gulf of Mannar. Possible link to India via interconnector.
Turkey	Roadmap started in November 2020. Focus on economic analysis, regulatory gaps, and environmental and social risks. Parallel work to help prepare for a future auction.
India	Started roadmap study in December 2020. Focus on economic benefit and a first pilot project in waters off Tamil Nadu.
Azerbaijan	Roadmap study started in early 2021. Challenges include transport of large equipment to the Caspian Sea and the oil and gas sector transition.
Colombia	Started roadmap in March 2021. Key topics are integration with hydroelectric generation and environmental and social aspects.
Philippines	Commenced roadmap study in March 2021. Focus is on floating offshore wind and the displacement of coal fired generation.
South Africa	An early-stage study is underway to scope the opportunity for offshore wind and to plan future support.
Small Island Developing States	Exploring opportunities and risks for offshore wind in Fiji, Papua New Guinea and Caribbean islands.
Brazil	Despite the lack of a policy framework over 40 GW of offshore wind projects have entered planning. WBG is finalising the terms of reference for a roadmap study.

GWEC is proud to cooperate with the WBG program on a global scale. The next few years will see a progressive move towards implementation of projects, therefore increasing offshore wind's global reach.

For further information, see: https://esmap.org/esmap_offshore-wind

Priority themes to create a successful offshore wind industry



Source: BVG Associates

Other new markets

From the perspective of GWEC Market Intelligence, it is important to highlight the potential development for offshore wind in newer markets. Even if actual installations will not happen immediately. The five selected markets, Ireland, Poland, Estonia, Australia and Romania are representative of markets with high offshore wind potential but varying political support and targets to date.

Still, in all five markets there is an increasing awareness that offshore wind at large scale can provide cost-competitive and efficient solutions for these countries.

GWEC Market Intelligence monitors activities in 46 markets on a regular basis to document the opportunities and progress of taking offshore wind global.

Ireland	Poland	Estonia	Australia	Romania
Development stage	**Development stage**	**Development stage**	**Development stage**	**Development stage**
Pre-approval of 7 offshore wind projects by government totalling 3.5 GW; first offshore wind auction scheduled for 2021 out of three offshore wind-specific Renewable Energy Support Scheme (RESS) auctions to meet 5 GW target by 2030; development plans for 1.4 GW Moneypoint floating farm and an offshore wind-to-hydrogen project unveiled.	1st phase awarded ~5.86 GW by June 2021 through CfD scheme. During the 2nd phase, another 2.5 GW each in 2025 and 2027 to be awarded in competitive CfD auctions.	Initiated the construction permit approval process for Eesti Energia's 1 GW offshore wind project in the Gulf of Riga, together with Latvia; 1 GW 'Elwind' Estonian-Latvian cross-border project tender planned for 2026. More than 12 GW capacity of offshore wind projects are under various development stages for consenting, EIA, and relevant preliminary studies etc.	Progress continues on the ground-breaking 2.2 GW Star of the South offshore wind energy farm, with contracts signed for design of the project's onshore transmission network and grid connection. Plan submitted by Australis Energy Ltd for a 300 MW project; while its two projects of ~1 GW are under planning. Interest for offshore wind in Australia is increasing as companies are looking at a total potential of around 16 GW.	One study identifies total technical offshore wind potential up to 100 GW in the region. Another study assessed 94 GW potential, including 22 GW for fixed-bottom. As of today, the Romanian energy companies Hidroelectrica and Romgaz have made public statements that they will invest in offshore wind energy technologies.

Ireland	Poland	Estonia	Australia	Romania
Political support	**Political support**	**Political support**	**Political support**	**Political support**
Strong and clear political support for a 5 GW offshore target by 2030 set in the Programme for Government in 2020, referencing ~30 GW floating offshore wind potential; a broader climate neutrality target by 2050 is in place. Government approved a new framework for Ireland's offshore electricity transmission system in April 2021 to provide clarity on development, operation and ownership for transmission system. Launched National Marine Planning Framework in July 2021 and approved Maritime Area Planning Bill 2021 for integrated maritime related planning and consenting system. Geological Survey Ireland awarded 17 assessments over 14 months for topics including geotechnical engineering assessments helpful for offshore wind farms.	Offshore Wind Act signed into law in January 2021 to streamline the permitting, grid connection rules and supply chain requirements. Adopted important regulation on the Polish marine spatial planning strategy for seabed permitting. In May 2021, the EU approved 22.5 billion EUR to support offshore wind development through CfD scheme. These two steps are to allow ~10.9 GW offshore wind capacity to be installed or under development by 2030, quicker than envisaged in the earlier Energy Policy of Poland which outlined 10 GW by 2040. For funding from EU Reconstruction Fund, Polish offshore wind development and port upgrades are required as per National Reconstruction Plan.	Renewable energy to account for 50% (from current 30%) of final consumption of domestic electricity by 2030, as announced in Estonian Energy Development Plan (ENMAK 2030). Signed Baltic Sea Offshore Wind Declaration with six countries to accelerate the development of offshore wind capacity and cooperate in spatial planning for maritime areas, grid development, capacity planning and support mechanisms.	At the start of 2020, a plan for an Offshore Clean Energy Infrastructure bill was issued by the Department of the Environment and Energy. Once implemented, the framework will fill an existing regulatory and legislative gap that can kickstart a viable offshore clean energy industry in Australia. Around EUR 2.9 million from Victoria's Budget 2020/21 allocated for delivering the offshore wind regulatory framework. This budget also includes EUR ~333 million for establishing six Renewable Energy Zones, including offshore wind.	Draft laws for offshore wind projects allocation are under legislative process for finalisation; they propose that the Ministry of the Economy, Energy and Business Environment introduce support mechanisms and grant projects mainly by means of concessions, tender procedures, or direct licenses.

Ireland	Poland	Estonia	Australia	Romania
Challenges	**Challenges**	**Challenges**	**Challenges**	**Challenges**
Strategic investment to build an indigenous and economically sustainable local supply chain, including improving port infrastructure. Well-organised lease and licensing processes, and clear regulations filling the gaps around grid connection are needed, in addition to robust planning and consent.	Strengthening and modernising Poland's grid and transmission network, especially in the north of the country.	Strengthen Estonian-Latvian cooperation in marine spatial planning for development of joint wind farms, to avoid past challenges to offshore projects on national security terms. Russian naval base near Estonian offshore development zone Baltic Sea is among security concerns.	Patchy track record on general support and policy measures to back renewable energy generation, especially with respect to long-term certainty for measures such as a Feed-in-Tariff scheme.	Challenges regarding existing grid and establishment of rules and regulation for offshore grid connections.
Next milestone	**Next milestone**	**Next milestone**	**Next milestone**	**Next milestone**
Open qualification process for first offshore RESS Auction in 2021. Steps need to be taken to grow the local supply chain; currently, no port in Ireland meets all the requirements for offshore wind projects.	Need to issue relevant executive regulations by responsible ministers such as a regulation on maximum price for electricity generated by offshore wind, technical specifications for installation, marine safety requirements and principles for possible purchase of offshore grid connections by the TSO.	Estonia and Latvia work to develop guidelines for a collaborative project and intensify the cooperation for projects to come online. Finalisation of the proposed draft maritime spatial plan.	Policy and regulatory framework formation.	Finalise the draft offshore wind laws and outline a clear offshore wind installation target. Prepare and submit marine spatial planning strategy.

FLOATING WIND

Principle Power | Globalizing floating wind

Chapter Sponsor

Floating offshore wind: Technology

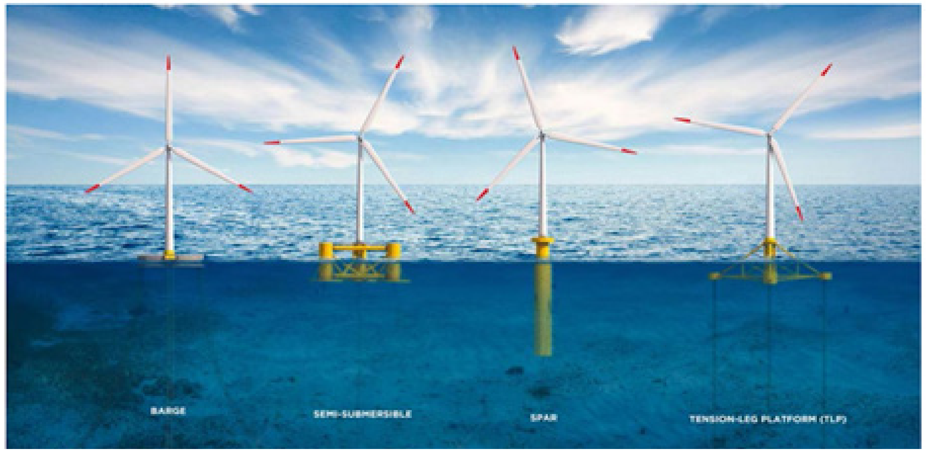
80% of the world's offshore wind resource potential lies in waters deeper than 60m. The best locations for floating wind are Europe, Japan, South Korea, Taiwan, South Africa, Australia, New Zealand, Argentina, Chile, off the west coast of the US and off the south coast of China (see Floating Wind Market Resource map on page 23). To fully harvest the global offshore wind potential and expedite the energy transition and eventually meet the net zero target, it has become imperative for governments to set up floating offshore wind targets, to streamline the project permitting process, and to provide support schemes to help this less-established technology to quickly achieve the commercialization and in turn to reduce the cost and make it an affordable energy source. As well as providing even better wind resources and larger technical potential than bottom-fixed offshore wind, floating wind could help create socio-economic benefits such as jobs and most importantly engage the oil and gas industry to complete a smooth energy transition, for example, bringing their expertise in foundation construction and unparalleled skills in delivering huge engineering projects into offshore wind while re-skilling workers who may be dislocated from the fossil fuel sectors.

Floating wind technologies

Beginning with the first MW-scale floating offshore turbine installation in Norway in 2009, the offshore industry connected the world's first commercial floating offshore wind project, the Hywind Scotland (5 units of SGRE SWT 6.0-154, turbines with a single floating cylindrical spar structure), in the UK in 2017 and commissioned the world largest floating offshore wind turbine, Vestas V164-9.5 MW model, at the 50 MW Kincardine project in Scotland this summer. With turbines installed on semi-submersible floating structures the Kincardine project is also representing the largest floating offshore wind project in the world as of today.

As illustrate by the floating offshore wind platform diagram below, there are four dominant types of floating wind foundations which are mainly derived from oil and gas experience namely, Deep-water floating Spar, Semisubmersible, Tension-leg platform (TLP) and Barge. Associated benefits and challenges of the basic floaters are presented in table below. It is worth to mention that no universal solution is available for floating wind. Different geographical situations will favour different solutions, and factors such as political need, opportunity for localization, local infrastructure and different turbine design will also come to play in floating foundation selection. As the total installations for floating wind is relatively lower than fixed bottom wind, operations and maintenance (O&M) solutions to maintain the floating turbines are still being developed at present and it may favour some types of designs considering the OPEX control.

