GWEC | GLOBAL OFFSHORE WIND REPORT 2022

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FOREWORD

Welcome to the Global Offshore Wind Report 2022

Welcome to the Global Offshore Wind Report 2022 - "Offshore Wind - the Next Horizon". It feels like the world has changed substantially since our 2021 edition. It also seems evident that we are working towards a new horizon for offshore wind technology, where wind will play an increasingly critical role in energy systems across the world.

Countries globally are now grappling with the unprecedented twin challenge of ensuring secure energy supplies and meeting climate targets to stem the worst effects of global heating. 2022 so far, has seen consumers globally bear the brunt of spiraling fuel and power prices as well as associated inflation, creating a cost of living crisis being felt in every corner of the world. It has also seen record emissions and temperature increases, and ever graver warnings from international climate bodies, as encapsulated in the latest IPCCC report.

As we set out in the Global Wind Report 2022 earlier this year, GWEC believes that the only permanent way to solve the challenges of energy security, climate change and affordability is an accelerated transition away from volatile fossil fuels towards renewables. Offshore wind represents a key opportunity for countries to push the energy transition forwards at scale, creating significant national and local jobs and economic growth and jobs, and lowering energy prices, while supporting energy security.

I am, therefore, pleased to share with you that 21.1GW of offshore wind was connected to the grid last year, making 2021 the best ever year for the offshore wind industry. 2022 is likewise set to be a record-breaking year for offshore wind growth globally.

Policymakers are now fully waking up to the opportunities that offshore wind can provide. The last few months following COP26 have seen a rapid expansion of ambition for offshore wind around the world. We have seen many governments either setting offshore wind targets for the first time or increasing targets in response to the energy crisis.

For example, the European Commission recently released the REPowerEU plan, aiming to achieve independence for Europe from Russian fossil fuels well before 2030. The Esbjerg Declaration from the North Sea nations of Denmark, the Netherlands, Belgium and Germany set out a new target of 150 GW of offshore wind by 2050. We have also seen the UK Government raise its offshore wind target by another 10 GW, to 50GW by 2030; and Vietnam is targeting a huge offshore wind increase in its PDP8 (Power Development Plan 8).

In the United States, the total announced offshore wind procurement targets at the state level increased by 28.6% to nearly 50 GW within a year. In Australia, the Victoria State Government has set a target of 9 GW of offshore wind by 2030. Crucially governments are also starting to put in place the right policy frameworks to achieve their goals. We have also seen the publication of the Decree 10,946/2022 in Brazil which lays the regulatory ground for offshore wind, and in Columbia, the government is moving forwards towards a seabed leasing framework.

Rebecca Williams
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Collectively this increase in ambition is taking headline targets for offshore wind close to the 380 GW by 2030 which GWEC and IRENA proposed in their UN Energy Compact in 2021. However, policymakers and industry will now need to make a gargantuan effort to make sure these targets are met, as this will require around 70 GW of installations per year, compared to the current level of around 20 GW. So far, only China has shown itself capable of constructing at close to the required levels to meet its targets.

Many countries, such as South Korea, Vietnam, India, and Brazil, have impressive ambitions but are relatively new to offshore wind. These newer markets will, therefore, need to be supported by industry bodies such as GWEC, experienced national governments and other institutions to quickly kick start their sectors and get steel in the water in the right time frames to meet their targets. Redesigning regulatory frameworks to more rapidly lease seabed and permit sites will be of crucial importance if offshore wind is to fulfill its role in replacing fossil fuels. This year's Global Offshore Wind Report sets out details of how this can be achieved.

New policy solutions will also have to be adopted to ensure that the global supply chain can meet ever increasing demand against a backdrop of rising commodity prices and shrinking margins. Continued offshore wind growth cannot be achieved without a buoyant supply chain able to supply a growing pipeline of projects across the world.

As the size of the industry increases, a sustainable approach to expansion will be key. This year's report explores the different challenges that are being faced by the industry as it scales up and discusses how offshore wind can be deployed in harmony with nature, communities and shared users of the marine environment.

Offshore wind is ready to play its part in mitigating climate change and tackling the energy crisis. Now is the time to redouble our efforts, working collaboratively with policymakers, communities and wider stakeholders, to accelerate the transition towards a renewable future.

A lot has changed in the energy sector over the past year. The rebound in the world economy from COVID-19 has led to increased demand for energy and other commodities, with sharply rising prices as a consequence. Global supply chains have been disrupted, challenging the ability of industries to deliver on time and within budget. The energy and supply chain crisis has been further exacerbated by Russia's unwarranted invasion of Ukraine. Facing these grave challenges, it has become clear that the transition away from a fossil-dependent energy system must be accelerated.

Today, the offshore wind industry finds itself at a new inflection point. After a decade of industrialisation and cost reductions, offshore wind has become a well-established and mature industry. Despite recent cost inflation, offshore wind is firmly cost-competitive with fossil-powered alternatives, and even more so in light of the current high price environment for fossil fuels.

There is no longer any doubt that large-scale offshore wind will be an important part of the future decarbonised electricity system. Governments in Europe, the Asia-Pacific, the US and beyond are looking to offshore wind as a means to diversify and decarbonise their energy supply.

2021 was a remarkable year for new offshore wind capacity with a record 21 GW being installed globally, more than triple the capacity deployed in 2020. Europe had another strong year, installing around 3 GW. The big change happened in mainland China, where nearly 17 GW was installed, bringing its total installed capacity almost up to par with Europe. Meanwhile, the industry is seeing new build-out targets announced that would be almost unfathomable just a few years ago. These targets hold promise that the record installations seen in 2021 will not be a one-off event.

The offshore wind industry, however, cannot rest on its laurels and must continue to evolve and innovate. The carbon footprint of the industry needs to be minimised through the decarbonisation of supply chains, including the steel that goes into producing wind turbines and towers. Offshore wind needs to be built in balance with nature, carefully managing its impact on the environment and biodiversity. While climate change is the single largest threat to global biodiversity, including in the ocean, the industry also has a responsibility to avoid, mitigate and address potential environmental impacts as offshore wind expands off our coasts. There are exciting opportunities for innovation by integrating offshore wind at scale with energy islands, interconnector links and through Power-to-X.

Delivering on the ambitions for offshore wind capacity deployment will require a massive expansion of the supply chain. In Europe, supply chain capacity will need to more than triple towards 2030, and other regions will have to build up supply chains almost from scratch. A main challenge will be to attract the necessary investments while ensuring a healthy and economically sound supply chain industry. At the same time, the industry needs to continue to demonstrate the sustainability of offshore wind, including to local communities and biodiversity.

Ørsted appreciates the good working relationships in the sector, not least as expressed by GWEC. We look forward to continuing to work with these important agendas in 2022 and beyond, including at COP27 in Egypt.

Ulrik Stridbæk
Vice President, Group Regulatory Affairs, Ørsted

Ørsted

EXECUTIVE SUMMARY

The Data: 2021 - The best year for the offshore wind industry

Market status
2021 saw 21.1 GW offshore wind reach grid connection worldwide, three times more than in 2020, setting a new record in the offshore wind industry. The 21.1 GW of new installations brings global cumulative offshore wind power capacity to 56 GW, showing year-over-year (YoY) growth of 58% and representing 7% of total global cumulative wind installations.

Of the 21.1 GW in new offshore installations, 80% was contributed by China. This makes 2021 the fourth year that China has led the world in new offshore wind installations. This astounding growth in China was chiefly driven by the FiT cut-off for offshore wind starting from 1 January 2022. A similar situation also occurred in Vietnam, which commissioned 779 MW of intertidal (nearshore) projects last year, making it the third-largest market in new installations in 2021. Taiwan only commissioned the 109 MW Changhua demonstration project in 2021, due to COVID-19-related disruptions.

In addition to the new capacity from Asia, Europe is the only region which reported new offshore wind installations last year. The UK had a record year in 2021 with more than 2.3 GW reaching grid connection; however, it lost its title as the world's largest offshore wind market in total installations to China. Coming in second for new installations in Europe is Denmark with 605MW commissioned last year, followed by Netherlands (392 MW) and Norway (3.6MW).

In total installations, Europe remains the largest offshore wind regional market as of the end of 2021. The region was responsible for 50.4% of total cumulative global offshore wind installations, followed by Asia with 49.5% market share. Outside Europe and Asia, North America has 42 MW offshore wind in operation as of the end of last year, contributing only 0.1% of total offshore wind installations.

Last year also saw 57 MW of new floating wind installed worldwide, of which 48 MW was in the UK, 5.5 MW in China and 3.6 MW in Norway. As of 2021, a total of 121.4 MW of floating wind is installed globally, of which 110.9 MW (91.4%) is in Europe and the remaining 10.5 MW (8.6%) in Asia.

Market Outlook
Political commitment to net zero gathered global momentum at COP26 in Glasgow. Offshore wind power is poised to play a vital role on achieving carbon neutrality. Coupled with renewed policy urgency for achieving energy independence from Russian oil and gas, and volatility in fossil fuel markets in general, the global offshore wind market outlook in the medium and long-term looks extremely promising.

With an expected compound average annual growth rate (CAGR) of 6.3% until 2026 and 13.9% up to the beginning of next decade, new annual installations are expected to sail past the milestones of 30 GW in 2027 and 50 GW in 2030.

GWEC Market Intelligence expects that over 315 GW of new offshore wind capacity will be added over the next decade (2022-2031), bringing total global offshore wind capacity to 370 GW by the end of 2031. Of this new volume, 29% will be connected

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in the first half of the decade (2022-2026). This still falls short of the 380 GW offshore wind installation target by 2030 set by GWEC and IRENA in its UN Energy Compact in 2021.

As the volume of annual offshore wind installations is expected to more than double from 21.1 GW in 2021 to 54.9 GW in 2031, offshore's share of new global wind installations is set to grow from 23% in 2021 to at least 30% by 2031.

Considering the increased floating wind target in the UK and the accelerated floating project development activities in Europe, Asia and North America, which bring the current global floating project pipeline to 120 GW, GWEC Market Intelligence has upgraded its global floating wind forecast and predicts that 18.9 GW is likely to be built globally by 2030, of which 11 GW will be in Europe, 5.5 GW in Asia and the rest in North America.

It is important to emphasise that our near-term outlook is primarily based on the existing global offshore project pipeline, but our medium-term outlook (2027-2031) reflects current declared national and regional targets. Given the energy system reform packages still underway in Europe and other regions in response to Russia's invasion of Ukraine and fossil fuel price volatility, it is highly likely that these targets will increase further and GWEC Market Intelligence's 10-year forecast could be significantly revised upward this year.

On the other hand, there is currently an implementation gap between declared targets and the rate of annual installations. Enabling an acceleration in offshore wind energy deployment requires measures to accelerate permitting procedures for wind projects in the near-term, policies to initiate structural policy framework changes in the mid-term and commitments that can justify early and sustained investment in supply chain and infrastructure.

Offshore's share of new global wind installations is set to grow from 23% in 2021 to at least 30% by 2031.

The Story: The next horizon

2021 was a record year for the offshore wind industry. With 21.1 GW connected, we saw more installations than ever before, and cumulative installations reached 56 GW, contributing 7% of total global wind power installations.

Countries around the world are now focussing on offshore wind, as policymakers recognise the sector's capacity to transform energy systems, displace fossil fuels and provide jobs and economic growth. Since COP26, we have seen a "race to the top" from governments in terms of setting offshore wind targets. On targets alone, the world is edging closer to the levels of offshore wind set out in the GWEC-IRENA UN Energy Compact, in alignment with a net zero pathway: 380 GW by 2030 and 2,000 GW by 2050.

Our market outlook shows that by 2031 cumulative global installations will reach 370 GW. Looking into the coming decade, Asia will replace Europe as the world's largest regional offshore wind market by cumulative installations by the end of 2022, although Europe is expected to recapture this title from 2031. We also see many new offshore wind markets now emerging as serious contenders; the US, Vietnam, Brazil and Australia are poised to accelerate offshore wind rapidly in the coming years.

However, there is a growing gap between installations and targets. To meet net zero globally, according to the IEA, the world needs to install 80 GW of offshore wind annually by 2030 and then 70 GW by 2050.

Global governments urgently need to put in place the policy and regulatory frameworks to deliver against their promises.

Global governments urgently need to put in place the policy and regulatory frameworks to deliver against their promises.

This year's report outlines the significant challenges that industry governments and other stakeholders face in the rapid scale-up of offshore

wind. In Part One, we focus on the global offshore wind supply chain. The report asks whether the global offshore wind supply chain will be able to scale up to meet rapidly growing global demand. The chapter also delves into the significant issues arising from increasing commodity prices, shrinking margins and growing geopolitical considerations in the sector.

> At present, the limited release of seabed is causing the market to overheat.

In Part Two, we focus on the policy actions that governments need to enact for a rapid increase in offshore wind. The report sets out the role of efficient leasing processes, and argues that the amount of seabed being leased needs to increase in alignment with greater offshore wind ambitions and targets. At present, as the limited release of seabed is causing the market to overheat, GWEC is calling on governments to increase and speed up the release of seabed leasing over the next decade to meet climate goals, and create a more sustainable pipeline for the industry. The chapter also explores global permitting regimes, and outlines a range of best practice measures that would rapidly lower global permitting times.

In Part Three we look at industry sustainability across the value chain, examining the future challenges the industry will face with regard to critical minerals and the decarbonised supply chain. The chapter focuses particularly on the need for offshore wind to be deployed in harmony with nature, and highlights the role that marine spatial planning can play in balancing the interests of different marine users.

Part Four looks at new technology development in the industry, including offshore wind turbine technology innovation and trends of turbine drivetrain. We set out developments in green hydrogen and power-to-X, and highlight our recent report on the role of floating wind.

Our ever-popular "Markets to Watch" section takes a deep dive into emerging and maturing offshore wind markets. In "Exploring New Markets" we focus on four new offshore wind markets that are set to quickly rise through the ranks. Our detailed market outlook can be found at the end of the report.