Floating offshore wind platform types



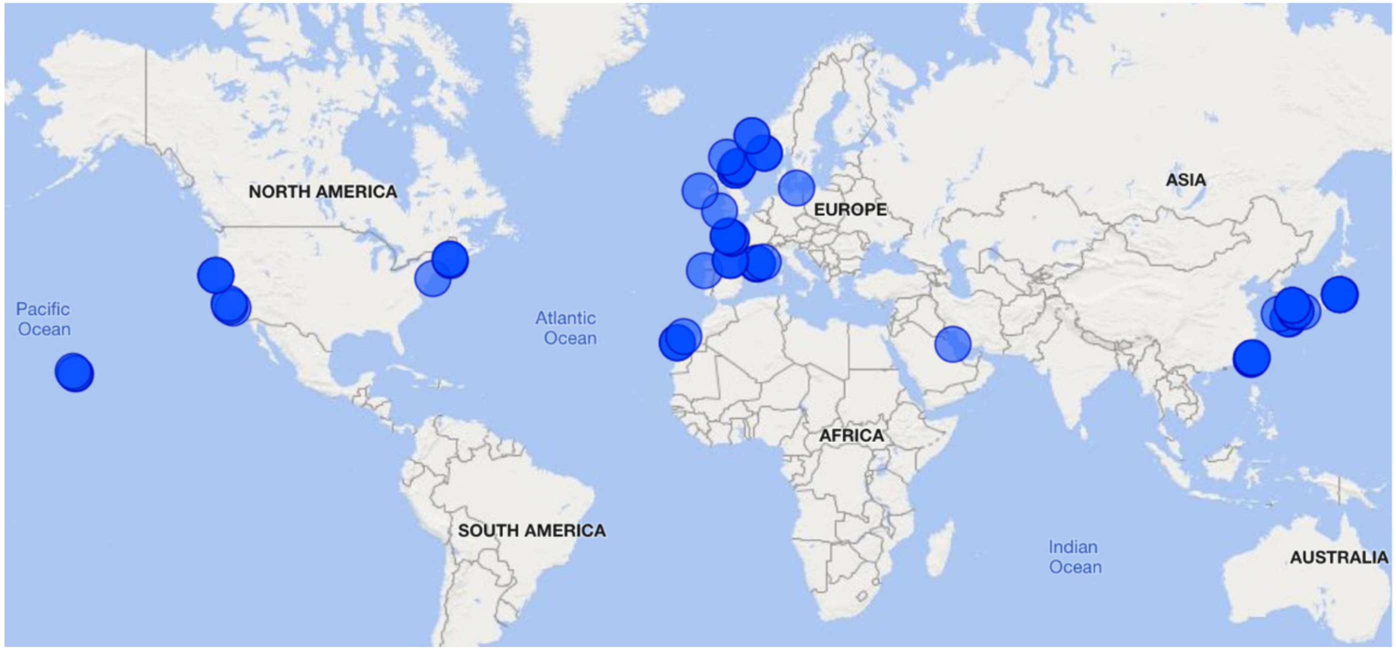
Source: WindEurope

The benefits and challenges associated with four dominant floater concepts

Spar	Semisubmersible	TLP	Barge
Overview: • Simplest concept and attractive dynamics • Minimum depth 80m during whole installation process • Achieves stability through ballast installed below its main buoyancy tank • Complex manufacturing and Weight for 6 MW: ~3.500 t	**Overview:** • Most popular concept, already proven, with good dynamic stability • Achieves static stability by distributing buoyancy widely at the water plane • Weight for 6 MW: 1800-2200 depending on site conditions	**Overview:** • Attractive dynamics but not widely deployed • Achieves static stability through mooring line tension with a submerged buoyancy tank • Typically requires purpose-built installation vessel • Weight for 6 MW: ~2.000 t	**Overview:** • The shallowest draft of all the floating foundation types • Square footprint • Some barge designs include a moonpool to suppress wave-induced loading. • Weight for 6 MW: 2.000-8.000 t depending on materials
Benefits: • Inherent stability • Suitable for even higher sea states • Soil condition insensitivity • Cheap & simple mooring & anchoring system • Simple fabrication process • Low operational risk • Little susceptible to corrosion	**Benefits:** • Depth independence. • Soil condition insensitivity • Cheap & simple mooring & anchoring system • All heavy lifting performed in port • Simple installation & decommissioning as no specialised vessel required • Broad weather window for installation • Simple tow-to-shore maintenance (at quayside)	**Benefits:** • High stability, low motions • Having a good water-depth flexibility • Small seabed footprint and short mooring lines • Simple & light structure, easy for O&M • Lower material costs due to structural weight of the substructure • Onshore or dry dock assembly possible	**Benefits:** • Operable at depths starting 30 meters to accommodate complex seabed conditions • Buildable in steel or concrete, or hybrids between steel and concrete, offering flexibility in using the highest local content near the project • Simple shape will employ equally simple fabrication techniques • Scalable to support heavy substation
Challenges: • High cost, 5-8 mEUR/MW (based on the 30 MW demo) • Heavy weight, with long mooring lines and long & heavy structure • Deep drafts limit port access and large seabed footprint • Relatively large motions • Assembly in sheltered deep water challenging and time-consuming • High fatigue loads in tower base • Specialised installation vessels needed	**Challenges:** • Complex fabrication as more welds (but high potential for modularization) • Large footprint requiring space in transport and final assembly yard	**Challenges:** • Unstable during assembly, requiring the use of special vessel • High vertical load moorings • Complex & costly mooring & anchoring system making it the most expensive floater design type • Mooring tendons presenting higher operational risk in case of mooring failure and add requirements on site seabed conditions	**Challenges:** • Particularly exposed to wave, so having greater motions • Demanding more robust mooring systems, increasing complexity

Source: Stiesdal A/S, NREL, DNV.GL, Carbon Trust, IRENA

Global floating offshore wind resource map

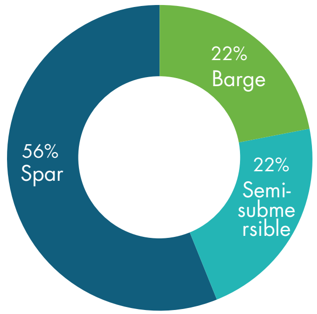


Source: Q FWE

Data on platform types used in existing demonstration schemes has shown a preference for spar type platform models. However, looking at schemes now in development, a clear shift to semi-submersible platforms is easy to spot, with close to two-thirds of schemes in development expected to use different semi-sub technologies. This highlights the breadth of semi-submersible options with full or near technology readiness, as well as familiarity with the technology from oil and gas use. Over time, the balance of platform choice may shift as other concepts become proven or can demonstrate opportunities for cost reduction or increased performance, particularly for spar, semi-spar and tension leg platform variants.

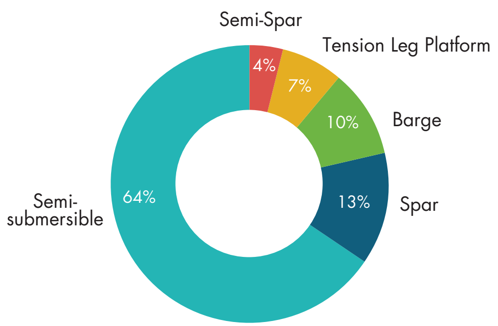
According to GWEC Market Intelligence, global floating offshore wind (FOW) project installation capacity stands at 71.3 MW with the highest share of spar floater type as of July 2021. As project activities grow with increasing interest from key players in Tier-1 and Tier-2 FOW markets, almost 16.5 GW of FOW turbines are forecast to be operational by 2030. As per GWEC Market intel FOW project database July 2021, share of floater types in these global FOW projects at various development stages excluding commissioned ones will utilise semi-submersible floater type with highest share of 64% followed by spar 13% and barge 10%. TLP and semi-spar have the lowest share of 7% and 4%, respectively. TLP has better flexibility in shallower and deeper waters; although its current market share is relatively lower due to complex installation and needs a cost reduction strategy for mooring installation. The names of global players in providing floater designs by five types along with the share of the floater types in FOW projects are presented in the graph below.

Share of floater type in global FOW installations, July 2021



Source: GWEC Market Intelligence, July 2021

Share of floater type in global FOW projects at various development stages, excluding commissioned ones



Floater Suppliers by Floater Type

Wind float by Principal Power has Highest Share,
Others key designs are Floating Power Plant (P80), Sailtec SATH, Aerodyn Nezzy2, CSIC, Dr,Techn, Otav Olsen, EDF Renewables-Blyth Floater, Eolink (Demonstrator), Ferravial-SATH, Hexicon, Milsui, Nagal Energies, VoltumUS (University of Maine)

Tetraspar has Highest Share
Other key designs are Sea Twirl, JMU, Kvaerner, Navantia Windar, Technip, Toda Corporation

Ideol-Dampling Pool

Salpem (Hexafloat)

Glon (SOF)

SBM Offshore

X1 Wind (PivotBuoy)

With an urgent need to achieve cost reduction for floating wind while accelerating the decarbonisation of "hard-to-electrify" sectors, the wind industry is also developing technologies and engineering solutions that can host multi-wind turbines on one floater (to reduce the CAPEX on cables, foundation and installation and maximise the production) and/or integrate other renewable energy technologies such as wave and hydrogen (Power-to-X) into the same platform. Table 2 shows the selected solutions announced either by floater designers or project developers, of which none of them has entered the commercialisation stage of development today. It is interesting to see that all the concepts have pursued the semi-submersible floater concept to host wind turbines and other renewable and Power-to-X solutions.

Selected multi-turbine and integrated floater concepts

Company	Concept or project name	Solutions	Scale of concept	Type of floater	Current stage of development
Hexicon	TwinWind	Multi-turbines (twin-rotor)	Up to 10 MW + (Project pipeline in 6 markets picked up this concept)	Semi-submersible	Model test completed in June 2021 with full-scale test expected in 2023
Aerodyn & EnBW	Nezzy2	Multi-turbines (twin-rotor)	Up to 15 MW	Semi-submersible	1:10 prototype tested in 2020
Pelagic Power	W2Power	Multi-turbines (twin-rotor) + Wave energy	Up to 10 MW including 3 MW wave energy	Semi-submersible	1:6 scale tested in 2016
Bombora and TechnipPMC	InSPIRE (Integrated mWave™)	Single turbine +wave energy	Up to 12 MW wind + 6 MW wave power	Semi-submersible	A 4 MW wind +2 MW wave demon planned
Floating Power Plant (FPP)	FPP Flatform	Single turbine + wave (or plus hydrogen)	4-15 MW wind + 2-4 MW wave power	Semi-submersible	Small scale floater tested in 2020
ERM, Tractebel Engie, Principle Power	ERM Dolphyn	Single turbine + hydrogen	10 MW wind + integrated hydrogen	Semi-submersible	A 2 MW proof of concept unit up and running by 2024
Acciona lead consortium including Wunder Hexicon	OCEANH2	Floating wind+ solar + hydrogen	Integrated floating power plant with multiple floaters	Semi-submersible	Spanish government funded R&D project in 2021

Source: company news and GWEC Market Intelligence, July 2021

Case study: Industrialising floating offshore wind - Five lessons learned

Provided by: Principle Power

Floating offshore wind is set to become a large-scale source of affordable renewable energy. Achieving ambitious deployment levels will require industrialised supply chains to deliver and install more than 50 turbines rated at 15+ MW in one-two offshore construction seasons. As a result, "industrialisation" is one of the hottest topics in the industry today; but it is also complex, with drivers and solutions often misunderstood.

Principle Power has designed WindFloats® for projects ranging from pre-commercial scale (3 – 5 units) to full industrial-scale developments of more than 50 units. These projects cover a wide spectrum of requirements, including, turbine size, project size, environmental conditions, local content, infrastructure constraints, and others.

Our experience designing, constructing and operating WindFloat Atlantic (25 MW, Portugal) and Kincardine (50 MW, Scotland) yields several lessons learned:

Each project has unique constraints that require the resolution of a series of coupled design problems, where each decision has the potential to introduce knock-on effects into connected systems and processes. As a result, the design process must holistically address the full project lifecycle to optimise cost, performance and schedule, while ensuring appropriate management of risk.

Accommodating 15-20 MW turbines requires platform configurations that can be efficiently scaled to manage the increased loads from the wind turbine and environment. The use of numerical models that have been validated against operational experience brings confidence to all parties involved.

Feedback from full-scale projects is an essential input for establishing industrialisation requirements. Return on experience is most effective if incorporated into the early phase of the design process.

The number of units in a project is an increasingly important driver for design decisions. As each unit is identical, smart design decisions and investments in infrastructure can deliver dramatic improvements in commercial-scale project LCOE.