PART ONE: SUPPLY CHAIN

Chapter Sponsor

LINCOLN ELECTRIC

Securing the supply chain

GWEC Market Intelligence's Global Wind Supply Side Data 2021 report shows that 10 wind turbine manufacturers installed 3,340 units of offshore wind turbines in 2021, making it a record year in offshore wind turbine delivery. Of the 10 suppliers, seven are based in China, two in Europe and one in Japan. Thanks to an astounding level of offshore wind growth in China driven by the feed-in tariff cut-off, Chinese suppliers dominated the offshore wind rankings last year with Siemens Gamesa and Vestas dropping out of the top three for the very first time. However, the global offshore wind market excluding China has been dominated by Siemens Gamesa, Vestas and most recently GE Renewable Energy, and until 2021, no Chinese offshore wind turbines had been installed outside China.

Globally, 16 wind turbine suppliers are still active in the offshore sector, of which 10 OEMs are based in China. This makes China the world's largest offshore turbine manufacturing base, followed by Europe (including Denmark, Germany, France and the UK), Taiwan, South Korea and Japan.

Based on GWEC Market Intelligence's the latest offshore wind market outlook (see page 84), we believe that China has the capacity to deliver the expected demand in this decade. In Europe, no bottlenecks are expected for offshore wind turbine supply in the near-term. However, expansion and new investment may be required in preparation for strong growth from 2025 onward. As the offshore market continues to globalise and moves into new markets away from Europe and China, it is becoming increasingly imperative for top tier supply chain providers to invest in emerging markets ready to supply growing demand.

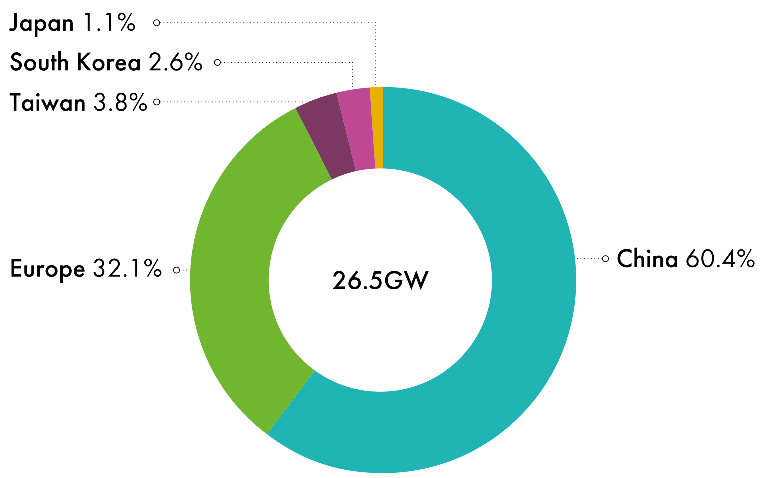
Compared with onshore wind, the global supply chain which sits behind offshore wind is more diverse. It includes not just the OEMs and key component suppliers of nacelles, blades, generators and converters, gearboxes, bearings and control equipment, but also suppliers of cabling, foundations and substations, as well as suppliers to engineering, procurement and construction (EPCs) and other installation contractors.

The graphic below sets out the split in value for an offshore wind farm, highlighting that almost two-thirds of the value from offshore wind comes from non-turbine elements. That includes 40% of value from other capital elements such as substructure and foundations, electrical infrastructure, and assembly and installation.

For Chinese projects, this supply chain is also based almost entirely within China, mirroring the situation with OEM supply. However, for the rest of the world, the supply chain is more diverse. The supply chain for critical components such as cabling and foundations is dominated by European suppliers, but there is also deep experience in Asia and the Middle East. Installation capability is focused in countries such as Norway, the Netherlands, Belgium and Denmark, but there is also growth in expertise in other European countries as well as South East Asia.

As we see ongoing growth in important markets like Southeast Asia and the US, we are also seeing growth in supply chains, through a

Global offshore wind turbine manufacturing capacity, 2021



Note: Wind turbine manufacturing capacity refers to wind turbine nacelle assembly capability and does not represent actual nacelle production in 2021 Source: GWEC Market Intelligence, June 2022 combination of inward investment, partnerships and diversification of domestic players.

Headwinds facing current wind supply chain

Continued growth of offshore wind requires a healthy supply chain able to meet the demands of a growing pipeline of projects, as well as supply into new markets across the world. Yet the offshore wind sector's supply chain remains under pressure from rising commodity prices and shrinking margins, which is undermining the offshore wind industry's ability to grow enough to meet rising global demand and address the challenge of decarbonisation.

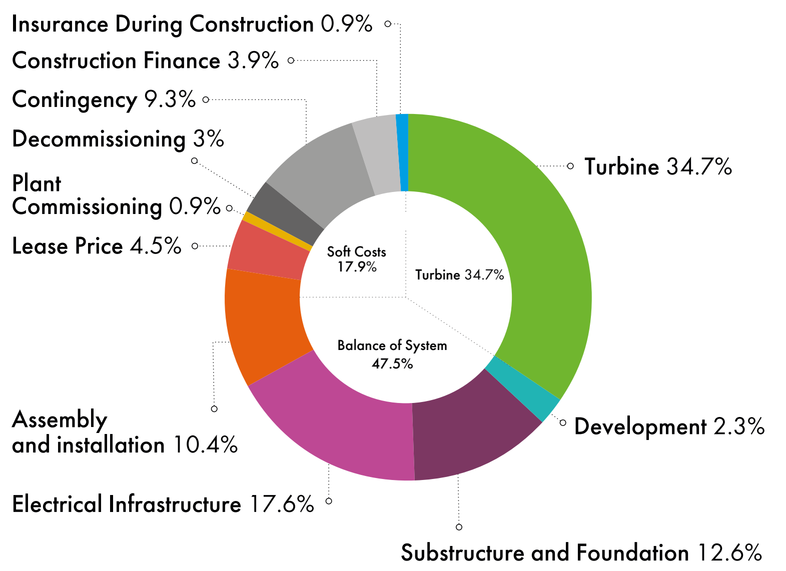
These pressures have been created by a successful period of growth, where the offshore wind sector has rapidly brought down costs while demonstrating the ability of offshore wind to deliver at scale. Turbine sizes continue to increase rapidly: rotor diameters have increased by nearly 50% to 163m by 2020, while turbine sizes have ballooned by 138% to an average 8 MW over the last decade.[1]

The growth in size and capacity has been a story of successful innovation and investment across the whole supply chain, not just OEMs. Foundations, towers, cables and installation vessel suppliers are all working hard to keep up this rapid growth, while also looking at the rapidly emerging floating offshore wind sector and its own growth needs.

Over the last few years, revenue pressure, pandemic-related challenges in logistics and workforce availability, the ongoing US-China trade conflict and a rise in prices for raw materials and commodities have impacted costs and profitability across the offshore wind supply chain. As the recent re-imposition of restrictions in China has also shown, the potential for delays and supply chain bottlenecks due to new and ongoing lockdowns also remains a concern.

The global wind supply chain responded to cost pressures as the market grew and as auctions worked to bring cost down in two ways. First through innovation and working to change the cost base of projects with a particular emphasis on the use of larger turbines. Second, with the exception of the Chinese market where a number of OEMs have recently moved into offshore wind, there has been ongoing consolidation in the rest of the global market, with fewer OEMs active across the supply chain.[2]

CAPEX for typical fixed-bottom offshore wind farm, 2020



Source: 2020 Cost of Wind Energy Review, Tyler Stehly and Patrick Duffy, National Renewable Energy Laboratory, 2021. Note: The reference project represents a typical 600 MW fixed-bottom offshore wind project comprising 75 wind turbines at 8.0 MW each, operating for 25 years with no major O&M events.

Despite this, the sector remains exposed to headwinds, from competition for critical minerals to local content requirements to unexpected geopolitical events. The need for long-term and adequately ambitious policy frameworks, as well as remuneration mechanisms for stable cost reductions, will be increasingly important for mitigating supply chain risks.

Investing ahead, scaling up and moving into new markets

In the wider supply chain, there is a need to build confidence so that investment continues to support the

1. Renewable technology innovation indicators: Mapping progress in costs, patents and standards, IRENA, 2022
2. GWEC (2022) Global Wind Market Development – Supply Side Data 2021

next generation of projects built using larger turbines. Installers need to invest in new vessels and equipment to successfully install these bigger machines, while infrastructure like ports must also invest to accommodate these larger turbines and the anticipated growth in project volume.[3]

This is true even in mature fixed-bottom markets. In floating offshore wind markets, there will be new challenges: port requirements are significantly different, with floating platforms needing additional space for fabrication and storage, as well as new anchor and mooring fabrication and marshalling requirements. These additional capacity demands will be on top of growing demand for larger sites needed for manufacture of larger components. In addition, both fixed-bottom and floating sites require space for project staging and assembly.

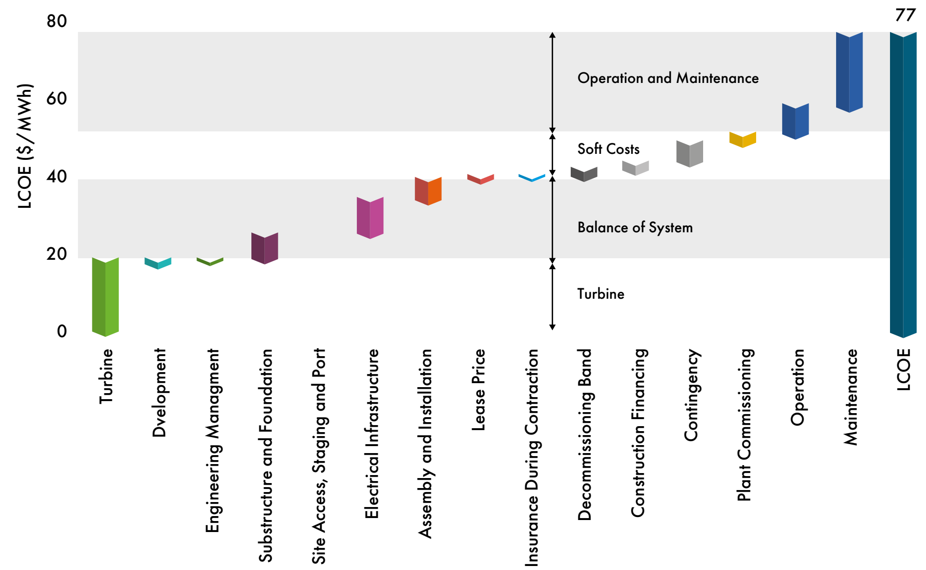
The floating offshore wind market is still maturing, however, it has multiple players and concepts approaching a high state of technology readiness. This creates a challenge for ports in floating offshore wind markets that are looking to prepare for a growing volume of floating offshore wind activity, but do not yet have clarity over which concepts or fabricators they need to be working with.

Not only does the industry need to invest to maintain growth in mature markets like Europe and China, it is also seeing a rapid scale-up in the US and the rest of Southeast Asia, as well as emerging demand in South America and the Pacific. This globalisation of offshore wind will test logistics and supply chains that are already under pressure. There will need to be investment in new manufacturing and installation capacity in emerging offshore markets, in part to meet local content requirements, but also to ensure sufficient sector capacity. Most obviously, the US market is continuing to grow with a multi-GW pipeline in place across the length of the Eastern Seaboard, as well as an emerging pipeline on the west coast. Market scale, activist state legislatures and supply chain laws will lead to new investments both in turbine manufacture and associated industries.

In growing markets like South Korea, Japan, Taiwan and Vietnam there are differing expectations on local content. Most challenging for the offshore wind industry has been local content provisions in place in Taiwan, which have slowed market growth due to the challenge of offshore wind developers finding sufficient local capability. In other markets the presence of existing manufacturing conglomerates means there are potential partners looking to work with OEMs and other suppliers as these markets grow.

However, in all of these new markets, investment in new manufacturing facilities will be difficult to justify if project economics remain

Component-level LCOE breakdown for typical fixed-bottom offshore wind farm operating for 25 years, 2020



Source: 2020 Cost of Wind Energy Review, Tyler Stehly and Patrick Duffy, National Renewable Energy Laboratory, 2021. Note: The reference project represents a typical 200 MW onshore wind plant in the interior US, comprising 73 wind turbines at 2.8 MW each, operating for 25 years with no major O&M events.

3. See for example this reaction from leading port Esbjerg to the signing of the May Esbjerg declaration raising offshore wind ambitions in Europe. https://portesbjerg.dk/en/about/news/six-billion-danish-kroner-secure-ambitious-eu-offshore-wind-targets

challenging. It will be hard for mature market players to justify inward investment decisions based on low prices, but equally hard for indigenous companies to move into new markets, if economics remain challenging in comparison to markets like oil and gas. The risk is either that projects are stalled due to delays in manufacturing capacity, or that local content aspirations cannot be delivered upon.

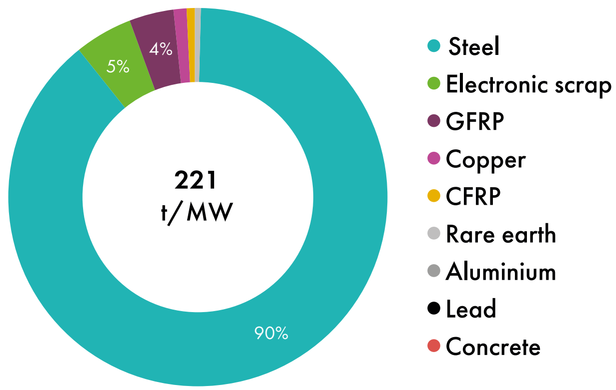
Industry is increasingly concerned that wider commodity and other cost pressures will undermine efforts to accelerate offshore wind delivery. Suppressed demand coming out of the global pandemic has created global supply chain pressures across the global economy, including offshore wind. Growing demand across the economy for materials like copper, steel and rare earth elements (REEs), coupled with supply chain bottlenecks means that demand is outstripping supply, leading to long-term sustained price increases.