Our ability to flexibly configure the WindFloat®, and its modular architecture, allows us to accommodate diverse project requirements. These features ensure that developers have access to the broadest range of delivery options to ensure a competitive supply chain.

Turning this vision of floating offshore wind into reality will require a coordinated effort from developers, designers and contractors to build supply chains that are adapted to local conditions. Delivering commercial-scale projects will require investment in workforce, ports and infrastructure. These investments will have useful lives extending beyond individual projects. As a result, successful markets will be the ones where governments establish conditions for sustainable, long-term growth.

Find out more:
https://www.principlepowerinc.com/en/windfloat

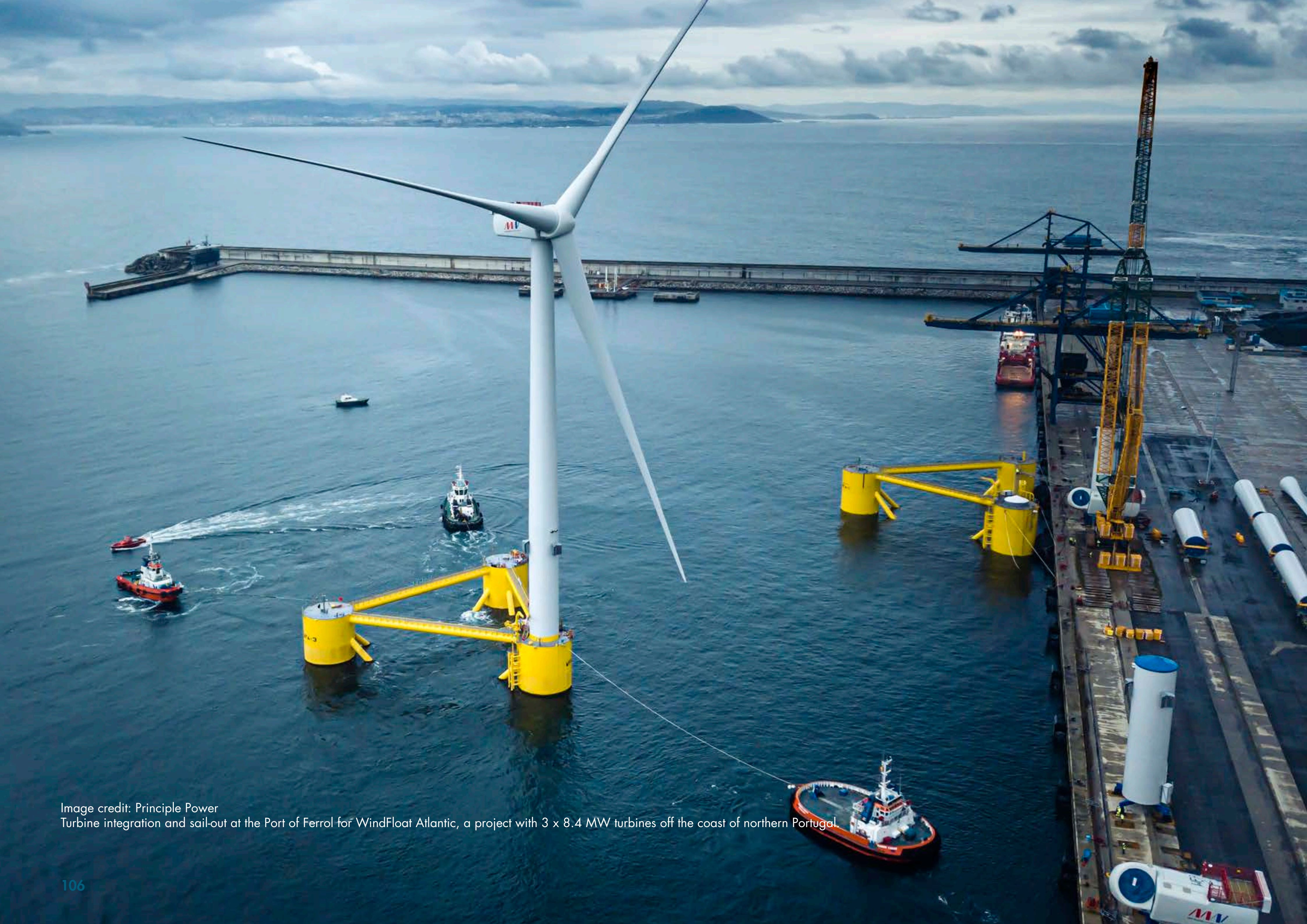


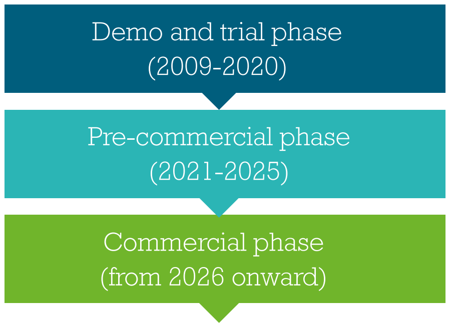
Image credit: Principle Power
Turbine integration and sail-out at the Port of Ferrol for WindFloat Atlantic, a project with 3 x 8.4 MW turbines off the coast of northern Portugal.

Floating offshore wind: Market status and activities

In the past decade MW-scale floating technologies have been tested through demonstration and pilot projects in both Europe and Asia. However, current floater production is not industrialised yet and development has just entered the pre-commercial phase.

According to GWEC Market Intelligence's global offshore floating wind project database, floating wind installations are likely to take off from the second half of this decade (expecting to reach the 1 GW of floating wind annual installations milestone in 2026). Full commercialisation is expected to be achieved toward the end of this decade (when multi-GW level large scale floating projects could be connected in both Europe and East Asia). Our projection for the commercialisation of floating wind could also be justified by recent development targets announced by governments in both Europe and Asia as well as those announced partnerships established by oil majors, large European utilities and floating technology providers. The table below summarises the latest market status and dynamic in tier 1 and tier 2 floating offshore wind markets.

Roadmap of floating offshore wind commercialisation



Floating offshore wind market status and activities - Tier 1 and Tier 2 Markets

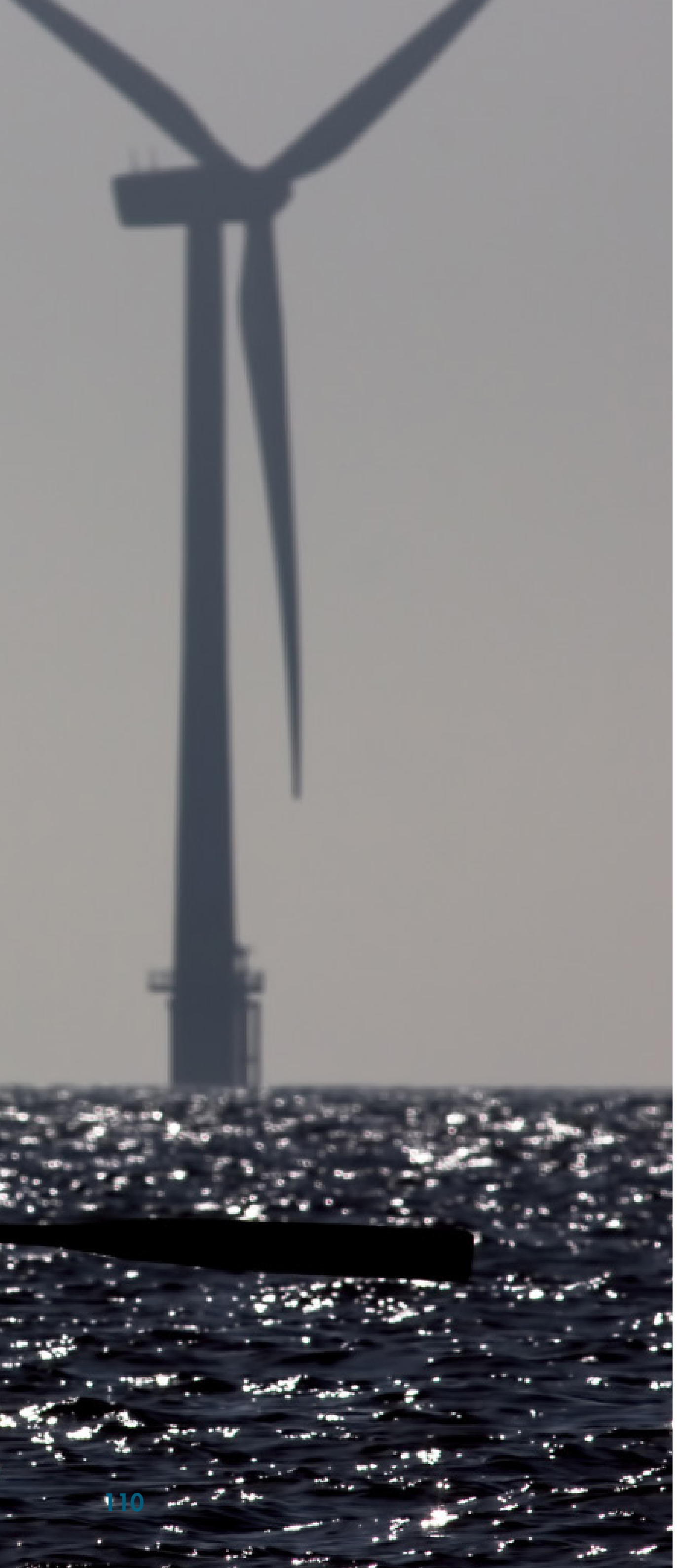
Tier-1 Markets	Target or development potential	Development Stage/activity	Selected Key Players
UK	1 GW FOW capacity installation by 2030; Major Potential lies off the Coast of Scotland and the Southwest of the UK	30 MW Hywind Scotland Pilot Park and 50 MW Kincardine floating wind farm scheduled for commissioning August 2021; Government in March 2021 launched a £20 million competitive funding scheme The Floating Offshore Wind (FOW) Demonstration Programme to focus on mid-technology readiness level under Net Zero Innovation Portfolio; The Crown Estate has awarded three Test & Demonstration projects of total 300 MW capacity in Celtic Sea; ScotWind seabed leasing round results awaiting by January 2022; FOW projects of over 4 GW capacity in UK including Scotland are at various stages of initial planning to be ready for consenting and development process, larger capacity outside of that is being planned to offset UK oil & gas footprint.	BW Ideol, Principle Power, TotalEnergies, EDF Renewables, Equinor, Copenhagen Offshore Partners (COP), Shell, RWE, SSE Renewables, Falck, Ørsted, BayWa r.e., Flotation Energy, Cobra Group, DP Energy FPP, Simply Blue Energy, ERM, Cerulean Winds, Bechtel, Hexicon