Looking at a materials breakdown for offshore wind farms, 90% of offshore wind, in tonnes per MW is steel. But over the last two years, steel prices have increased by 50% from the start of 2020 to the end of 2021, and are being further impacted because of the invasion of Ukraine. The offshore wind industry also depends on copper for cabling and electrics, yet is having to manage price increases of 60%. Prices for neodymium and dysprosium, the two key rare earth elements (REEs) for direct drive and hybrid drive wind turbines, have tripled in price over the same period.

A particular challenge for offshore wind is the long-term nature of project planning and delivery. Turbine prices for projects are negotiated years in advance of manufacturing and delivery, meaning that prices are already locked in, leaving OEMs exposed to price volatility and logistics risks outside of their control.

On top of commodity price risks, logistics bottlenecks and freight cost increases are also impacting the global offshore wind supply chain. Bottlenecks have caused delivery timescales of some key components to increase from five weeks to as many as 50 weeks, while freight costs have also risen: By the middle of last year, spot rates for a 40-foot ocean freight container from Asia to the US reached a record-high – 10 times higher than rates just a few years ago, particularly as freight contract rates rose after the Suez Canal crisis in March 2021.[4]

Materials breakdown for offshore wind farm



Source: BloombergNEF. Note: GFRP = Glass fiber reinforced plastic. CFRP - Carbon fiber reinforced plastic.

As a result, turbine prices for future projects are forecast to rise by 9% in the second half of 2021, according to the BloombergNEF turbine pricing index. This increase will make it even more challenging for wind energy to continue to compete for razor-thin margins in tenders and procurement schemes around the world, as well as impact on the industry's ability to invest in supply chain growth and innovation.

While these headwinds are now well understood within the sector, there are differing views over whether these challenges are the result of a commodity super-cycle, or just a short-term blip as the world adjusts to new business realities post pandemic. What is clear, however, is that offshore wind as a sector needs to grow rapidly, both to support the delivery of global climate ambitions, as well as aid action on global energy security. As this report sets out, offshore wind needs to accelerate its growth to play its part in keeping the world on a trajectory to net zero. But these growth ambitions risk being held back due to supply chain lead times and price volatility.

4. https://www.bloomberg.com/news/articles/2021-07-15/container-rates-to-u-s-top-10-000-as-shipping-crunch-tightens

These pressures impact not just OEMs but the whole supply chain. The complexity of offshore wind projects compared to onshore, means that turbine costs are a lower proportion of capital costs. This means that changes in the cost base of companies providing critical elements of an offshore wind farm, including the towers, substations, cables, jackets, as well as critical components such as generators, can also have a significant impact on project costs and economic viability.

This wider offshore wind supply chain, of course, faces the same pressures on commodity pricing and supply chain bottlenecks. Installers and shipping providers also face the same issues. These companies all need to invest in new equipment both to meet growing demand, and to adapt to be able to deliver bigger projects using bigger turbines. Companies must plan for the long term and need early investment to ensure they are ready to meet future demand, but this means negotiating prices years in advance to secure contracts from developers or OEMs. Industry is used to hedging to help manage different risks, but as a strategy hedging is not sustainable if problems such as commodity price volatility remain over the long term.

On top of this, the sector is now beginning to plan out and deliver a first generation of new GW-scale floating offshore wind projects in markets like the UK, France, Korea and Japan. The sector has a lot of confidence that comes from the valuable lessons of scaling up fixed bottom offshore wind. However, floating offshore wind projects will need to be able to demonstrate rapid cost reduction, which is made more challenging in the face of wider cost pressures in the market.

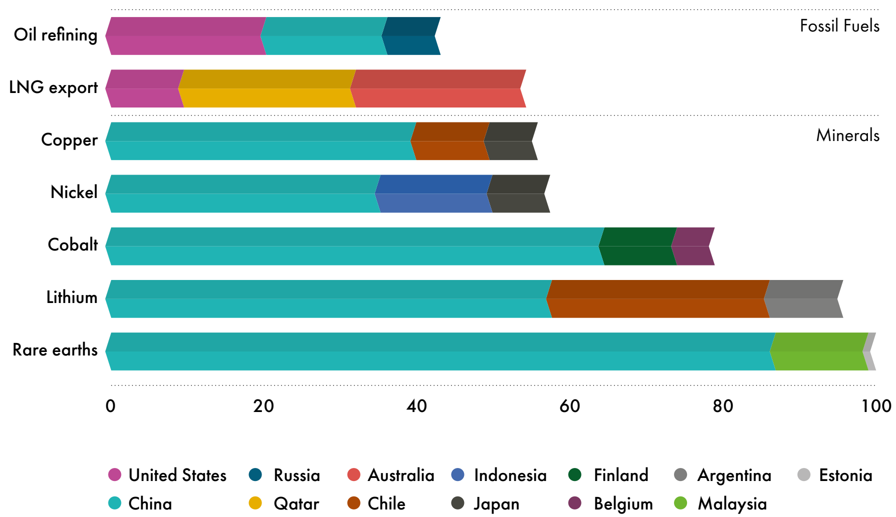
Managing supply chain risks within the industry

Despite pressures on supply chain, there is a lot the sector can do to work together as well as alongside policy makers.

First, it needs to be restated that offshore wind, alongside other renewables, is a vital component of global efforts for decarbonisation and for increasing energy security for all. The sector has delivered rapid cost reductions and is now able to deliver power at a price comparable to or cheaper than fossil alternatives.

Therefore, the primary focus needs to be creating markets that protect consumers while helping fast-track projects. As many countries also

Share of top three producing countries in total processing of selected minerals and fossil fuels, 2019 (%)



Sources: IEA (2020b), USGS (2021), World Bureau of Metal Statistics (2020); Adamas Intelligence (2020)

want to see local content successfully growing as home markets take off, this also means policy makers taking on board the need to ensure a sufficient pipeline of projects, so that the industry is able to focus on delivering a sustainable pipeline. Secondly, policy makers need to understand that the energy transition also requires economic sustainability in the offshore wind sector.

Public-private cooperation on supply chain risks

The supply chain can also do more to cooperate, not just within the wind industry, but with other sectors critical to our global energy transition. A good example of this work is the agreement between GM and GE to cooperate on REE supply, linking in with related European and US efforts to manage risks of the energy transition due to geopolitics

and supply constraints of critical minerals.[5] European and US efforts to ensure that the whole energy transition is not derailed because of lack of access to supplies of these minerals must continue. At the same time, efforts inside China to ensure that the extraction and processing of minerals is done in a sustainable manner, will help ensure that externalities are properly costed into commodity pricing, helping to ensure a level-playing field in the market.

In the same way that OEMs are leading efforts to ensure blades are recyclable, looking at new materials and manufacturing processes, demonstrating sustainability and circular economy principles, and forming alliances to bring forward the commercialisation of green steel, they can also cooperate with top tier suppliers to build supply chain relationships. By doing so, they can ensure wider sustainability and robust supply chains for the necessary critical materials. OEMs can also work alongside governments to invest in new manufacturing processes or alternative products that will result in more efficient use of these materials or find ways to bring alternatives to market.

Policymakers can play an important role here too. They need to better understand the challenge of supply chain pressures and the risks these pose for their own aspirations to transition their economy to low carbon industries as they themselves shift to clean sources of power and wider electrification.

Policy makers need to better understand the impact of geopolitics on our energy transition, and follow through on policies which aim to increase diversity of supply in critical minerals. In many of the critical minerals needed for offshore wind manufacturing, supply is dominated by two or three countries (see the graph below). This consolidation needs to be addressed by supporting both sustainable extraction and processing of critical minerals so that demand for these materials is not constrained in the future.

Public-private cooperation on price risk and economic sustainability

As well as looking at the supply of critical materials which underpin our energy transition, governments also need to that ensure that policy,

5. https://www.ge.com/news/press-releases/general-motors-signs-mou-with-ge-renewable-energy-to-develop-supply-chain-of-rare-earth-support-ev-renewable-energy-growth

regulatory and tariff frameworks are drawn up in a way that can respond effectively to future upward price pressures.

The war in Ukraine, and the subsequent rise in energy prices globally, has forced governments to actively engage in and support energy markets. This action is vital for protecting industry and consumers, and there is an understanding that these are issues beyond the ability of individual businesses or sectors to manage. A parallel challenge exists in our energy transition, however.

As renewable energy has matured, it has delivered rapid price reductions that have benefited consumers. Part of the credit for these cost reductions must go to governments which have moved from unilateral tariffs that top up market prices to mechanisms that give price stability and create a ceiling on cost. This shift has been successful in protecting consumers, attracting finance and bringing down costs.

But with renewables now clearly low cost, there is now a need to look at how to use these mechanisms as a way of absorbing inflationary pressure, so that investment in new projects and associated supply chain growth are not held back. The design of support systems can better be factored in price risk into long term project management, for example linking contract pricing to delivery dates, and ensuring that tariff support programmes are able to account for price changes over time. In the same way that auction processes currently take account of supply chain and project readiness, so they also need to look at how they help remove delivery risks due to changing costs that are outside of an individual project or even the sector's control.

There are important lessons that can be drawn from how governments have supported the growth of offshore wind and other industries seen as critically important. For example, within the UK, between the closure of the Renewables Obligation and the commencement of the Contract for Difference regime, the UK Government awarded a series of FIDER (Final Investment Decision – Enabling Renewables) contracts.[6] These contracts successfully created a pipeline of offshore wind projects and avoided the challenge in the shift between support mechanisms leading to a gap in orders at the time the UK was seeking to capture and grow investment in blade manufacturing, cables, and other inward investments. Contracted tariffs were inflation-index linked, protecting contracts and suppliers in the event of inflation. There is an opportunity to learn from this experience and look at the design of tariffs to take account of future price risks and changes to capital costs.[7] Similarly taxation policy has been used in various markets e.g., the US.

What is clear though is that while supply chain and cost pressures are creating headwinds for many in the offshore wind industry, the longer-term outlook remains strong, but we must avoid delays in scaling up offshore wind because of current and potential persistent cost challenges, that are impacting sector profitability and supply chain competitiveness, though are not taking away from the cost competitiveness of offshore wind as an energy technology.

There is a need to focus on practical steps within industry and government so that the offshore wind industry can continue to grow and deliver on wider ambitions to decarbonise and deliver new employment. Offshore wind has shown in its 30-year lifetime how it can innovate and scale up effectively, and it is working hard to ensure that

wider sustainability goals are maintained. Economic sustainability needs to remain part of this effort to ensure the long-term health of this vital industry.

6. https://www.gov.uk/government/publications/final-investment-decision-fid-enabling-for-renewables-investment-contracts
7. https://www.gov.uk/government/news/future-funding-for-nuclear-plants

Case Study: Building the offshore wind factory of the future

Provided by: Bryan O'Neil, Director Global Offshore and Power Generation, The Lincoln Electric Company

With the urgency to rapidly increase installed offshore wind capacity by 2030 and 2050, key industry leaders and new market entrants for fabrication are investing significantly in the expansion of the supply chain capacity.

100 mm cross section (avg. steel thickness),
Monopile: 2200 MT weight / 99 M long
Photo courtesy of The Lincoln Electric Company

As foundation weight and diameters increase, capacity from the past decades is undersized to meet the practical requirements of new wind tower sizes and installation schedule. Leaders in fixed foundations (jackets and monopiles) and future floating concepts are investing to build the factory of the future to accommodate increasingly larger turbine sizes.

The factory of the future is underway now, with new sites under construction at all corners of the world. New factories are incorporating the highest levels of automation for metal forming, welding and material handling to manage the complexity of producing such large structures, never fabricated before. Investment in additional supply chain capacity and technical capability will solve many of the constraints existing within the current global supply chain.

The factory of the future depends on an expanding supply chain of new steel mill capacities to reduce the impact acquisition and transport cost. Larger plate sizes aid tremendously in the process of plate lengthening and rolling for such large diameter foundations. For example, recent improvements in welding processes and plate preparation is now considered "industry-leading to world-class performance" when narrow grooves are used (photo below ranging from 8° to <16°). At the same time, lessons learned from other operations common to the shipbuilding industry also apply to new floating foundations concepts.

The adoption of newer manufacturing technology for offshore wind will drive the requirements to deliver consistent quality, with reduced production, fabrication and installation cost.

The expansion of higher levels of automation technology is driven by economic and resource necessity. This is only possible through the integration of advanced adaptive process controls, industrial robots and customized hard automation and metal processing equipment for the new industry size and weight requirements.

This key industry driver also backfills one of the largest challenges the entire global industry faces: a declining base of highly skilled trade workers relative to demand. Concerning the global workforce, noticeable progress is underway with growing partnerships made up of local trade unions, technology and trade schools to close the workforce gap. These cooperative industry building blocks are critical to increasing the global supply chain capacity to support the ambitious global production required.

There is no doubt that the evolving complexity of large-scale offshore wind projects will continue testing global supply chain resiliency and the industry will need to respond in kind. A key to success will be industry leaders, trade groups and suppliers advocating for the expansion of technology, who will also lead the way to build the factory of the future together.

Find out more here: https://www.lincolnelectric.com/en

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PART TWO: POLICY

Leasing seabed rights

'Leasing' is a broad term to describe how seabed rights for offshore wind development and operation are contracted.

Equivalent terms for leasing vary from country to country. In Denmark it is called a 'concession'. In the US it is a 'lease' but with two stages, the first is called a 'Site Assessment' (for five years) and the second, 'Operations' (33 years). In the UK it is divided into two separate documents, the first called 'Agreement for Lease' (up to 10 years) and the second, 'Lease Agreement' (60 years).

Due mostly to historical precedents, there are very different organisations, including government departments and public bodies, that tender and award leases for offshore wind around the world. For example:

- Denmark – Danish Energy Agency (DEA)
- UK – The Crown Estate (TCE) and Crown Estate Scotland (CES)
- Netherlands – Rijksdienst voor Ondernemend (RVO)
- Germany – Bundesamt für Seeschifffahrt und Hydrographie (BSH)
- US – Bureau of Ocean Energy Management (BOEM)
- Vietnam - Ministry of Natural Resources and Environment (MONRE)
- Japan - Ministry of Land, Infrastructure, Transport and Tourism (MLIT)

Approaches also vary from country to country. In Denmark, the Netherlands and Germany specific project sites are selected and detailed data is provided ahead of single-stage bidding. In the UK, US and Taiwan some data is shared but the onus is on developers to carry out detailed surveys and gain consent before entering the second stage of bidding for a power purchase agreement. Both approaches work and some developers prefer that there are diverse approaches which can help to mitigate risk across their portfolios.

Examples of rental fees (not including other fees) for offshore wind leases

Country	Public agency	Project phase/element	Rental	Units
England and Wales	The Crown Estate	Operation	2%	Of gross revenue[41]
Netherlands	The Central Government Real Estate Agency	Operation	€0.98 (US$1.15)	Per MWh[42]
		Construction	€650 (US$763)	Per MW per year
		Array cables	€3.29 (US$3.86)	Per m² (single, one-off payment)
Scotland	Crown Estate Scotland	Operation	£1.07 (US$1.48)	Per MWh[43]
United States	Bureau of Ocean Energy Management	Construction	US$3.00	Per acre per year
		Operation	2%	Of gross revenue
		Export cable	US$70.00	Per mile

Source: World Bank Group. 2021. Key Factors for Successful Development of Offshore Wind in Emerging Markets. ESMAP, World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO

The fees in different markets also vary. In Denmark there is no fee for leasing. However, in most countries there are fees and seabed rental but with varying structures. Generally speaking, operating fees equate to 2% of gross revenue though by different means.

All leasing methods provide exclusive rights for:

a. Development which is critical for developers to invest up to $100 million, in environmental, geophysical and geophysical surveys, consent application, engineering and procurement, up to final investment decision.

b. Operation and maintenance of the wind farm for power generation which is critical to raise typically USD 1-2 billion of capital for equipment and construction.

In two-stage markets it is common for there to be a wide project area, within which the final site can be optimised. The same wide area is true for cable corridors, giving flexibility on grid connection points.

Each lease agreement has similar but differing terms. It would help the industry speed up development and repeatability if, through good practice sharing, greater commonality of leasing agreements could be arrived at. Some best practice principles have emerged in offshore wind leasing:

- Leasing should cover Territorial Waters (out to 12 nautical miles) and the Exclusive Economic Zone (out to 200 nautical miles) to maximise opportunities in each country.
- Marine spatial planning (MSP) should be used to identify large sea areas within which projects can be located. A pragmatic and proportional approach can be utilised.
- Leasing processes should be robust and transparent. This aids developers in understanding the process. It also reduces the possibilities of legal challenges.
- Tendering should commence with a prequalification questionnaire (PQQ) stage to ensure tenderers have the capability to deliver on projects.
- Leasing should be kept simple and encourage the pace of development while maintaining flexibility in the light of unforeseen obstacles. A good example is the UK Round 4 Agreements for Lease where only two milestones are used – material evidence of initial site development and consent application – with flexibility for force majeure events.
- Sharing of survey data into the public domain, which allows other sea users to become informed. Note wind resource data is commercially sensitive and so its release is commonly delayed for two years or until power price auctions are completed.
- Depositing health and safety (H&S) data into an industry accepted system allows improved H&S management for the good of all. A good example of such as system is the G+ Global Offshore Wind Health and Safety Organisation.
- Regular release of seabed, for example every 2-4 years, to give a steady flow of projects.

The renewables sector is committed to sustainable development and harmonious co-existence with local communities and ocean users where wind farms are built, as well as adhering to high environmental and social standards. The industry takes into consideration the impacts of its projects and strives to do everything it can to prevent, manage and mitigate them.

As the sector grows globally, and the proportion of sea area that is used increases, the cumulative effects of sites need to be better understood. A leading initiative is the North Sea Net Gain study, led by The Crown Estate in partnership with the Dutch-led Rich North Sea programme, which aims to ensure that decisions about the next generation of offshore wind farms are based on the most comprehensive information and will bring about net gains for biodiversity. The learnings from this work will have relevance for other markets, though they will need to be adapted for local and regional circumstances.

During the formative stages of the offshore wind market, the cost of seabed rights for development was nominal. However, in 2018, the US introduced competitive auctions for development rights. This was first adopted for the Massachusetts award of three wind energy areas and resulted in option fees that trebled in comparison to previous awards.

Under its constitution BOEM is required to achieve "fair value" for

its land transactions. Similarly, The Crown Estate (TCE), through The Crown Estate Act 1961, is required to achieve "best consideration" for its dealings. Therefore, the results of BOEM's auctions somewhat forced the hand of TCE to use competitive bidding in Round 4.

Unfortunately, the result of Round 4 in the UK, assuming a five-year development cycle, was option fees six times higher than those of Massachusetts on a $/MW basis. The subsequent New York Bight auctions in 2022 then delivered similar option fee levels. These fees equate to approximately 20% of total project capital investment – raising the concern that this will subsequently find its way into prices paid by consumers, and also squeeze out smaller local developers at the leasing stage.

This overheating of the market appears to be a result of new entrants with deep pockets and the limited release of development seabed into a hungry market. The Carolina Long Bay auction of two wind energy areas in May 2022 resulted in option fees a little under half those of Round 4 and New York Bight, likely as a result of less attractive sites and fewer bidders, but they are still material.

The overriding challenge for leasing is that the current pipeline of projects across the world, especially allowing for attrition and delay, is insufficient to meet the long-term needs of the offshore wind sector. Currently there are some 700 GW of projects in development,[1] however more than half of these are at the conceptual or very early stages. The total amount with approved consent or in operation is just 141 GW.

The industry target (in line with IEA and IRENA 1.5°C scenarios) is 380 GW by 2030 and then 2,000 GW by 2050. GWEC therefore calls on governments to increase and speed up the release of seabed leasing over the next decade to meet climate goals, create a more sustainable pipeline for the industry and ensure steady delivery of offshore wind benefits to local communities.

Source: RenewableUK EnergyPulse database

Permitting for offshore wind

As the world's appetite for large-scale offshore wind has grown in line with increasingly demanding climate targets, the complexity of permitting systems continues to constrain developers' ability to deliver projects at pace.

In 2022, industry association WindEurope reported that the EU was only on-track to install about half of the new wind capacity needed to achieve its 40% target of renewables within the bloc's energy mix by 2030. The sector could see even more of an uphill struggle if the target is raised to 45%, as recently proposed by the European Commission.

Globally, a target of 380 GW of offshore wind capacity by 2030 has been set under the UN Energy Compact signed in 2021 by GWEC and the International Renewable Energy Agency (IRENA). This is the volume required by the end of the decade to meet IRENA's 1.5C and net zero-compliant energy system roadmap. But despite governments' stated intention to prioritise renewable energy generation, there is widespread concern that permitting delays are hindering progress towards these targets.

The burden of complex permitting procedures is greater for offshore wind projects than many other renewable energy installations. They tend to be much larger than onshore wind farms, straddle different jurisdictions or usage zones and require the use of extensive areas both on land and at sea.

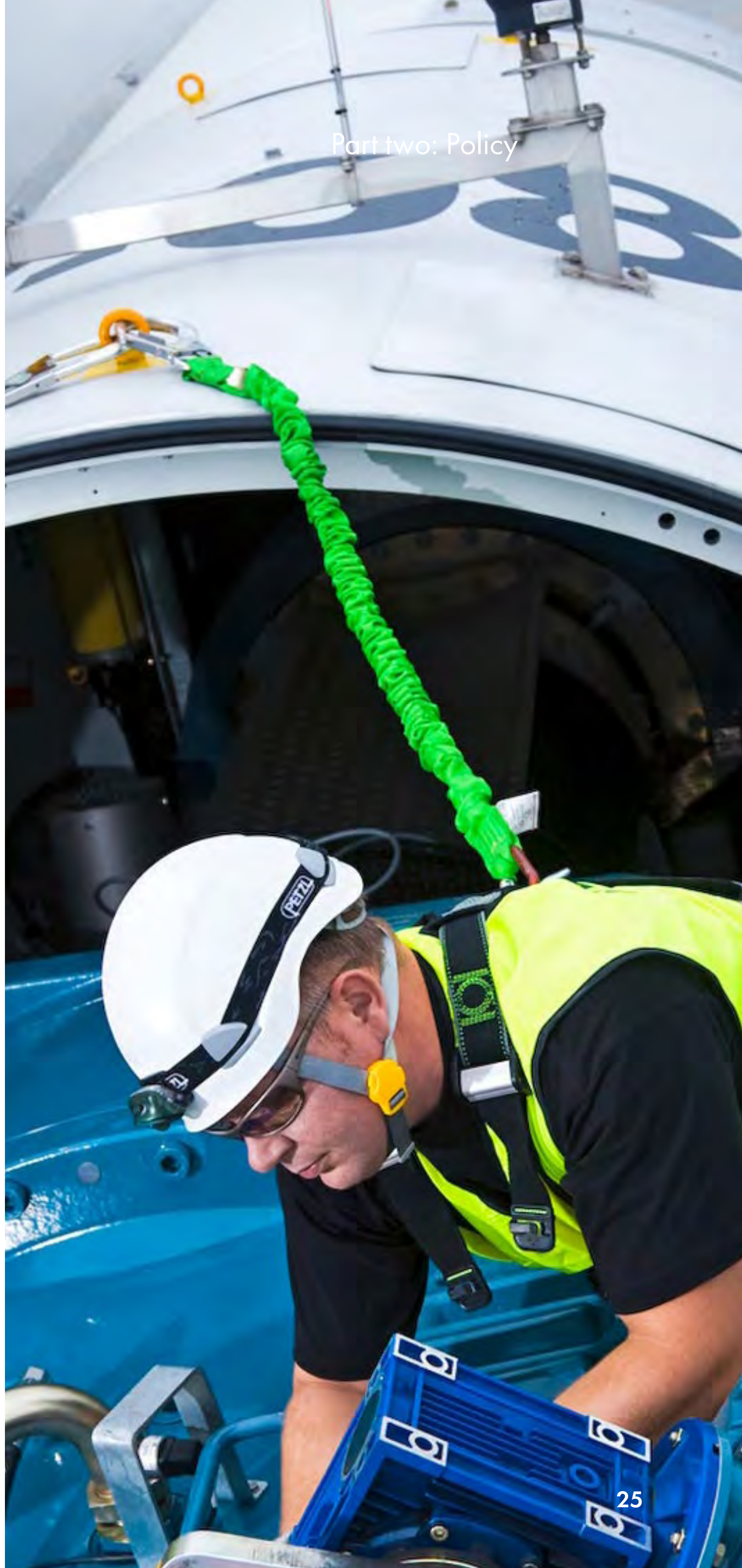
The impacts of complex permitting procedures

Slow, complicated and unpredictable permitting procedures affect both the more mature offshore wind countries of northern Europe and emerging markets such as the US, Japan and South Korea. Everywhere, the toxic mix of complexity and uncertainty damages the investment case for offshore wind power development and ultimately hampers progress for the sector.

Normally, a developer will need an initial permit to conduct site investigations and decide whether the project is worth pursuing. Several rounds of consultations will usually follow, including with often-oppositional stakeholders such as fishing organisations, conservation societies and local residents.

In most jurisdictions, developers need to secure permits from several layers of government, ranging from local to federal. In the US state of New Jersey, for example, a minimum of 7 permits – 5 at state level and 2 federal – are required for offshore wind projects planned within 3 geographic miles of shore in state waters. A similar number of permits is needed for projects to be sited further away from shore, in federal waters.

Even when all consents are granted and construction starts, the road to project completion is not necessarily clear. Construction of the first commercial-scale offshore wind farm in US waters, Vineyard Wind I, started in November 2021 after a multi-year gestation process. A lawsuit was filed in February 2022 challenging the US Department of the Interior's (DOI's) approval of the 800 MW project off Martha's Vineyard, Massachusetts. The case brought by the Responsible Offshore Development Alliance (RODA), which describes itself as a coalition of fishing industry associations and fishing companies, hinges on an alleged breach of several environmental protection laws by the government agencies that



authorised the project.

At the heart of the lawsuit is the allegation that the DOI's Bureau of Energy Management (BOEM) failed to adequately "balance ocean resource conservation and management" when authorising Vineyard Wind I. This sets a dangerous precedent for the "enormous pipeline of projects the government plans to facilitate", the complainant claims. The case highlights the lack of shared recognition on the balance of interests between conservation and renewables development.

Also in the US, the trailblazing Cape Wind project, which was to install 468 MW of capacity in the shallow waters off Massachusetts, was "litigated to death" after 16 years and $100 million in private capital. Despite passing stiff environmental scrutiny from the federal government, developer Energy Management Inc (EMI) pulled the plug in 2017 after more than 20 lawsuits.

Mature offshore wind markets such as the UK have not been spared similar difficulties. In May 2022 the nature campaigning group Suffolk Energy Action Solutions (SEAS) filed an application for a judicial review of the UK government's decision to approve the remaining 1.7 GW of the East Anglia Hub offshore wind cluster of projects.While the two wind farms will be sited more than 30km from the coast, SEAS alleges that construction works and onshore substations would have a detrimental impact on the local farmland. Approval of the 1.7 GW tranche was already delayed to allow for more extensive consultation, including on wildlife protection, causing the developer to miss the deadline for Round 4 of the UK's Contracts for Difference (CfD) auction.

Another UK offshore wind project, Vattenfall's 1.8 GW Norfolk Vanguard, had its initial development consent quashed following a judicial review, but was finally authorised nearly two years later. It also missed the deadline for bidding in Round 4 of the CfD auction.

Tackling the bottlenecks

The Danish Energy Agency introduced a "one-stop shop" concept in 2020 by leading an intergovernmental exploratory phase during which any potential hurdles to development are cleared before an application is processed. Once an area is approved for development, the applicant is automatically allowed to carry out preliminary investigations, including an environmental impact assessment (EIA).