Tier-1 Markets	Target or development potential	Development Stage/activity	Selected Key Players
France	To tender 8.75 GW offshore wind capacity including FOW by 2020-2028, but no specific FOW target	With 2 MW Floatgen FOW demo installed to date, consented projects of ~118 MW capacity are expected to be commissioned by 2022-2023; Multi-annual energy program (Plan de programmation pluriannuelle del'Energie (PPE), April 2020 have planned commercial FOW tenders of total 1.25 GW capacity by 2024 (off the Mediterranean and Brittany coast), out of which first tender of 270 MW off the south Brittany is launched in April 2021; From 2024 onwards France will plan tenders of 1 GW/year depending on the floating cost.	TotalEnergies, EDF Renewables, Engie, EOLFI, BW Ideol, Principle Power, Equinor
Ireland	No official FOW target, but a total of 25-27 GW FOW potential area identified without likely significant environmental impact	With a stated ambition of more than 30 GW of floating wind in its deep Atlantic waters, a total of 800 MW capacity FOW projects is in the consenting stage; >3 GW capacity projects are at initial planning stage including recently unveiled development plan for 1.4 GW Moneypoint FOWF on site of ESB coal power station.	Simply Blue Energy, Shell, Saipem, Iberdrola, Equinor, ESB, DP Energy, BW Ideol, Cobra and Flotation Energy
South Korea	6 GW FOWF installation by 2030	Construction work is expected to start at the first phase of 6 GW FOWF Ulsan at Donghae 1 gas field site in 2022 with full commissioning of the entire project expected in 2030; Multi-GW FOW project plans by local players and government, including foreign investors, - projects of over 1 GW are under consenting while interests have been shown with initial plans of developing greater than 4.5 GW FOW projects; Local players have also shown R&D plans to develop new floating foundation design and power offshore Hydrogen plants through FOW turbines.	KNOC, Korea East-West Power, KHNP, TotalEnergies, GIG, CIP, Shell, Macquarie, Ørsted, Equinor, Ocean Winds, Aker Solutions, EDP Renewables, Principle Power, Samsung, Hyundai, SK E&S and Doosan, POSCO
Japan	4 GW by 2030 and 18 GW by 2050 according to JWPA roadmap; With FOW potential of ~500 GW as per JWPA since larger part of Japanese offshore wind zones is suitable for FOW technology than fixed bottom	12 MW FOW capacity commissioned to date; METI and MLIT launched Japan's first auction in July 2020 for a floating offshore wind farm (8 turbines, not less than 16.8 MW total) off Goto City in Nagasaki Prefecture. The sole bidder, a consortium led by Toda Corporation, was selected in June 2021. Japan unveiled its vision for offshore wind, including targets of 10 GW by 2030 and 30-45 GW by 2040, however it does not specify FOW capacity.	JERA, Iberdrola, BW Ideol, Green Investment Group, Hitachi Zosen & Naval Energies, Mitsubishi, Marubeni, Toda Corporation, MOL, Principle Power

Tier-2 Markets	Potential Zones/Target	Development Stage/activity	Selected Key Players
Norway	No official FOW target, but up to 1.5 GW, consisting of three projects, FOW capacity proposed at Utsira Nord site	Ministry of Petroleum and Energy plans up to 1.5 GW of FOW projects at Utsira Nord site under first FOW round of Norway 2021; To date 2.3 MW Hywind FOW Demo is commissioned, two projects of total 91.6 MW capacity are under construction, and 10 MW FLAGSHIP FOW demo under consenting process; Country has Norwegian Offshore Wind Cluster aiming to be the strongest global supply chain for floating offshore wind. Local and international partnerships already established to compete in Norway's upcoming licensing round.	Equinor, Aker Offshore Wind, Statkraft, Fred. Olsen, RWE Renewables, Olav Olsen, Stiesdal, Orsted, Shell, BP, ENI, RWE, Knutsen Group, BW ideol, Hexicon
USA	30 GW offshore wind by 2030, but without the specific FOW target at present	More than $100 million in researching, developing, and demonstrating FOW technology; Projects of 12 MW consented, 40 MW under review and 2.3 GW under planning stage at states along the west coast and Maine; Oregon state will have 3 GW FOW plan once Floating Wind Bill enacted; Biden administration to work on Pacific coast for advancing areas northwest of Morro Bay and off Humboldt County, California, for offshore wind development especially for FOW.	EnBW, Principle Power, BW Ideol, RWE Renewables, Aker Offshore Wind, Ocean Winds Mitsubishi Corporation, Trident Winds
Spain	Draft plans for 1-3 GW FOW target by 2030	Ministry for the Ecological Transition and the Demographic stated 1-3 GW FOW target by 2030 under the draft roadmap for development of Offshore Wind and Marine Energies in Spain, which would be finalised after consultation ending by 6 August 2021; The country houses strong multiplayers with floater designs, production and engineering skills; Projects of >2 GW are under various stages of initial planning and proposals, ~260 MW FOWP are either under consenting process or consented.	Greenalia, Iberdrola, RWE Renewables, Saitec, Equinor, Ocean Winds, DISA Group, BlueFloat Energy, Falck Renewables
Italy	No official FOW target, but with potential zones located at Mediterranean Sea	~750 MW FOW projects under consenting and planning stage; As per Italian wind association president[35] Italian wind energy sector is targeting 5 GW of FOW between 2030 and 2040.	CIP, Ichnusa Wind Power srl, Saipem, Stiesdal, EDF Renewables
Greece	No official FOW target, GWEC estimates 413 GW FOW potential[36]	Project pipeline in excess of 1.5 GW envisaged by 2030 under Ocean Winds-Terna Energy collaboration; Legislation is under preparation for offshore wind project development by the Ministry of Environment and Energy which has greatly increased interests of key players in Greece.	MYTILINEOS, CIP, Equinor, Ocean Winds, Terna Energy

Source: GWEC Market Intelligence, company announcements, industry media, July 2021

35 https://www.montelnews.com/en/news/1189892/italy-aims-for-5-gw-floating-wind-by-2040--anev
36 https://gwec.net/discover-the-potential-for-offshore-wind-around-the-world/



Challenges in Floating Offshore Wind Development

The focus of the floating offshore wind sector is now on rapid scale up of project size, to support rapid learning and cost reduction. This is being supported in different forms by a number of countries. In the UK for example, the initial focus is on smaller test and demonstration projects of up to 100 MW, moving to 300 MW scale projects mid-decade, and 500-1000 GW projects expected by end of decade/early 2030s through ScotWind leasing. In South Korea, Government and developers are pressing ahead with more ambitious multi-GW schemes, though in practice these schemes are expected to be delivered in stages to allow learning.

Industry is confident of its ability to scale up floating offshore wind rapidly. Continued innovation is expected in the market, with new technologies and products expected to support better mooring and anchor solutions, longer term maintenance regimes, deep water substations and dynamic cabling. The extent of innovation in the market is best characterised by the large number of participants and designs in the floating platform market. The bulk of market activity is in semi-submersibles at present, though there are active market players looking at barge, spar and tension-leg platform options. The focus of a number of platform providers is demonstrating their technologies at full scale ready to supply into the rapidly emerging market.

The wide variety of platform concepts highlights some of the different technical and market challenges that projects will need to address. Port access, water depth, ease of manufacture, turbine integration, cost and performance are all issues being explored by different platform companies. It is not expected that the market will consolidate significantly across the decade until industry has gained more experience and different concepts have had sufficient time in the water. However, to survive in this market platform companies will need to secure developer partners and be able to supply into this first cluster of commercial projects, or be confident that they can deliver significant innovation and cost reduction to be considered as part of a second generation of platform options.

Floating offshore wind: Market outlook to 2030

2009 saw the world's first MW-scale floating offshore wind turbine grid-connected by Equinor in Norway, but as the end of 2020 only 73 MW of net floating wind capacity was in operation worldwide.

Nevertheless, progress has been made in the past decade and floating wind is no longer an area dedicated just for R&D purposes. At present, floating wind has passed the demonstration stage and entered the pre-commercial phase. With floating development targets announced by governments in Europe and Asia in the past 12 months, and with more investors (especially major oil and gas companies) including floating wind as a significant part of their strategies to achieve energy transition and net zero targets, GWEC Market Intelligence has upgraded its global floating wind forecast and predicts 16.5 GW is likely to be built globally in the next 10 years, compared with 6.5 GW predicted a year ago.

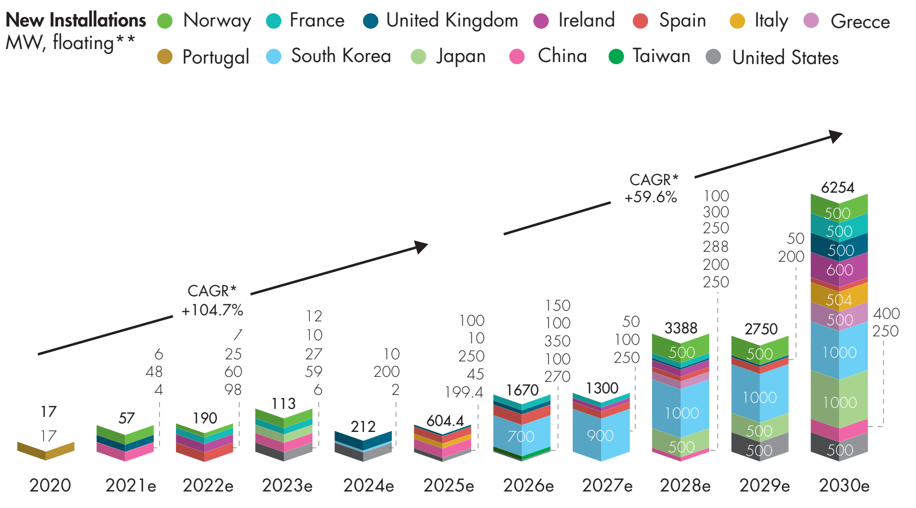
Our previous year's outlook was based primarily on the existing global floating offshore project pipeline (bottle-up approach), but a top-down approach has been applied in this year's outlook which takes into account the floating wind targets and development plans set up by national governments and major offshore wind investors.

Out of the 16.5 GW floating wind installations, we expect only 7.1% (or 1.2 GW) to be built in the first half of this decade; the majority of new volume will come online from 2026 when GW-levels of annual installations are likely to be achieved.

As of today, the UK, Portugal, Japan, Norway and France are the top five markets in total floating wind installations, but the situation is predicted to change and by the end of this decade, South Korea, Japan, Norway, France and United Kingdom are likely to be the top five floating markets.

As regards to regional distribution, we expect Europe to make up 68.2% of total installations added in 2021-2025, followed by Asia (21.4%) and North America (10.4%), but the global market share of Asian countries is likely to more than double in the second half of this decade, making it the largest region in total new installations in that period. In total floating wind installations at the end of 2030, however, Europe will retain the title as the largest floating wind market with 47% global market share, closely followed by Asia (45%) and then North America (8%).

Floating wind's current contribution to total wind installations is only 0.1%, but it will play an increasingly important role toward the end of this decade, accounting for 6.1% of global new wind installations in 2030. To help unlock future potential, GWEC launched its Floating Offshore Wind Task Force in July 2020.



* CAGR = Compound Annual Growth Rate

** Note: this floating wind outlook is already included in GWEC's global offshore wind forecast

Source: GWEC Market Intelligence, July 2021

Case study: FLAGSHIP project leading floating offshore wind power

Provided by: Iberdrola

The European Union has the goal of achieving climate neutrality by 2050, as underlined in the European Green Deal. To help achieve this, offshore wind energy is key: An abundant, natural and clean source of energy

The cost of floating wind can be reduced by optimising industrialisation and mobilising the entire supply chain. For that reason, Iberdrola leads a consortium to develop a floating offshore project funded by the Horizon 2020 program of the European Commission: "FLoAtinG offSHore wInd oPtimization for commercialization" (FLAGSHIP).

FLAGSHIP aims to validate and demonstrate a cost-effective 10+ MW Floating Offshore Wind Technology to ensure the reduction of the Levelised Cost of Energy (LCOE) in the range of 40-60€/MWh by 2030.

The main challenge of this project is to design and fabricate an innovative and cost-effective floating semi-submersible concrete structure to support the first Wind Turbine bigger than 10 MW. This demonstration will be operated for a minimum of two years in the North Sea.

FLAGSHIP is currently in the design phase, purchasing assets and materials, and about to launch the manufacturing activities. The Norwegian companies Olav Olsen, Aker Solutions and Unitech are in charge of designing, manufacturing and installing the assets.

The deployment of the floating turbine at 200m water depth in the MET Centre is planned for September 2022. The North Sea is the world's leading region for deployed capacity and expertise in offshore wind.

FLAGSHIP also includes an exercise to raise the maturity of the concept to a commercial level, allow its industrial production and pave the way towards future developments. This exercise is supported by other consortium partners including DTU, CENER, IHCantabria, DNV-GL, CoreMarine, Zabala Innovation, and EDF collaboration for location analysis.

All the knowledge generated by FLAGSHIP and the results of the demonstrative scenarios will be crucial for the industrialisation of floating offshore wind farms and their replication all over the world.

Floating wind is now on the verge of becoming a commercial reality, and the FLAGSHIP project is the starting point. The combined efforts of the companies that have partnered up in FLAGSHIP can accelerate the commercialisation of floating wind. Together we can develop a clean and profitable energy source that helps pave the way to the future climate-neutral Europe by 2050.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 952979.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 952979

Find out more: https://www.flagshipproject.eu/

Image credit: Flagship

OFFSHORE WIND TECHNOLOGY

Chapter Sponsor

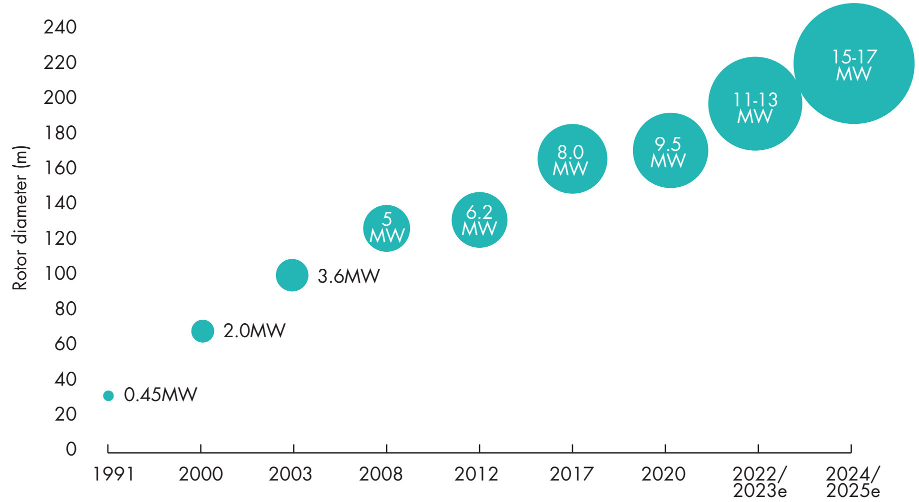
Next generation of offshore wind turbine technology

The nominal capacity of each wind turbine installed 20 years ago at Vindeby, the world's first offshore wind farm, was only 450kW. Since then, offshore wind turbine sizes have grown significantly with the global average offshore wind turbine size passing the milestone of 1.5 MW in 2000, 2.5 MW in 2005 and 6.0 MW in 2020. As more smaller offshore turbines installed in Asia (excluding Taiwan), the average turbine rating for new installations in Europe are even higher. It already reached 8.3 MW in 2020 and is likely to surpass 12 MW in 2025.

Compared with the first offshore wind turbine Bonus B35/450kW installed in 1991, the rotor diameter of offshore turbine has also increased dramatically in the past two decades. Siemens Gamesa SG8.4-167DD and DEC DF10.0-185DD represent the largest rotors installed in Europe and Asia respectively last year, but GE Renewable Energy's Haliade X offshore model with a rotor diameter of 220 metres installed in Rotterdam in 2019 retains the world's record. However, this is not the end of the race. 2020 saw Siemens Gamesa, the world's No.1 offshore wind turbine supplier, release its SG14 DD offshore model with a rotor diameter at 222 metres. The new turbine, that can reach 15 MW with Power Boost, will be commercially available from 2024. In February 2021, Vestas, the world's No.2 offshore turbine producer, launched the V236-15 MW offshore model. The serial production is expected to take place in 2024. In August 2021, Chinese turbine manufacturer MingYang released the MySE 16.0-242 hybrid drive turbine, making it the world's largest offshore wind model. The prototype will be installed in 2023 with commercial production from 2024.

Another trend for the next generation of offshore wind turbine is that direct drive and medium speed drivetrain continue to gain popularity for new turbine with ratings greater than 10 MW.

Rotor size and power rating continue to increase
Based on commercial offshore wind turbine installation



Source: GWEC Market Intelligence, July 2021

The increase of offshore wind turbine size and the continuous turbine technology innovation have been driven by the following factors:

- Pressure to reduce LCOE. To reduce LCOE, size matters. When the bigger offshore turbine is released with a bigger capacity rating, larger rotor diameter, and higher tower height, technically the capacity factors are better, which in turn increase the annual energy production (AEP). According to GE Renewable Energy, the Haliade-X 14 MW model can increase the AEP by 9% compared with the Haliade-X 12 MW model.

- CAPEX saving for foundations, inter-array cables and installation. Although the larger turbine per unit is more costly than a smaller one, a recent Rystad Energy research project shows that using the 14MW turbines for a new 1 GW windfarm offers cost savings of nearly $100 million versus installing the currently available 10 MW turbines.
- OPEX saving due to less turbine units. O&M costs account for approximately 25-30% of total project life-cycle costs. Less unit also means optimization in LCOE.
- To enhance the value of wind energy to the electricity system and energy markets through reduced transmission expenditure, lower balancing costs and improved output certainty.

Rotor size and power rating continue to increase

Considering the increasing pressure for offshore wind to reach grid parity in both Europe and China, GWEC Market Intelligence believe that the offshore wind turbine size will continue to grow moving forward. Our GWEC offshore wind ambassador Henrik Stiesdal has predicted that the next generation offshore turbine technology could probably be around 20 MW with a 275m rotor diameter by 2030. A recent cost reduction survey conducted by NREL and Berkeley LAB also shows experts predict that a 17 MW offshore turbine with a rotor size of 250 meter is expected to be installed in 2035 in order to reduce the LCOE.

However, the limitation for future offshore turbine design will be determined by factors such as the existing supply chain and infrastructure, drive-train optimization, foundation design, materials constraints, the logistical constraints for both transportation and installation, and permitting.

Case study: Innovation to increase green energy reliability

Provided by: DuPont

Achieving a global energy transition that is compatible with the world's climate goals is unquestionably a formidable task. Much depends, for example, on the pace of innovation in new and emerging technologies, the extent to which citizens are able or willing to change their behaviour, the availability of sustainable renewable energy and the extent and effectiveness of international collaboration.

From a technological perspective, the offshore wind industry has improved remarkably in past years. Offshore wind capacity factors have increased by 18%, reaching an average of 44% in 2019. These improvements were largely driven by R&D innovations in turbine design and manufacturing, contributing to increased hub height, rotor diameter and turbines doubling in size. Innovations have also contributed to enabling deep sea offshore wind farms.

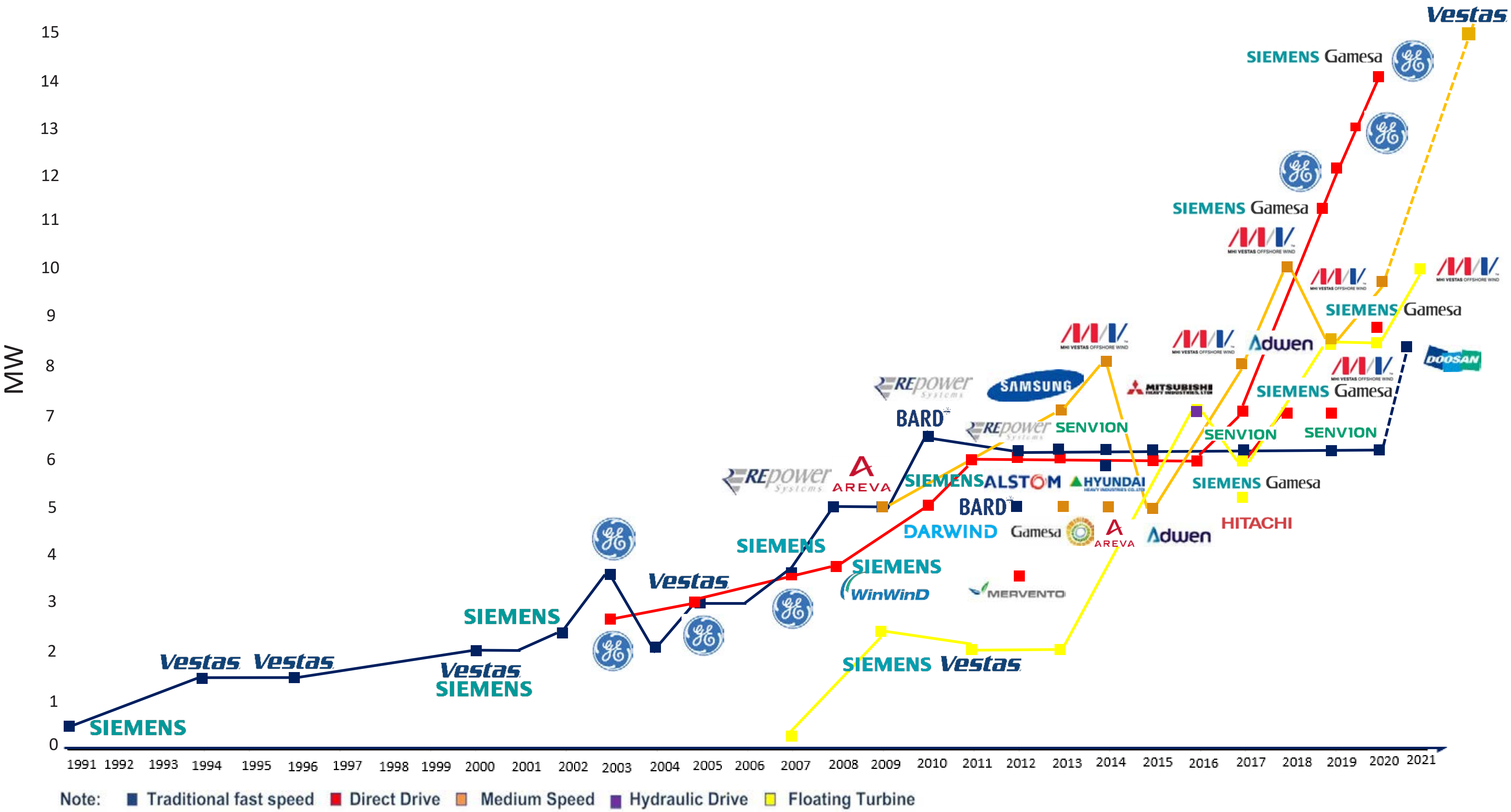
The increase in turbine size increases their cost-competitiveness, resulting in fewer and more efficient turbines, which in turn require less maintenance, reduced installation and operating costs and a more positive impact on the environment. Turbines deployed in 2010 had an average size of 2.7 MW, while in 2020 this average increased to 6.5 MW. For 2025, the estimated average turbine size is expected to be between 10 MW and 12 MW.

Technological advancements supporting larger turbines help to reduce LCOE. However, higher power per turbine also means that the cost of failure has a significantly higher impact on ROI for developers. In addition, the cost of replacement of any equipment inside the turbine is often prohibitively high. Core turbine equipment such as generators, converters and transformers need to be extremely reliable and possibly maintenance-free.

Solutions are needed for more compact and reliable equipment with extended lifetimes. As an example, with the application of Dupont's Nomex® insulation technology in combination with dielectric liquids (typically biodegradable esters), global transformer manufacturers have been able to design and build over 20 GW (approximately 9,000 units) which weigh less, occupy less space and are significantly more reliable. At the same time, these insulated transformers require less servicing, have reduced fire hazard and are environmentally safer, thereby reducing total ownership costs.