In its first offshore wind energy roadmap, dating back to 2018, the Netherlands committed to 11.5 GW by 2030 and identified specific areas for project development. It also set out conditions for wind farm construction, including on location, nature protection measures and the necessary permits.[1] By researching the structure of the site, the seabed, wind speeds and water data in advance of bidding, developers have up-front access to information required for development and financing. The Netherlands has since raised its target to 21 GW by 2030.

At a summit in May 2022, the Netherlands was one of four North Sea countries, alongside Germany, Belgium and Denmark, to commit to accelerating the buildout of offshore wind to achieve 65 GW of installed capacity by 2030 and 150GW by 2050. The pledge was prompted in part by the energy security crisis arising from the military conflict in Ukraine.

A crucial factor of this commitment, and of the recent REPowerEU Action Plan, is to tackle the permitting bottlenecks that are holding back the expansion of wind and solar energy. This includes enshrining a principle that renewables are in the "overriding public interest", which would strengthen the hand of developers by prioritising the buildout of projects on a case-by-case basis within the overarching aim of achieving climate neutrality.

Measures to support project deployment

Streamlined and sensible permitting schemes for offshore wind projects are needed to accelerate deployment and minimise project attrition. The following measures should be considered, among others:

- Mandated maximum lead times to permit wind energy plants, such as 3 years for offshore wind projects, with additional discretionary time allowance under extraordinary circumstances.
- Digitised, searchable and up-to-date databases for siting of

https://www.government.nl/topics/renewable-energy/offshore-wind-energy projects, including an inventory of local ordinances and records of where energy projects have met community resistance, which can support local authorities with zoning for projects.

- Dedicated centralised authorities and single focal points who can work with offshore wind developers to streamline the siting and permitting process.

- More staff and digital resources for the various authorities which make decisions during the permitting process of an offshore wind project.

- Transparent land and ocean use guidance, aligned at the national and sub-national levels, which prioritises DNSH, green economy and nature-positive initiatives, and even identifies areas suitable for wind projects where planning could be fast-tracked.

- Active dialogue between communities and industry throughout the lifecycle of a wind project, particularly in developing economies where energy justice and energy sovereignty are emerging narratives.

- Where local opposition and NIMBYism is particularly challenging, policymakers can consider encouraging community benefit schemes attached to renewables projects to improve public support.

- A clearing house mechanism for legal disputes to prevent extended delays to critical infrastructure projects, and a structured and time-limited process for developers to provide evidence.

Making offshore wind the option of choice

While investors have shown an insatiable appetite for offshore wind, the gap between ambition and reality appears to be widening. Without streamlined procedures that grant permits through centralised systems and help developers navigate approval procedures, offshore wind projects risk losing out to other investment opportunities that are less exposed to the vagaries of multi-layered decisions by different institutions.

Excessively lengthy permitting processes can also result in outdated equipment being used on a project, given the fast pace of technological advances and the risk of further delaying construction by applying for a modification to the original project design.

The increasingly large amounts of energy that offshore wind projects generate will need to be delivered to robust transmission networks. Grid upgrades are also burdened by slow bureaucratic procedures, dependent as they are on significant capital investment and community consent. Even in markets where project development has been fast-tracked, for example in China, grid constraints have caused connection delays.

Planning for a massive increase in offshore wind installations requires several crucial and efficient steps, from land allocation to building permits to grid connections. While different markets will choose different approaches, it is clear that a more coordinated permitting strategy is essential to ensure the success of offshore wind deployment everywhere.

PART THREE: SUSTAINABILITY OF THE INDUSTRY

Chapter Sponsor

CRU

Sustainability of offshore wind industry growth

The offshore wind industry is poised to become one of the most important custodians of our oceans in the years to come. Staggering projected growth for the industry is now bringing overall industry sustainability considerations to the fore, as stakeholders inside and outside the industry begin to imagine the volume of wind turbines expected out at sea, and the impact this will have on the environment and economy, both locally and globally.

It is no longer enough for offshore wind to simply produce clean electrons. As a pillar of our world's future energy mix, a great deal of responsibility is now attached to the anticipated growth trajectory expected for offshore wind technology on the road to net zero by 2050. The offshore wind industry's 'license to operate' is being held to an increasingly high standard by governments, wider industry and civil society. The industry is proactively answering this call, responding to criticism and embracing the responsibility that comes with being a key pillar of the world's future energy mix.

The wide-ranging issue of 'sustainability' in offshore wind will be addressed across two dimensions. The first being sustainability challenges associated with the expected growth and expansion of offshore wind, in line with global climate goals. The sustainability of offshore wind growth comes down to the industry's supply chain and the materials required, and how both of these are managed and sourced.

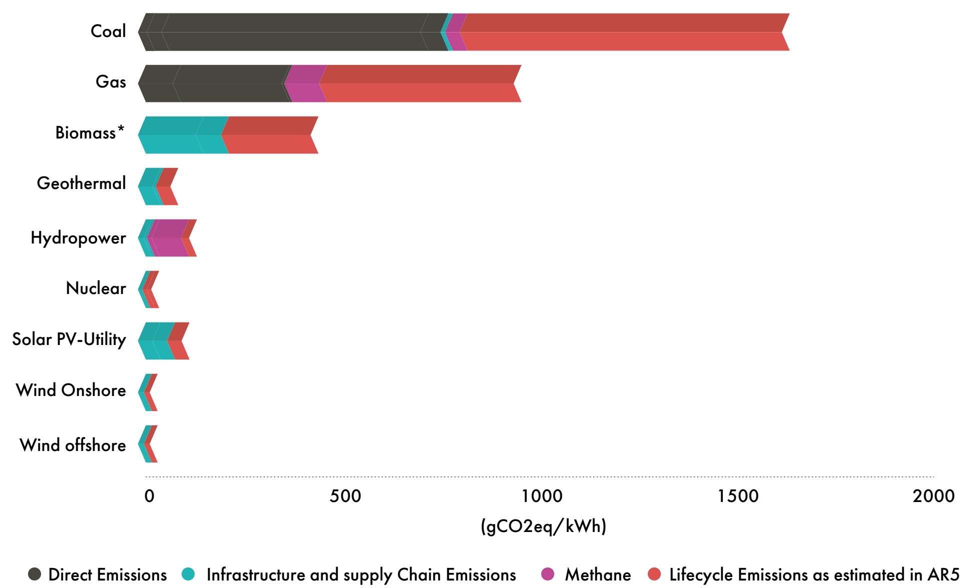
The second dimension is about offshore wind's coexistence with the natural world, where challenges related to the ocean's biodiversity must be considered. As a responsible custodian of the ocean, it is incumbent on the industry to ensure the health of the environment is both protected and even enhanced where possible.

Making offshore wind a truly sustainable energy

Offshore wind has the lowest greenhouse gas emissions (GHG) footprint of all energy technologies. Full lifecycle GHG emissions assessments provide an important benchmarking exercise to understand the emissions attached to various electricity generation technologies. The IPCC's AR5 report, representing the global scientific consensus on energy systems and climate change shows that a range of technologies can provide electricity with less than 5% of the lifecycle GHG emissions of coal power – with offshore wind having the lowest emissions of them all.

For wind and other renewable energy technologies, emissions are mainly associated with manufacturing and installation activities. Further reductions of lifecycle GHGs in these segments

Comparative lifecycle GHG emissions by electricity technology



Sources: AR5- IPCC WG III Fifth Assessment Report, (Caduff et al., 2012; Dale and Benson, 2013), (Arvesen and Hertwich, 2011) ,Wind (Arvesen and Hertwich, 2012), PV (Kim et al., 2012; Hsu et al., 2012), geothermal power (Sathaye et al., 2011), hydropower (Sathaye et al., 2011; Hertwich, 2013), nuclear power (Warner and Heath, 2012), bioenergy (Cherubini et al., 2012). Annex II, Annex II.6.3 and Section A.II.9.3 for methodological issues and core literature. *Note: Lifecycle emissions from biomass are for dedicated energy crops and crop residues.

could be attained through cleaner production, raw materials alternatives and improvements in performance and efficiency. Despite offshore wind energy's low full lifecycle emissions, sustainability challenges are being acted upon with new innovations to reach net zero and "waste zero" through a circular economy approach within this decade.

The amount of steel used in one turbine is in the range of 107-132 kt/GW, accounting for 24% of the total materials in an onshore turbine and 90% of the total materials in an offshore turbine.[1] The steel and concrete needed for wind turbines are largely produced from carbon-intensive processes, which has led to the creation of new initiatives such as The Climate Group's SteelZero – a partnership with Responsible Steel to address decarbonisation. Leading offshore wind developers such as Ørsted, Iberdrola and Vattenfall and turbine manufacturers such as Siemens Gamesa have announced their commitment to 100% net zero steel. Offshore wind companies that have joined the initiative have set interim targets of using 50% low emission steel by 2030, setting a clear pathway to being net zero by 2050.

Enhanced collaboration between these key upstream materials sectors such as steel and the offshore wind industry sends a strong demand signal to steel and concrete producers. However, a clear pathway to decarbonising steel production is still needed, where there is a clear role for wind energy to power the decarbonisation of these upstream production processes.

Building a sustainable supply chain for critical minerals

The sustainability of the sourcing and processing of rare earth elements (REEs) is a particularly key issue for offshore wind. According to GWEC Market Intelligence, nearly 30% of the wind turbines installed in 2020 used direct and hybrid drive generators which required neodymium and dysprosium, primary REEs, for permanent magnets. That share is expected to increase to more than 45% by 2025, given that most offshore wind turbine models use permanent magnet generators. A megawatt of direct drive wind turbine capacity may require around 500 kg of permanent magnets, a third of which are made

1. In a 221 t/MW offshore wind and 640 t/MW onshore wind farm, according to BloombergNEF.

Case Study: Three key materials challenges as offshore wind grows

Provided by: CRU

Rapid growth in offshore wind capacity offers a strong demand opportunity for metals producers. But it also presents large challenges for the whole industry supply chain. Here we highlight 3 of them: decarbonisation, materials availability, and price volatility.

Renewables need decarbonised materials supply

Switching the world to renewable energy is a powerful method of decarbonisation. Supply chains to build that renewables capacity themselves need to be decarbonised to achieve a true energy transition.

Offshore wind is steel-intensive but producing steel is CO_2-intensive. CRU data shows that making plate steel - typically used for monopile construction - using a blast furnace today emits a global median of 2.4t CO_2/t steel.

Companies developing offshore wind projects are targeting net zero Scope 3 emissions. Low-CO_2 steel must be sourced to achieve this. But decarbonising steel production is a huge task, requiring massive capital expenditure, process flowsheet change and sufficient supply of energy and raw materials. The market opportunity exists but can it incentivise all of these to occur?

Are enough materials available?

The question of materials supply to offshore wind has particular resonance in wire and cable. Including installation costs, it can account for almost 17% of the total project cost of an offshore wind farm. This is due to the extensive usage of high-value subsea export and array cables and the sophisticated cable-laying works required by specialist vessels. CRU forecasts global subsea cable demand in offshore wind applications will grow by at least 17% CAGR between 2022-2027.

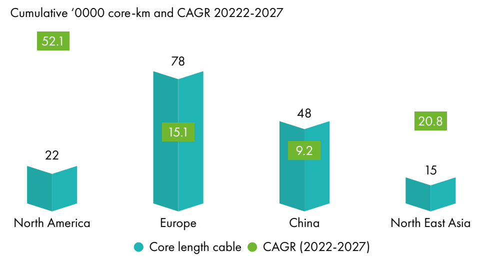
However, we foresee a clear challenge for subsea cable producers to meet such exceptional demand. Out of thousands of cable factories worldwide, only 30 sites can currently produce subsea cable due to relatively high technical and capital entry barriers. Consequently, a European offshore wind or interconnector project owner may need to wait for up to five years for cable delivery if placing an order today. The issue is further complicated by an aversion to non-domestic cable manufacturers.

Large, long-life projects need to manage their price risk

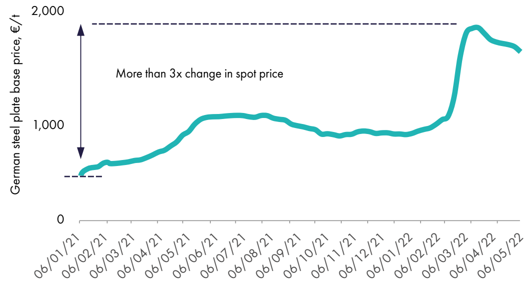
Assuming the above challenges can be resolved there remains an important question of how to manage materials price volatility. This can be extreme: there was a difference of more than 3 times between the minimum and maximum steel plate price in Germany since January 2021. A 100,000t order placed at the highest price would have cost €125M more than if it was placed at the lowest price.

Purchasing teams in offshore wind therefore either have a huge challenge of market timing, or they need to be equipped with risk management tools. Indexing their purchases to steel prices, like those discovered by CRU, offers a powerful such tool. It removes market timing risk, creates a fair distribution of value between seller and buyer, and allows commercial discussions to focus away from the fraught area of price and instead on other value-adding areas of the supply partnership.