Find out more here: https://www.dupont.co.uk/nomex-for-electrical-infrastructure.html?src=EMEA_EN_Safety_EEQM_Article_GWEC2021

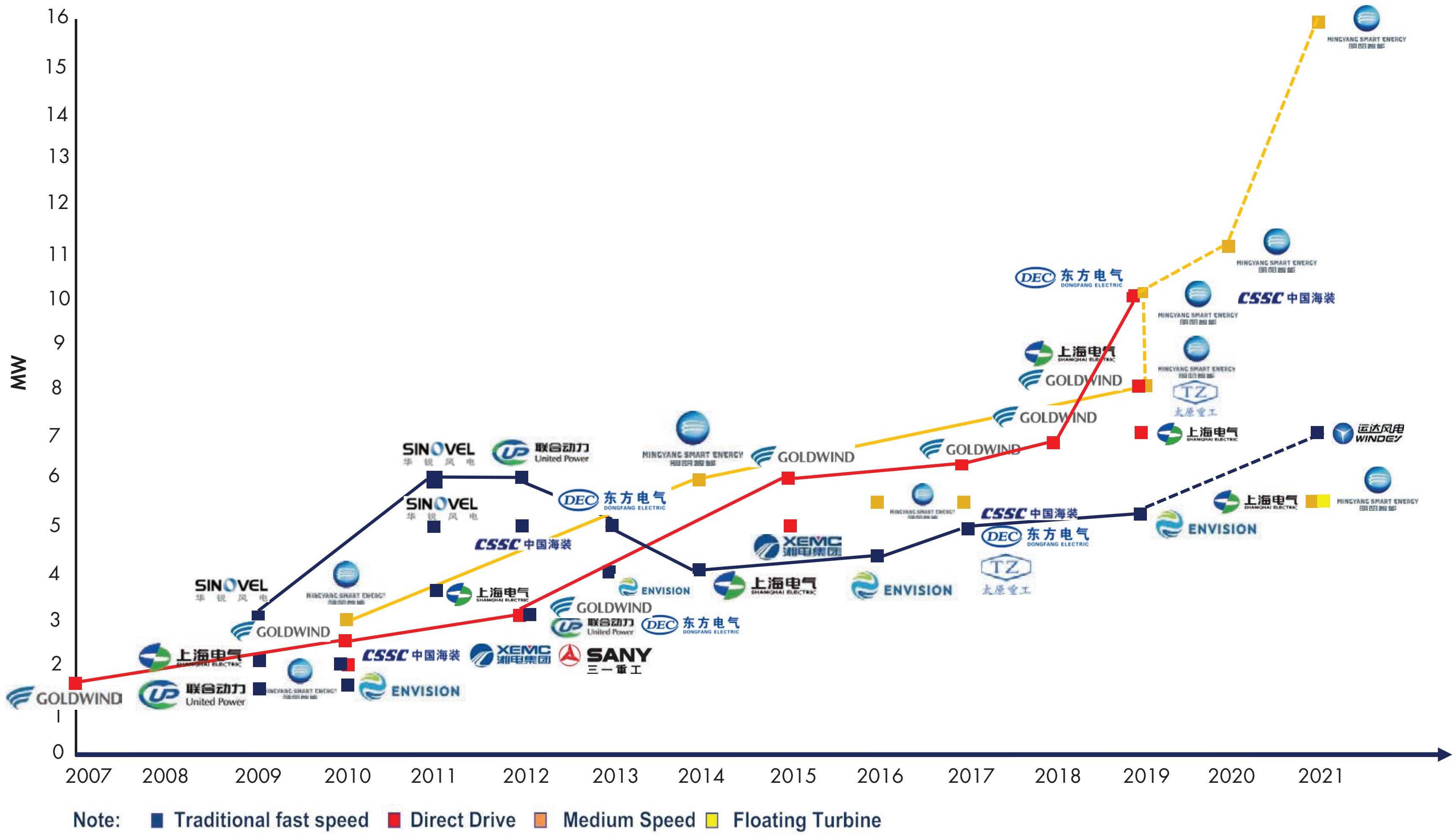
Offshore Wind Turbine Technology Road (excluding China)



Solid line: the installation has been completed; **Dashed line**: new product was released but the prototype is not installed yet.
Source: GWEC Market Intelligence, July 2021

Source: GWEC Market Intelligence, July 2021

China is playing catch-up in Offshore Wind Turbine Technology



Solid line: the installation has been completed; Dashed line: new product was released but the prototype is not installed yet.
Source: GWEC Market Intelligence, July 2021

Source: GWEC Market Intelligence, July 2021

Case study: How plug and play connectors can reduce project operating costs

Provided by: HARTING

OPEX can contribute 35-43% to an offshore wind energy project's 20-year lifetime costs.37 This percentage can increase to more than 50% if a project's lifetime extends to 30 years of operation. In order to keep these costs down, wind turbine manufacturers are turning to plug and play solutions to simplify their operations.

Even optimally designed wind turbines need to be well maintained. A modern offshore wind turbine is expected to have at least two scheduled and seven unscheduled maintenance cases per year. These are primarily due to failures in the subassemblies - such as the pitch systems, auxiliary systems, generators, yaw systems and other areas.38 In 20 years of operation, 180 maintenance cases are expected to occur.

In every maintenance case, at least two electrical or fibre-optic connections must be disconnected and connected by maintenance personnel. These could be a connection of power and signal between the pitch box and the battery backup box in the hub, or a connection of power, signal and single-mode glass fibers for the highly sensitive slipring, or power and signal to a yaw motor. All these connections should have an effective EMC shielding capability which necessitates additional care and effort by maintenance teams when servicing the subassemblies.

Designing "hard-wired connections" with terminal blocks seems simple but leads to very high costs. A HARTING White Paper on Connectivity in Wind Turbines describes a case of ten – 7 MW wind turbines. We found labour, training and especially turbine downtime costs could reach as high as €2.8 million over the 20-year turbine lifetime. At the same time, if the hard-wired connections in each turbine were replaced with approximately 150 HARTING plug and play connectors, which incorporate a combination of power, data and signal, the investment would be around €0.1 million in CAPEX. However, these advanced connectivity solutions could provide a cost saving of €2.5 million, equivalent to approximately 4% of the total CAPEX investment.

Find out more: https://www.harting.com/DE/en-gb/capex-opex-wind-energy

Image credit: HARTING

37 https://eit.europa.eu/sites/default/files/KIC_IE_OffshoreWind_anticipated_innovations_impact.pdf
38 Carroll, McDonald and McMillan. Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines. Wind Energy. 2016.

Power-to-X and Renewable Hydrogen

Power-to-X – a stepping stone to achieving global energy transition

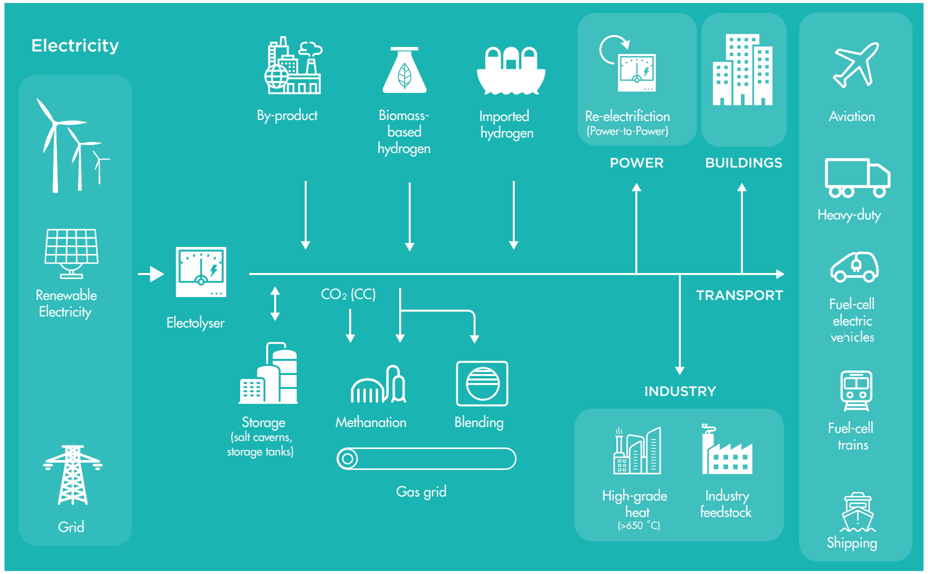
Electrification, efficiency and renewable energy all play a central part in reducing emissions across all sectors in IEA's Net Zero 2050 roadmap. However, those hard-to-abate sectors where direct electrification is challenging still require a massive scale up of the required technologies like hydrogen to achieve the energy transition. As the world races against time to fight climate change, hydrogen has become one of key pillars of decarbonisation of the global energy system. Continued advancements in Power-to-X technology and falling renewable energy costs, along with government ambition to integrate hydrogen into their long-term climate strategies, suggest that the unprecedented momentum around the world could not only accelerate global decarbonisation, but also could constitute an emerging economically viable business model to unlock the benefits of a Power-to-X economy.

Innovation for multiple end-uses

Power-to-X refers to the conversion of surplus renewable energy into liquid or gaseous chemical energy sources through electrolysis and further synthesis processes. Power-to-X is a promising and innovative storage solution for wind that minimises waste and maximises efficiency by deploying stored power for myriad uses. Stored electricity can be electrolysed into hydrogen to be used as feedstock to produce bulk chemicals like methanol or ammonia for industrial processes (Power-to-Gas or Power-to-Chemicals) or combined with captured CO2 to make carbon-neutral liquid fuels such as gasoline, diesel and aviation fuels (Power-to-Liquid Fuels). Stored green power can generate heat through heat pumps or electric boilers for houses and factories (Power-to-Heat), or contained in underground formations such as salt domes and fed back to the grid when needed (Power-to-Power).

According to the IEA, the power sector accounts for nearly 40% of CO_2 emissions worldwide, and this share is declining due to the expansion of renewable generation; transport and industry make up nearly half of remaining global emissions, with buildings comprising around 10%. Each sector and end-use requires targeted solutions. Energy carriers and chemical products provide significant

Power-to-X : Integration of renewable energy into end-uses



Source: IRENA, 2018d.

versatility in renewable energy storage, transport and subsequent conversion to end-use products. The sector-coupling approach of Power-to-X is a critical response to the "hard-to-electrify" sectors, such as heavy trucks, shipping, aviation, steel and cement production and chemicals manufacturing.

Hydrogen production must be green

While much has been made of hydrogen's applications, the key is production: Hydrogen is a clean-burning gas which emits only water at the point of combustion. The emissions challenge is related to production: Conversion of fossil fuels with heat or steam is currently the primary method of production, but this process emits CO_2 and creates so-called "grey hydrogen". Most hydrogen production today is "grey", based on methane and coal, and emits 830 million tonnes of CO_2 annually, according to Carbon Brief.

"Blue hydrogen" pairs this process with carbon capture and storage (CCS) technologies which are currently capital-intensive. "Green hydrogen" is produced via electrolysis, fed by green power sourced from an adjacent renewable asset or on the grid.

Expansion and investment of enabling infrastructure for hydrogen must emphasise green production – this is not only an imperative to meet carbon neutrality goals, but also reflects the economics of declining costs for renewable power and electrolysers. Driven by R&D and economies of scale in manufacturing facilities, cost reduction and learning rates could make electrolysers 40% cheaper and green hydrogen cost competitive as soon as 2030, according to IRENA. IEA's Net Zero 2050 roadmap also suggests hydrogen production by 2050 will be almost entirely based on low-carbon technologies and green hydrogen (or water electrolysis) accounting for two third of global production. By 2050, electrolysis will absorb close to 15,000 terawatt-hours (TWh) electricity, or 20% of global electricity supply, of which 95% is from renewable resources.

Offshore wind-to-hydrogen: a flexible and economical option

With electrolysers just in their infancy and still expensive, the potential for hydrogen cost reductions not only replies on the electrolysers, but also depends on which energy sources will be coupled with. Of all the renewable electricity options, wind has the highest potential to produce sustainable hydrogen because of its economic competitiveness. According to BNEF 1H LCOE Update, the LCOE of offshore and onshore wind fell by 68% and 57% between 2012 and 2021 respectively. The Future Cost of Onshore and Offshore survey results released by NREL and Berkeley LAB in April show the LCOE can drop by another 49% for fixed bottom offshore and 40% for floating wind by 2050.