MV/HV/EHV subsea cable consumption in offshore wind applications



Locking in all project tonnes at one point in the price cycle can give very volatile results



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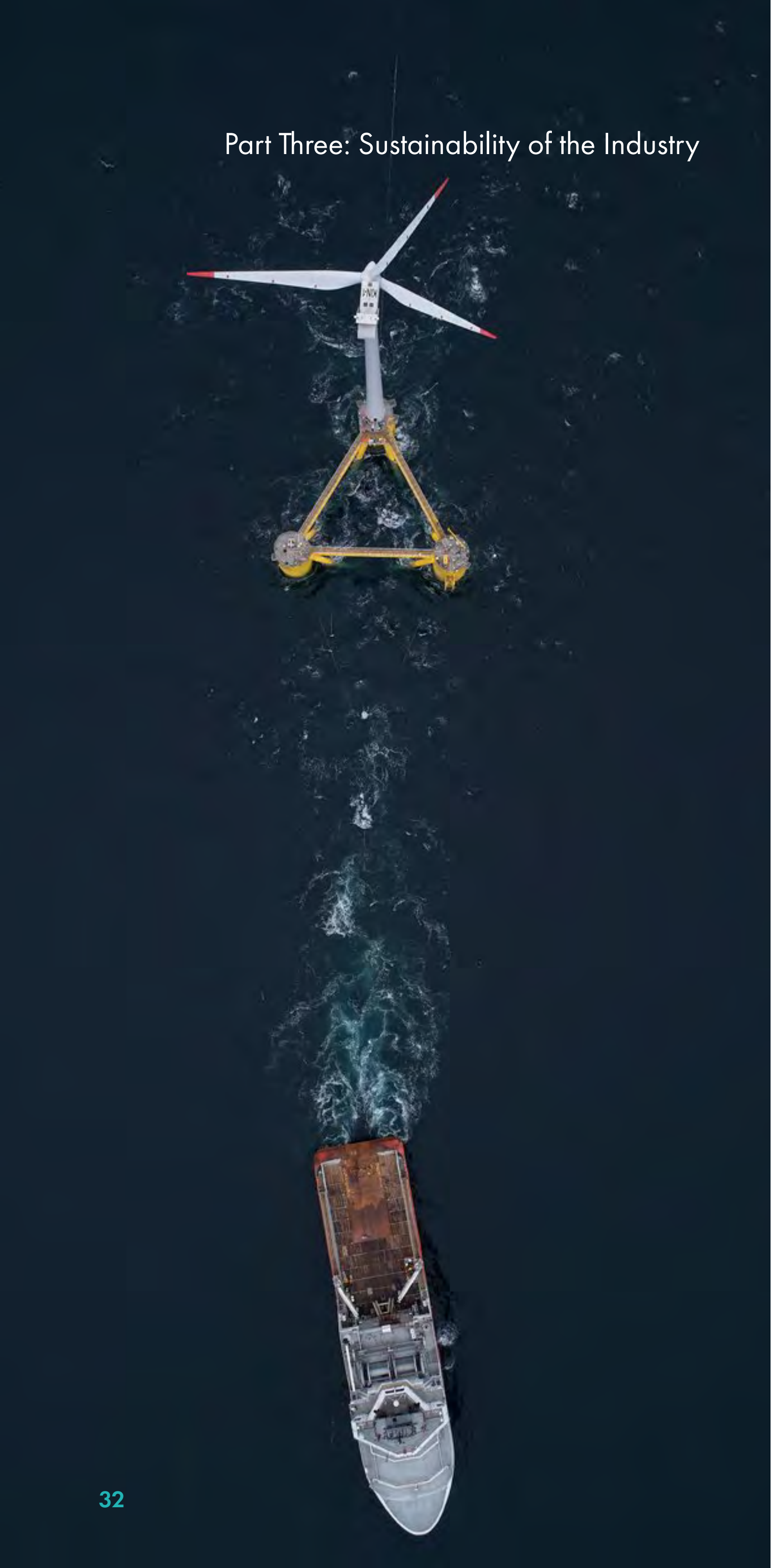


up of REEs for direct drive offshore turbines.[2]

By 2030, demand for REEs in the wind industry is likely to double from today's number.

This higher demand leads to two key considerations: addressing the sustainability of the mining and processing of REEs through international cooperation, policy and regulation, and how innovation can reduce offshore wind energy's reliance on REEs.

Governments representing leading offshore wind markets, such as the European Union, the United States, China and Japan are taking proactive steps to address the sustainability of the global supply and demand for REEs. Europe has established the European Raw Materials Alliance (ERMA), which has initially focused on REEs. In the United States, in the context of President Biden's sweeping $2 trillion infrastructure legislation, an executive order was signed in February 2022 designed to review gaps in the domestic supply chains for REEs, medical devices, chips and other key resources. Furthermore, the Department of Energy announced a USD 30 million initiative that will tap into researching and securing the US domestic supply chain for REEs and other important minerals in battery-making such as cobalt and lithium.

Japan, a country with one of the world's most ambitious offshore wind targets, was forced to take measures to secure its own supply of REEs following an embargo from China. The Japanese government's approach to regulating their own REE deposits along with bilateral offtake agreements with Australian producers is now seen as a valuable model for the US and other countries, as a way of creating a more balanced approach to production, supply and demand for REEs.

Above all, international cooperation must lead to a fair, sustainable market with long term price visibility for buyers and demand certainty for producers, given REEs' key role in the energy transition. What's more, public and private sector stakeholders across the global offshore wind industry must work together to ensure environmental and social concerns through the production and processing of REEs are addressed in parallel.

Innovation also holds significant potential in addressing the sustainability issues associated with the projected demand of REEs. In the future, as rare earth elements become scarcer, high-temperature superconductors could be used in offshore wind direct-drive turbines. This new technological development would not only cut reliance on REEs but would also enhance performance due to an overall decrease in weight. However, further cost reductions and technological progress will be necessary before this technology can be deployed.

Coexisting with biodiversity

The impact on biodiversity from offshore wind development has emerged as a crucial issue for project developers, as the industry positions itself as a responsible custodian of the ocean. It is incumbent on the offshore wind industry to ensure the health of the environment is both protected and even enhanced where possible.

In order to mitigate negative biodiversity impacts, project developers are investing in new solutions and approaches to better understand marine biodiversity and how offshore wind can harmoniously coexist with its natural environment. As evidenced by the initiatives already in place, achieving an acceptable level of coexistence

2. Critical materials for the energy transition: Rare earth elements, Technical paper 2/2022, IRENA

between offshore wind and marine life will require unprecedented cooperation between industry, government, NGOs and academia.

Significant work is underway in current offshore wind markets in the North Sea to assess the impacts of existing offshore wind farms, and to better plan for future ones. Across the North Sea, where offshore development is most advanced, new initiatives such as the North Sea Gain study led by the United Kingdom's Crown Estate in partnership with the Dutch-led Rich North Sea programme, has created a new international data collation exercise bringing together seabed biodiversity data from across the North Sea into a central data set. The study aims to respond to an urgent need to improve understanding of the biodiversity of the seabed on a larger scale and ensure that decisions on the next generation of offshore wind farms will be based on the most comprehensive information and will bring biodiversity net gain.

GWEC is also working closely with UN Global Compact, which is leading an initiative on marine spatial planning (MSP). The focus of this workstream is to establish best practice tools and guidance on MSP, as well as collaborating on research initiatives.

New innovative technologies are now available to minimise the impact of offshore wind on marine life, to better understand marine life activity and to reduce impacts such as underwater noise through the construction phase. In the US, where significant offshore wind is currently in development, leading project developer, Ørsted, has partnered with Rutgers University, Woods Hole Oceanographic Institution and the University of Rhode Island on the Ecosystem and Passive Acoustic Monitoring (ECO-PAM). The goal of this initiative is to better understand the habitat as well as the presence, distribution and seasonality of the endangered North Atlantic right whale within Ørsted lease areas. Across designated offshore wind areas from the North Sea, the US and even Taiwan, technologies such as the 'bubble curtain' are being employed to reduce underwater disturbances to marine mammals and other marine wildlife.

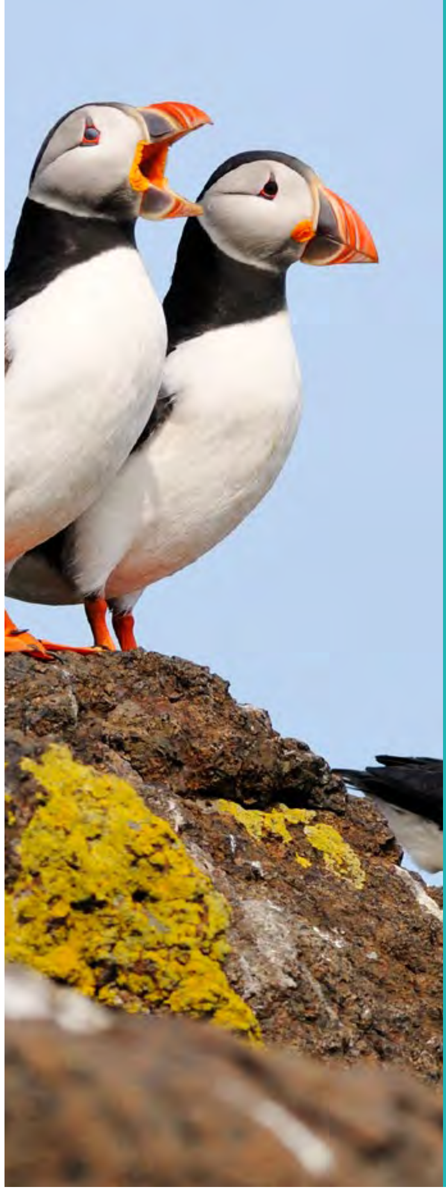
Leading industry players are also anticipating and mitigating the impacts of new technological developments such as the next generation of large-scale turbines and floating offshore wind installations. Ørsted, Ocean Winds, and Vattenfall have recently joined the Sustainable Installation of XXL

Monopiles (SIMOX) project that focuses on developing several innovative technologies that could be suitable for the installation of XXL monopiles, as an alternative to conventional impact hammering. The project aims to have innovative technologies for the installation of large wind turbines commercially available within five years from the launch by testing multiple techniques to enable the installation and decommissioning of XXL monopiles in a sustainable, cost-effective, and socially and environmentally responsible manner. In terms of floating offshore wind, Equinor's Hywind Scotland project team is analysing the environmental DNA from water samples to map any potential effects from floating offshore wind farms on marine life, instead of employing the traditional method of using dedicated vessels to trawl areas over time to perform studies.

As evidenced by these innovative initiatives, the offshore wind industry is leading the way by bringing in partners across government and academia to collaborate with companies' growing in-house capacity to address and minimise biodiversity impacts. However, what is becoming increasingly clear is that there is no template or 'one size fits all' approach to addressing biodiversity, as conditions vary between regions and each requires its own specific in-depth understanding.

Despite the growing consensus on offshore wind as a key climate solution, and the many of proactive activities underway to address the overall sustainability of the offshore wind industry, challenges and criticisms are still being voiced. What is clear however is that the industry has already made significant progress through open collaboration with a wide range of stakeholders, both on local, national and international levels, to address its key sustainability issues – from decarbonising its supply chain and sustainably sourcing its critical materials, to taking innovative steps to ensure a harmonious co-existence with biodiversity.

As the offshore wind industry emerges as one of the most prominent custodians of our oceans, it remains committed to learning lessons from other industries and stakeholders occupying ocean areas to ensure the development and geographic expansion of the industry is grounded in sustainable economic growth and coexistence with the natural world.



Case Study: Innovation to protect and enhance natural habitats around offshore wind farms

Provided by: SSE Renewables

Harnessing natural resources for renewable energy generation is the most sustainable way of mitigating the dangerous effects of climate change. But as these technologies roll out at scale over the next decades, there is a risk that, without careful management, the transition to net zero could come at the expense of the surrounding ecosystem close to these assets.

That's why SSE Renewables, which is currently constructing more than 4GW of offshore wind, have teamed up with technology leaders Microsoft and Avanade on a series of digital innovation projects which could change the way renewable energy is developed, constructed and operated.

Through the partnership, the companies have implemented a species monitoring technique using artificial intelligence (AI). As part of a planning condition for its operational Beatrice offshore wind farm off the northeast coast of Scotland, SSE Renewables is required to monitor local puffin colonies.

Four cameras were installed on the Isle of May to pilot the use of AI for species monitoring, gathering footage and automatically detecting and counting the birds during their breeding season. The AI technology learned not to count the same puffin twice in the field of view, meaning the method produced highly accurate results.

The puffin monitoring project represented the most sophisticated species monitoring SSE Renewables had ever undertaken. Core to its success was development of the project with environmental and natural heritage stakeholders, NatureScot. SSE Renewables has now gone on to use the technology for counting salmon at its hydro stations, with plans to use the technology at more sites.

SSE Renewables, Microsoft and Avanade have gone on to work together to establish what could be the world's largest digital research project of its kind: SSE Renewables' tender application for the Hollandse Kust (West) project includes a focus on how innovation can assist the rollout of offshore wind farms to meet the Dutch Government's ambitious targets.

The consortium plans to understand the impacts of the wind farm on the surrounding ecosystem through the creation of a 'digital twin' of the site. Using LIDAR, Sonar, hydrophones and AI, amongst other technologies, the digital twin will show in real-time what is going on below the surface of the water, enabling cause and effect to be modelled in a very transparent way.

A requirement of the Dutch Government is that this data must also be open source, meaning that unprecedented amounts of data will also be collected and shared with the public.

By conducting large-scale research into the effects of wind farms on the surrounding ecosystems, SSE Renewables believes these ground-breaking projects with Microsoft and Avanade will facilitate research and collaboration.

These innovations enable learning in real-time on how to limit and avoid negative impacts, while promoting the positive ones and offering incredible opportunities to support the protection and enhancement of natural habitats.