As the best wind resources are out at sea, Power-to-X complements offshore wind perfectly. It aids the integration of more offshore wind by avoiding curtailment or constraint due to the lack of transmission capacity and decouples renewables power generation from demand. The hybrid solution brings about increasing flexibility of the power grid, greater energy security and lower price volatility. At present, there are primarily two types of explored offshore wind-to-hydrogen solutions.

In the first offshore wind-to-hydrogen solution, surplus offshore wind energy that would otherwise be curtailed - or purpose-built offshore wind capacity

for hydrogen generation - will power electrolysers that split water molecules into hydrogen and oxygen. Green hydrogen is then compressed and stored in a tank system, waiting to be offloaded when energy is needed.

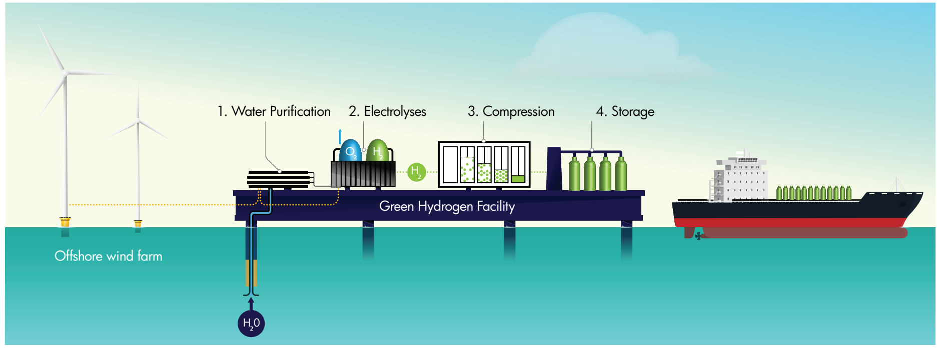
With an offshore hydrogenation platform available, liquid hydrogen (LH2) can be converted to synthetic natural gas (SNG), better known as methane, before being shipped to end-users for multiple purposes. In the concept of Energy Island in Denmark, the artificial island, VindØ, in the North Sea, is actually also serving as the offshore hydrogenation platform (see Illustration 1(a)).

As shipping is a relatively expensive form of transportation, electrolysers can also be deployed in coastal areas connected by HV subsea cables to substations to transport the green hydrogen directly with on-land hydrogen pipelines or by truck after compression (see Illustration1(b)). The 10 GW NorthH2 green hydrogen project currently under development by Shell consortium including the Groningen Seaports in the Netherlands is a perfect representative for this solution.

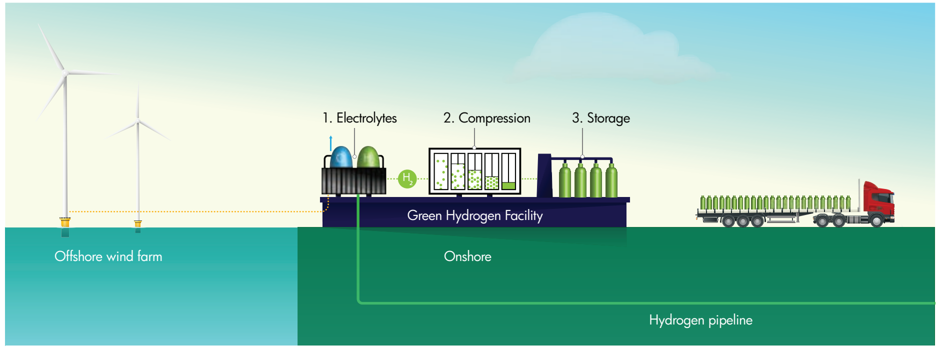
Projects that use hydrogen as the feedstock normally pursue this option.

Another innovative offshore wind-to-hydrogen solution aims at using excess offshore wind energy to power electrolysers located on oil and gas platforms to produce green hydrogen from seawater. The green hydrogen is blended into the gas export line and transported to land via existing gas infrastructure (see Illustration 2). This solution is already widely used by industrial gas producers to supply chemical and refining industries. It is expected that up to 20% of hydrogen by volume can be mixed into existing gas pipeline flows. While blending green hydrogen into existing natural gas pipelines cannot achieve 100% decarbonisation, it can still be a contributing solution in the short term as the existing natural gas supply will continue to be used to balance power systems in the immediate future and blending green hydrogen helps to partially decarbonise this flow. The PosHYdon green hydrogen project located in the Dutch North Sea and the H-Wind project planned by investors in Ireland are examples for this option.

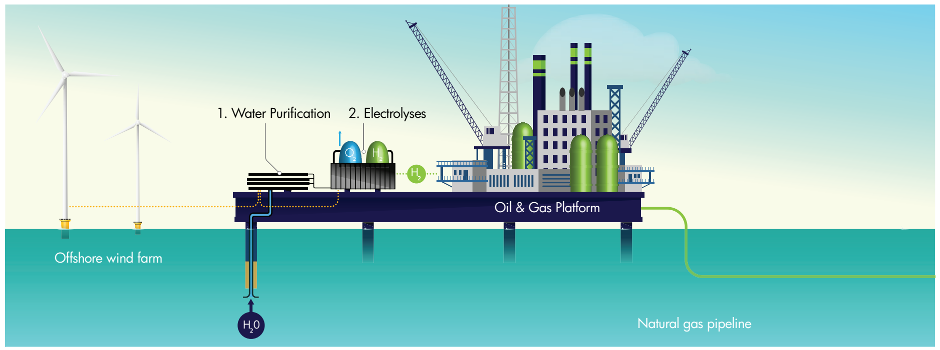
Offshore wind to hydrogen solution 1(a)



Offshore wind to hydrogen solution 1(b)



Offshore wind to hydrogen solution 2



Selected Offshore Power-to-X projects under development

Project	Location	Developers	Commissioning and Capacity	Status as of H1 2021
NortH2	Eemshaven, northern Netherlands	Shell, Equinor, RWE, Gasunie, Groningen Seaports	10 GW by 2040 (1 GW by 2027, 4 GW by 2030)	Fully powered by offshore wind, feasibility study to be completed by mid-2021.
AquaVentus	Heligoland, Germany	A consortium of 27 companies and research institutions, such as RWE, Shell, Equnior, Ørsted, Siemens Gamesa, Vestas, DNV, Hitachi ABB, Van Oord and more	2035 (30 MW by 2025, 5 GW by 2030)	Early stage, first sub-project by 2025 Note: AquaVentus comprises numerous sub-projects along the value chain from the production of hydrogen in the North Sea to transport to customers on the mainland, such as AquaPrimus, AquaSector (300 MW electrolyser by 2028), AquaDuctus, AquaPortus etc.
PosHYdon	Q13a platform, off the coast of Scheveningen, Netherlands	A consortium including Eneco, Neptune Energy, DEME, EBN B.V. and TAQA Offshore B.V.	1 MW (2021) 100 MW designed hydrogen capacity	Construction work kicked off in July and production expected for the 1 MW electrolyser pilot phase in late 2021.
H2RES Demo	Copenhagen, Denmark	Ørsted and GHS	2 MW (late 2021)	Construction already started in May 2021.
Greater Copenhagen	Copenhagen, Denmark	Ørsted, HOFOR, Maersk, DSV Panalpina, DFDS, SAS, COWI, BCG and others	1.3 GW by 2030 (10 MW pilot as soon as 2023, 250 MW by 2027)	Feasibility study under way for this full offshore wind to hydrogen project, with a view to a final investment decision in 2021.
OYSTER	Europe	A consortium of Ørsted, Siemens Gamesa, ITM Power and Element Energy	2021-2024	Investigating feasibility of offshore wind and 'fully marinised' electrolysers in a shoreside pilot trial.
'Deep Purple' Seabed Hydrogen Storage Pilot	Norway	A consortium led by TechnipFMC along with Vattenfall, ABB, DNV GL and more	2021-2023	Construction will commence in late 2021.
HYPORT® Oostende	Belgium	DEME, Oostende Port, and PMV	2025	A 50 MW demonstration project is scheduled. By 2022, the roll-out of a large-scale shore-based power project, running on green hydrogen, will start.
Tweede Maasvlakte project	Port of Rotterdam, Netherlands	Shell consortium	2023 (200 MW)	To serve as a steppingstone for the NortH2-project.

Project	Location	Developers	Commissioning and Capacity	Status as of H1 2021
Hyoffwind	Zeebrugge, Belgium	A consortium comprising the Belgian offshore wind developer Parkwind, Fluxys, and Eoly	25 MW (first production from 2023)	Plan to obtain the necessary permits by mid-2021.
Westküste 100	Germany	A consortium includes Ørsted, EDF Germany, Holcim Germany, OGE, and others	700 MW (Phase one at 30 MW)	Already secure EUR 30 million funding in 2020.
Lingen Refinery project	Germany	Ørsted and bp	50 MW (2024) 500 MW (long term plan)	Jointly agreement signed in November 2020.
Sluiskil Green Ammonia project	Zeeland, Netherlands	Ørsted and fertilizer producer Yara	100 MW by 2024/2025	A final investment decision to build the new plant could be taken late 2021 or early 2022.
SeaH2Land	Netherlands	Ørsted	1 GW by 2030	The development plan was announced in March 2021
VindØ	Denmark	A consortium of PensionDanmark and PFA, utility company Andel and CIP	2030	Artificial island with initial 3 GW of offshore wind capacity; plan to connect 10 GW offshore wind and host energy storage and Power-to-X facilities on this North Sea energy island.
Ulsan floating offshore wind-hydrogen project	Ulsan, South Korea	Ten major South Korean companies, municipalities, and organisations including Hyundai	100 MW (pilot plant 2025), 1.2 GW (2030)	Development plan announced in May 2021.
Ishikari offshore wind-hydrogen project	Northern island of Hokkaido, Japan	A consortium comprising of Hokkaido Electric Power, Green Power Investment, Nippon Steel Engineering, and industrial gas provider Air Water	550 tonnes hydrogen per year (2024)	Development plan announced in July 2021

Source: company news, GWEC Market Intelligence, July 2021

Case study: Green Fuels for Denmark

Denmark was one of the first countries to set out a legally binding target of carbon neutrality by 2050. To achieve the net zero target, the Danish government and industries have started exploring Power-to-X technologies with the goal of generating green fuels that can decarbonise sectors where direct electrification is challenging, such as heavy transport, aviation and maritime.

The Green Fuels for Denmark (GFDK) project is a good example and presents Denmark's ambitious vision for using the large-scale production of sustainable fuels to support its energy transition. The project, located in Copenhagen, will be built in three phases, each phase with approximately 10 MW, 250 MW, and 1,300 MW in total electrolysis capacity, respectively.

Phase 1 (2021-2023): Establishing a single electrolyser module of 10 MW producing renewable hydrogen for use in fuel cell buses and trucks in Denmark.

Phase 2 (2023-2027): Scale-up and commercial operation of a 250 MW electrolyser coupled with offshore wind, CO2 capture and chemical synthesis to produce sustainable renewable e-methanol for maritime transport and renewable e-kerosene for aviation.

Phase 3 (2027-2030+): Further scale-up to reach a combined electrolyser capacity of 1.3 GW, corresponding to 30% of Copenhagen Airport's fuel consumption, a large proportion of truck and bus operations in Greater Copenhagen and a full-sized container vessel.

The first partnership for this project was formed in May 2020 and it consists of leading companies across the value chain, including Copenhagen Airports, SAS (aviation), A.P. Moller–Maersk, DFDS, Molslinjen (shipping/ferry), DSV Panalpina (heavy-duty transport), Everfuel, NEL, Haldor Topsoe, COWI (Power-to-X technology and solutions), Ørsted (renewable energy developer) and the Municipality of Copenhagen (Denmark's Capital Region).

In May 2021, Ørsted and HOFOR (Greater Copenhagen Utility) entered into an agreement to secure green power for part of the GFDK project. As agreed, Ørsted will offtake the green power produced at the 250 MW Aflandshage offshore wind project, which is planned to be built by HOFOR in the Oresund Strait. The offshore wind farm's substation will be placed at the premises of Avedøre Power Station, which is owned and operated by Ørsted and where the GFDK project will be located. The power from the Aflandshage wind farm is expected

The view of Avedøre Power Station

Photo credit: Ørsted

to meet the power demand for GFDK project's first phase and enable parts of green fuels production for the project's second phase. According to Ørsted, it will continue to pursue opportunities to secure green power from additional sources for GFDK project towards the commissioning of the planned Danish energy island in Bornholm located in the Baltic Sea, which is one of energy islands approved by the Danish government in 2020.

Although the project will be located in Copenhagen, it should be viewed in a larger regional context since several Northern European regions (Oslo, Gothenburg, Malmö, Copenhagen and Hamburg) are cooperating on solutions to facilitate a green transformation through renewable hydrogen. According to the consortium, the project may consider onboarding infrastructure companies (such as electricity and gas TSOs) to support distribution of produced e-fuels in the long run.

The GFDK project has the potential to establish new solutions to global challenges in relation to energy, climate and transport and could become a leading example of how offshore wind technology can be combined with Power-to-X solutions to deliver on the vast European ambitions for sustainable fuels.

CONCLUSION

Offshore wind: Charting the way to net zero

Last year's Global Offshore Wind Report 2020 reflected on a decade of dramatic progress in the offshore wind sector across technology innovation, cost reduction and expanding installations in Europe and Mainland China. This year's edition highlights offshore wind's role in the decades ahead, as one of the central planks of the world's future energy system and a necessary vector in global climate change mitigation efforts.

Offshore wind ambitions are emerging from nearly every region of the world, as policymakers increasingly recognise the sector's capacity to transform electricity systems and accelerate decarbonisation beyond the power sector. Still, the roadmaps which set out milestones to reach global carbon neutrality and sustain a 1.5°C pathway aim for around 2,000 GW of offshore wind capacity by 2050 – and that means a long way to go from the 35 GW installed as of the end of 2020.

Last year was the second-best year for offshore wind in terms of new installations, with 6.1 GW installed globally, across China (3 GW), the Netherlands (nearly 1.5 GW), Belgium (700 MW) and other European countries. 2020 also saw more offshore turbines spinning in South Korea and the US, as well as more than 16 MW of floating offshore wind capacity that was grid-connected in Portugal.

Looking ahead to 2030, GWEC Market Intelligence is seeing greater promise in the sector compared to its outlook from last year. New annual installations are expected to sail past 20 GW in 2026 and potentially reach 40 GW in 2030. Over 235 GW of new capacity is expected to be added over the next 10 years, bringing total offshore wind capacity by the end of the decade to 270 GW. Two-thirds of these installations will occur in the latter half of the decade.

Key takeaways

- 2020 was the second-best record year of growth after 2019, with 6.1 GW of capacity added and cumulative global installations of 35.3 GW.
- Offshore wind now accounts for 5% of total global wind capacity, as of the end of 2020.
- Europe remains the largest offshore wind region by cumulative capacity.
- The sector is taking off in Asia where more than 10 GW is installed, and China led new installations globally in 2020 with more than 3 GW of offshore wind reaching grid connection.
- More than 235 GW of new offshore wind capacity is forecast through a 36 GW increase from last year's Business-as-Usual outlook, bringing the cumulative offshore wind capacity to 270 GW by 2030.
- The volume of annual offshore wind installations is expected to pass the 20 GW milestone in 2025, increasing its share of global new installations from today's 6.5% to 20% by 2025.
- The forecast for floating offshore wind has majorly increased from 6.5 GW of new capacity by 2030 in last year's outlook to 16.5 GW, spurred by ambitious government targets and major investors' development plans.
- Turbine technology continues to innovate, with turbine sizes set to increase as the sector is under pressure to reach grid parity in Europe and China.
- Horizon-scanning for sustainability challenges will be necessary as the sector grows, where constraints can come from existing supply chain and infrastructure limitations, the carbon footprint and circularity of materials, foundation design and geopolitical factors.
- To reach the necessary volumes of growth for a net zero by 2050 scenario, policy and regulatory frameworks in new and early-stage offshore wind markets must reflect sector learnings in support schemes and competitive tenders, permitting, marine spatial planning, grid integration, financing and workforce capacity.

In the floating offshore wind sector, GWEC Market Intelligence has majorly upgraded its forecast to predict that 16.5 GW is likely to be installed over the next 10 years, compared with the 6.5 GW predicted in 2020 – mainly in Europe, East Asia and North America. By the end of the decade, the top floating markets are shaping up to be South Korea, Japan, Norway, France and the UK – which will in turn transform regional supply chains and establish new export hubs for components and services.

The positive market outlook for offshore wind to 2030 has improved under widening recognition of offshore wind as a key ocean-based climate solution, increased ambition and capacity targets by policymakers, a sharp drop in LCOE which has enhanced the sector's ability to compete, and finally the unique role which offshore wind plays in facilitating cross-industry decarbonisation, including the oil and gas sector's transition to renewables, production of green hydrogen and Power-to-X solutions.

Turbine technology has drastically improved over the last two decades, and offshore wind turbine rating and rotor diameter are forecast to continue increasing under pressure to reduce LCOE in Europe and China. Key Balance of Plant elements, including foundations, cables and substations, and installation services, are under pressure for CAPEX reduction, while fewer but larger units will deliver savings in operations and maintenance. By 2030, next-generation offshore turbine technology could carry a 20 MW rating with a 275m rotor diameter, according to GWEC Market Intelligence.

Technology innovation and sector growth cannot happen unchecked. Offshore wind's role in delivering clean energy means that the carbon footprint of its own supply chain faces scrutiny. Improving circularity of projects, extending turbine lifecycles and investing in R&D for improved materials and commercial recycling processes, particularly for blades, will be necessary to achieve sustainable growth.

Evolving considerations are fostering offshore wind's expansion, from visions of renewable hydrogen export and national economy to large-scale job creation in the post-COVID-19 context. Market mechanisms are changing too, as international climate finance is creating a greater enabling environment for capital-intensive offshore wind projects and levers such as carbon border adjustment taxes and renewable portfolio standards are disincentivising fossil fuel offtake and generation.

It is certain that delivering on offshore wind's potential in a net zero world will require a step change in political will. But it will also call for greater collaboration between policymakers, industrial consumers, public funders, civil society and the industry itself to learn from the last decade of offshore wind's journey and foster a more sustainable, visible, ambitious and shared pathway to growth ahead.

APPENDIX

Methodology and Terminology

Data definitions and adjustments

GWEC reports installed and fully commissioned capacity additions and total installations. However, considering the delay of grid connection in China, GWEC uses installation data from the Chinese Wind Energy Association (CWEA) for China instead of grid-connected data. New installations are gross figures not deducting decommissioned capacity. Total installations are net figures, adjusted for decommissioned capacity.

Definition of regions

GWEC adjusted its definition of regions in 2018 and maintains these in the 2021 edition of this report, specifically for Latin America and Europe.

Latin America: South, Central America and Mexico

Europe: Geographic Europe including Norway, Russia, Switzerland, Turkey, Ukraine

Sources for the report

GWEC collects installation data from regional or country wind associations, alternatively, from industry experts. Historic installation data has been adjusted based on the input GWEC received. The 2021 Global Offshore Wind Report shows the accurate current and historic data.

Used terminology

GWEC uses terminology to the best knowledge. With the wind industry transitioning certain terminology is not yet fixed or can have several connotations. GWEC is continuously adapting and adjusting to these developments.

Abbreviation

CAPEX	Capital Expenditures
CfD	Contracts for Difference
CPPA	Corporate Power Purchase Agreement
ECAs	Export Credit Agencies
EOI	Expression of Interest
FiT	Feed-in Tariff
FOW	Floating Offshore Wind
FOWF	Floating Offshore Wind Farm
ITC	Investment Tax Credits
LCOE	Levelised Cost of Energy
LiDAR	Light Detection and Ranging
MSP	Marine Spatial Planning
MOU	Memorandum of Understanding
O&M	Operations and Maintenance
OPEX	Operating expenditures
PPA	Power Purchase Agreement
PTC	Production Tax Credit
R&D	Research and Development
RfP	Request for Proposal
RECs	Renewable energy credits
ROI	Return on Investment
SDGs	Sustainable Development Goals

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GWEC Market Intelligence provides a series of insights and data-based analysis on the development of the wind industry. This includes a market outlook, country profiles and policy updates, deep-dives on the offshore market among other insights.

GWEC Market Intelligence derives it insights from its own comprehensive databases, local knowledge and leading industry experts.

The intelligence team in GWEC consists of several strong experts with long-standing industry experience.

GWEC Market Intelligence collaborates with its regional and country member wind association as well as with its corporate members.

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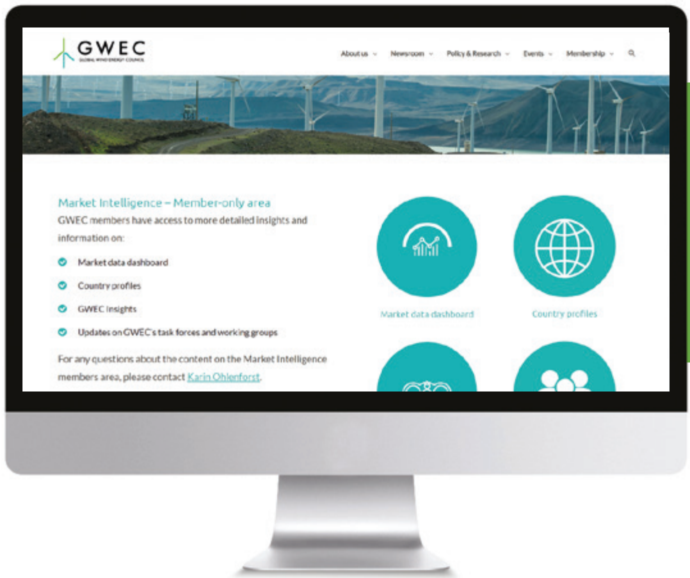
ISP - OEM - Self Perform database for key markets



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	Global Wind Report 2021	Annual
	Wind Energy Statistics (Wind energy penetration rate, jobs)	Annual
2.	**Country Profile/ Policy Updates**	
	Country Profiles Onshores/ Country Profiles Offshore	Quarterly/Ad-hoc
	Ad-hoc policy updates	Ad-hoc
3.	**Market Outlook**	
	Global Wind Market Outlook 2021-2025 (Q1 and Q3)	Semi-Annual
4.	**Supply Side Data**	
	Global Wind Turbine Supply Side Data Report (by market, technology, turbine size and numbers)	Annual
5.	**Auction/ Tender**	
	Auction Trends and Learnings	Annual/ Quarterly
	Global Auction Results (database)	Quarterly
6.	**Offshore Wind Market**	
	Global Offshore Wind Report	Annual
	Market Entry Opportunities Database	Annual/ Quarterly
	Global Offshore Project Pipeline (database, in operation and under construction)	Annual/ Quarterly
	Global Offshore Turbine Installation Vessel Database	Annual/ Quarterly
	Vietnam's Future Transition To Offshore Wind Auctions	Special Report
7.	**Components Assessment**	
	Gearbox (2019), Blade (2020), Generator (2021), followed by other components	Special Report
8.	**Wind Asset Owner/ Operation**	
	Ranking of Wind Asset Owners and Operation Globally (Onshore and Offshore)	Annual
9.	**O&M**	
	O&M Service Provider Database (ISP - OEM - Self-perform)	Annual
10.	**Energy Transition, Digitalisation, Hybrid, Hydrogen**	
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