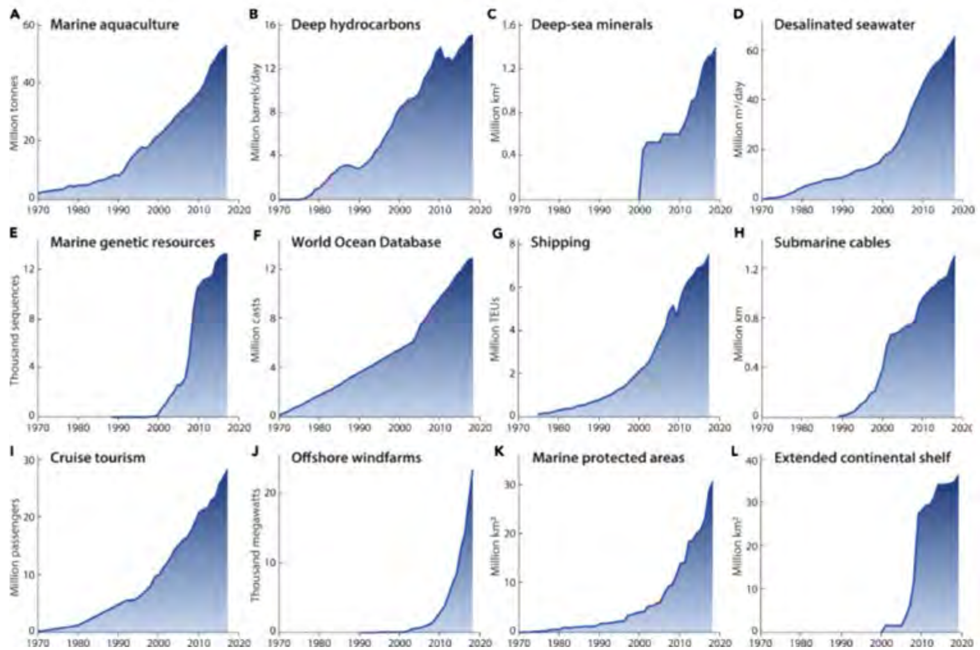
Find out more here: https://www.sse.com/news-and-views/2021/09/bird-s-eye-view-sse-partners-with-microsoft-avanade-and-naturescot-for-cutting-edge-puffin-monitoring-pilot/

sse Renewables

Marine spatial planning for offshore wind

Our oceans hold vital solutions for meeting the UN's Sustainable Development Goals (SDGs) and for supporting climate change mitigation, by restoring rich blue carbon ecosystems such as mangroves and seagrasses, and through sustainable, low-carbon aquaculture.[4] However, at present, offshore wind represents the chief ocean-based climate mitigation solution.[5] The continued advancement of offshore wind should be a strategic priority for countries striving to meet the Glasgow Climate Pact and create a sustainable future.

The Blue Acceleration



Source: "The Blue Acceleration: The Trajectory of Human Expansion into the Ocean," Jouffray et al., Perspective, January 2020.

However, the significant number of offshore wind projects that are either in the pipeline or already developed is leading to rising tensions and pressures on the amount of available ocean space.[6] While the demand for ocean space is so far only rising amongst industry stakeholders, the amount of space assigned to spatial conservation measures such as marine protected areas (MPAs) is also set to increase.[7]

MSP has emerged as an important process to drive the fair and sustainable integration of offshore wind into the context of traditional marine uses. MSP has been recognised by both industry and governments as a tool that can improve the level of certainty and predictability of offshore wind development. If done well, MSP, accompanied by a Strategic Environmental Assessment (SEA), can inform site selection, lower government regulatory costs, streamline developments by mitigating risks of litigation, speed up delivery and investment and ease permitting processes.[8]

The process of MSP is an important way of bringing stakeholders together to explore synergistic co-existence with each other, our environment and with communities. Multi-stakeholder planning can create management actions that are accepted and sustained over time by engaging a complex set of stakeholders, their interests and expectations.

But MSP needs to adapt to the climate emergency. While there is already considerable effort to develop and implement MSP worldwide, there is an urgent need to ensure that MSP is 'climate-smart'. Currently, only a few marine spatial plans integrate adaptation and mitigation to climate change in their objectives and planning frameworks.

MSP is a forum for social and public discussion. If done right – using a

3. United Nations Global Compact, The Ocean-climate Nexus: A Blueprint for a Climate-Smart Ocean to Meet 1.5°C, p. 13 (2021), available at https://ungc-communications-assets.s3.amazonaws.com/docs/publications/_Blueprint%20for%20a%20Climate-Smart%20Ocean%20to%20Meet%201.5%C2%B0C.pdf.
4. High Level Panel, Ocean as a Solution to Climate Change
5. For an example in France, see "France's offshore renewable strategy faces pushback from fishermen"; and in South Korea, see "Fishermen threaten South Korea climate plans".
6. Blue Acceleration, SRC
7. In the European Union, the North Sea Plan cut the cost of offshore wind permits in the Netherlands by two-thirds

climate-smart approach, it can be an opportunity to build climate literacy and ensure a just transition through building social and community acceptance for net zero policies. In addition, decision support tools are already being used by planners to assess the socioeconomic impacts of planning measures, including siting of offshore wind farms, thereby seeking to maximise societal benefits for all, in particular disadvantaged communities.[9]

While MSP is critical to ensuring that the placement of offshore wind does no harm to ocean ecosystems, bringing together project planners, industry and conservation organisations has also proven beneficial for identifying important areas for future research, as well as opportunities for synergies with nature. For example, nature-inclusive design such as smart offshore wind foundations and scour protection serving as an artificial reef, can boost local biodiversity and support local fish stocks.[10] In these examples, informal engagement opportunities outside of an MSP process, facilitated by authorities, have proven successful.[11]

The same applies for ocean users. While MSP has been praised as a process to reduce and resolve conflicts and build trust,[12] it can also be an opportunity for active synergy exploration, for example through ocean multi-use. Offshore wind can foreseeably be co-located with other marine industries, such as tourism (e.g., boat tours), low-trophic aquaculture or certain types of passive fisheries.[13] Alongside the role of governments in mitigating risk, cross-industrial collaboration has also been identified as a key enabler for multi-use.[14]

The offshore wind industry can also support more climate-smart MSP. The industry can provide evidence to enable MSP authorities to develop well-informed plans by providing non-commercially sensitive data assets. High-quality, real-time data is collected at operational sites and is already being shared through

Data Collected	Methods	Types of data	MSP uses
Metocean	Meteorological masts/LIDAR	Wind speed and direction	High; coastal risk assessments
	Acoustic Wave and Current Metres	Wave and current data	
	Directional Waverider Buoys	Wave height and direction	
	Acoustic Doppler Current Profilers	Tidal speed and direction	
Geophysical	Bathymetry	Seabed bathymetry and texture; morphological features; shallow geology; seabed habitats; archaeology; potential unexploded ordnance	High; suitable ground conditions
	Side-scan sonar		
	Magnetometer		
	Seismic		
Geotechnical	Boreholes	Site geology; archaeology	Low: not needed
	Cone Penetration Tests		
Seabed Communities	Grab samples or drop-down video or camera	Infaunal and epifaunal species composition; fish species composition	
	Trawl samples		
Marine Mammals	Aerial surveys and/or acoustic monitoring	Marine mammal species densities	High; biodiversity targets; generating sensitivity maps
	Boat-based surveys		
Birds	Aerial surveys	Bird species densities	
Shipping and Fishing	AIS Information	Shipping and fishing types and densities	
	Site-specific radar surveys	Live monitoring during construction	

Source: UN Global Compact (2021) Roadmap to Integrate Offshore Renewables into Climate-Smart Marine Spatial Planning. With inputs from Scottish Power Renewables and Vattenfall.

8. https://www.researchgate.net/publication/331683126_Spatial_Economic_Benefit_Analysis_Facing_integration_challenges_in_maritime_spatial_planning
9. Orsted/Iberdrola case studies.
10. Dutch community of practice
11. For example, studies have shown that fishers are significantly more likely to support a plan if they believed the consultation of the plan was adequate (Blau and Green (2015)
12. Angela Schultz-Zehden and others, Ocean Multi-Use Action Plan (Edinburgh, 2018), available at https://www.submariner-network.eu/images/news/MUSES_Multi-Use_Action_Plan.pdf.
13. Stuvier et al (2020) Stakeholder Involvement in Technological Design: Lessons Learned from the MERMAID and TROPOS Projects.
14. Stuvier et al (2020) Stakeholder Involvement in Technological Design: Lessons Learned from the MERMAID and TROPOS Projects.

certain platforms and partnerships.[15]

Under the auspices of the UN Global Compact Ocean Stewardship Coalition, industry partners and planners are coming together, to discuss how to accelerate data-sharing across regions and further understand the applicability and uses of offshore wind data in MSP. This will help to support more resilient ocean and data-driven planning which can respond to changes in our climate.

Under the UN Global Compact Sustainable Ocean Principles, responsible ocean-going companies are encouraged to share relevant data with academia and authorities to strengthen ocean science and science-based decision making.

While a holistic MSP process has been criticised by some for delaying the rapid scale-up of offshore wind, this does not necessarily have to be the case. In addition to avoiding litigation or conflict further down the line, depending on the local conditions and specific needs, a combination of planning mechanisms could even be used. For example, having a sectoral renewable energy plan nested within MSP can ensure more detailed siting and elaboration of sector-specific policies (e.g., mitigation measures, co-location and multi-use guidelines) and thus enable robust sector-based planning while still accommodating plans for multiple objectives.[16]

Taken against the backdrop of our increasingly busy oceans, which in fact, need to get busier to meet the SDGs and climate targets, now more than ever, we need a strategic, sustainable and inclusive vision of our oceans. We cannot operate in siloes and solve one challenge, without considering how it is part of and connected to our wider planetary and social crises.

For the offshore wind industry, the UN Global Compact Sustainable Ocean Principles offer a holistic framework to incorporate ocean sustainability into business operations and to consider individual companies within a wider context. And while certainly not perfect, MSP offers a framework to balance objectives, and especially when using a climate-smart approach, offers win-wins for nature, people and the climate.

With input from: Martha Selwyn, UN Global Compact

15. For examples, see Ocean Data Platform (https://www.oceandata.earth/) and Orsted and NOAA data-sharing MoU (https://www.noaa.gov/media-release/noaa-signs-data-share-agreement-with-offshore-wind-energy-company).
16. Government of Ireland

PART FOUR: TECHNOLOGY

Next generation of offshore wind turbine technology

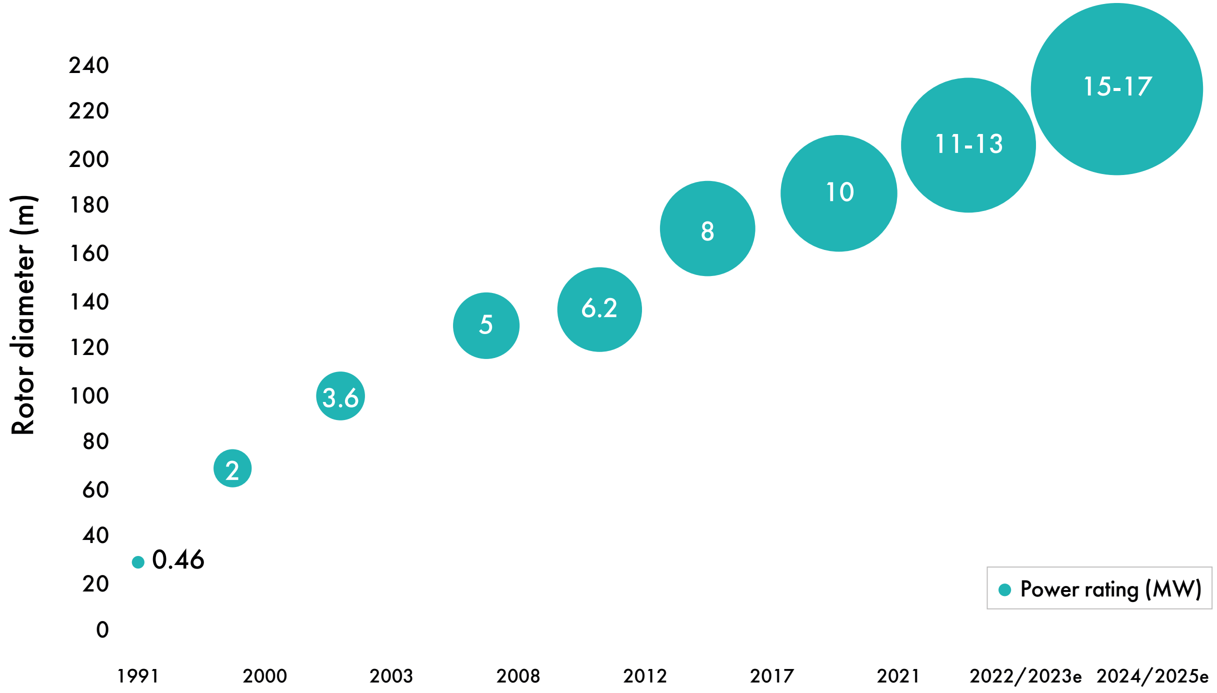
Technology innovation has been a primary driver in the dramatic cost reductions of renewables, allowing wind power, especially offshore wind, to move from the margins of the energy sector to the mainstream.

Rotor size and power rating continue to increase

Since the world's first offshore wind turbine, the Bonus B35-450kW, was installed at the Vindeby site in Denmark in 1991, the power rating of offshore wind turbine has grown significantly. The global average offshore wind turbine size has passed the milestone of 1.5 MW in 2000, 2.5 MW in 2005 and 6.0 MW in 2020. Excluding China and Vietnam where more of the smaller offshore turbine models have been installed, the average turbine rating for new installations reached 8.1 MW in 2021 and expected to pass the 12 MW mark in 2025.

Rotor size and power rating continue to increase

Based on commercial offshore wind turbine installation



Source: GWEC Market Intelligence, June 2022

Drivers of offshore wind turbine technology innovation

The increase of the power rating and rotor diameter for offshore wind turbines has been driven mainly by the following factors:

- Pressure to reduce the levelised cost of energy (LCOE) to make offshore wind a competitive energy source. To reduce LCOE, size matters. A bigger turbine has a higher power rating, longer blade, and a higher tower, increased technical capacity increases the annual energy production (AEP). For example, Siemens Gamesa's newest offshore model, the SG 14-236 DD, can increase AEP by more than 30% compared to its predecessor, the SG 11-200 DD. According to BloombergNEF, the global offshore average LCOE has dropped by more than 65% in the past ten years, a key contributor to this has been the scale that the deployment of the new supersized offshore wind turbines can achieve.

- CAPEX saving for foundations, inter-array cables and installation. Although a larger turbine per unit is more costly than a smaller one, recent research from Rystad Energy estimated that installing the 14 MW turbine for a new 1 GW offshore windfarm would create cost savings of nearly $100 million compared to the currently available 10 MW machine.

- OPEX saving due to fewer turbine units. O&M costs account for approximately 25-30% of total project life-cycle costs. Fewer units means fewer components, as well as the need for fewer vessels and fewer technicians.

- Achieving the large-scale integration of offshore wind through scale, reduced transmission expenditure, lower balancing costs and improved output certainty.

Direct drive and medium speed drivetrain continue to gain popularity

Four different drivetrain technologies have been used in the offshore wind industry in the last three decades. As of today, however, the direct drive turbine with a permanent magnet synchronous generator (DD PMSG) and the medium speed turbine with

Case Study: Advantages of an offshore yaw and pitch motor with permanent magnet technology

Provided by: Bonfiglioli

With over 30 years of experience with the world's major wind turbine OEMs, Bonfiglioli creates, designs and produces advanced solutions to deliver tailor-made Yaw and Pitch drives both for onshore and offshore wind applications. This includes an important design of the Yaw & Pitch Electric Motor for offshore wind, drawing on permanent magnet (PM) motor technology.

Today, PM motor technology (both interior permanent magnet, or IPM, and surface permanent magnet, or SPM) represents a key factor for the current and next generation of wind turbines. The clear advantages brought by PM to manufacturers and to power producers include: ease of installation, energy efficiency, improved energy harvesting and lower maintenance.

More specifically, the obvious advantage comes from the torque density of electric motors, thus reducing problems of space and installation constraints. Such motors have very low rotor inertia, which combined with a very high starting torque, enable an extremely fast and continuous micro-adjustment of blade pitching and nacelle yawing. This feature, along with the multi-turn encoder or resolver the motor is equipped with, allows for high positioning precision which can optimise wind energy harvesting.

By nature, PM motors have higher efficiency if compared to traditional AC induction or DC motors. They further avoid energy waste during the braking and deceleration phases of pitch and especially yaw drive. In fact, such regenerative energy can be recovered in energy-storing devices (i.e. batteries or supercaps) and then reutilised to support high energy demand, auxiliary devices or emergency cases.

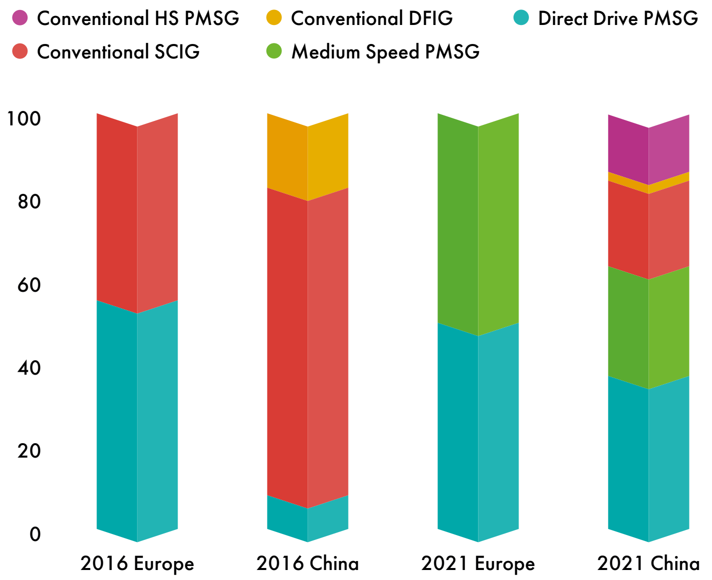
Thanks to four quadrant control modes and the capability of being controlled with full torque at zero speed, normal dynamic braking is exclusively electric (then potentially regenerated). This relegates the mechanical brake to the function of Static Holding Brake or Emergency Brake, and potentially removes the hassles related to mechanical brake maintenance.

Finally, Bonfiglioli's PM technology, both in SPM and IPM configurations, covers all possible wind turbine models currently operating in the market.

Find out more here: https://www.bonfiglioli.com/international/en

Bonfiglioli
We engineer dreams

Trend of offshore wind turbine drivetrain technology



Source: GWEC Market Intelligence, June 2022

a permanent magnet synchronous generator (MS PMSG) are the two primary drivetrain technologies in Europe, each with almost equal market share in 2021.

In China, in addition to these two technologies, the conventional high speed wind turbines with Double-Fed Induction Generator (DFIG), Squirrel Cage Induction Generator (SCIG) and High Speed PMSG (HS PMSG) are still commercially available with the conventional SCIG solution having the highest market share in China until 2021.

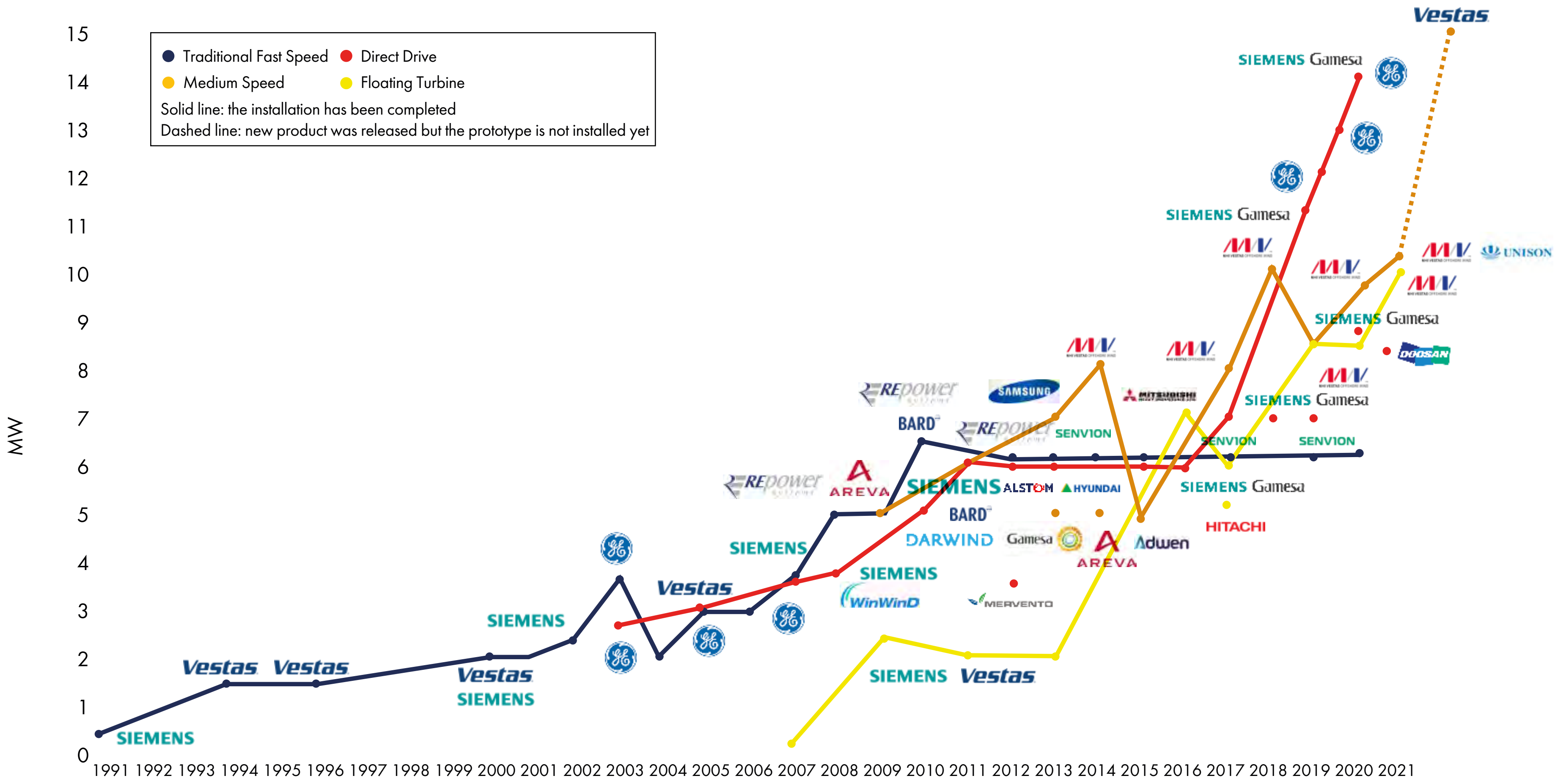
The DD PMSG technology started gaining market share in the Chinese offshore market from 2017 and became the most popular technology in 2021 as more large DD PMSG turbines were installed by local suppliers such as Goldwind, Shanghai Electric, Dongfang and Harbin Electric (XEMC). Nevertheless, the severe competition based on per MW cost as well as increasing commodity prices for key materials including rare earth elements (REEs) have put a lot of pressure on direct drive producers in 2021. In order to stay on top of the competition, Chinese direct drive turbine producers, including Goldwind, the world's largest DD PMSG producer, have recently switched to MS PMSG turbine technology for their next generation of offshore turbines.

Among the Chinese turbine OEMs, Mingyang is the first supplier to introduce the MS PMSG offshore turbine to the local market. The company is also the world's largest MS PMSG offshore turbine supplier, as of 2021. According to the Chinese offshore wind turbine technology road map for the next five years (see page 45), GWEC Market Intelligence predicts that the medium speed drivetrain solution is likely to overtake the DD PMSG solution as the most popular technology in China before 2025.

Continuous innovation

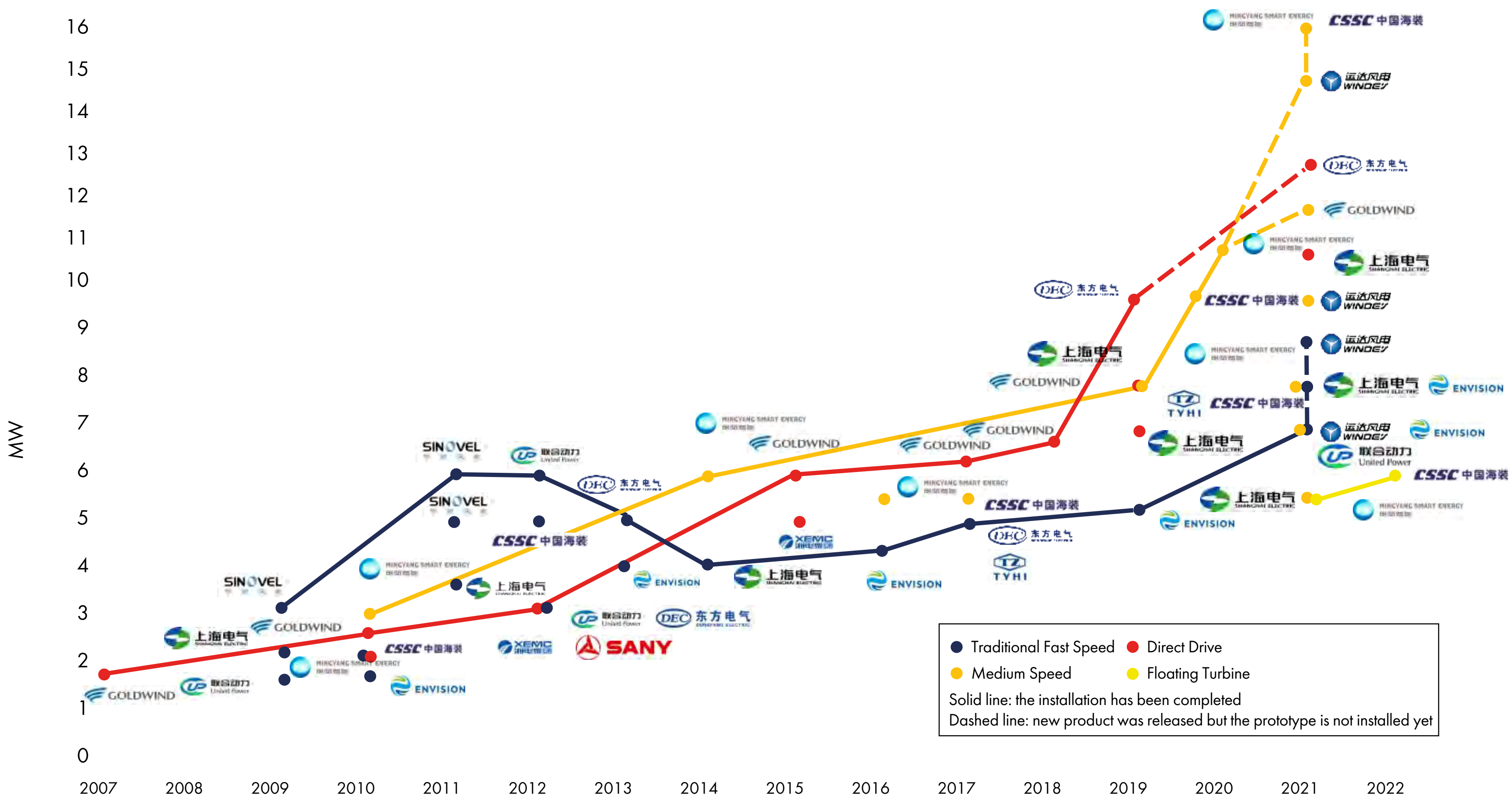
Considering the increasing pressure for offshore wind to reach grid parity, GWEC Market Intelligence believes that the size of offshore wind turbines will continue to grow. A cost reduction survey conducted by NREL and Berkeley LAB in 2021

Offshore Wind Turbine Technology Road Map (excluding China)



Source: GWEC Market Intelligence, June 2022

Offshore Wind Turbine Technology Road Map (China only)



Source: GWEC Market Intelligence, June 2022

> Considering the increasing pressure for offshore wind to reach grid parity, GWEC Market Intelligence believes that the size of offshore wind turbines will continue to grow.

shows that a 17 MW offshore turbine with a rotor size of 250m is predicted for instalment in 2035. GWEC's offshore wind ambassador and pioneer in offshore wind, Henrik Stiesdal has also predicted that the next generation offshore turbine technology could reach 20 MW with a 275m rotor diameter by 2030.

However, it must be noted that the possibilities and limits for future offshore turbine design will be determined by factors such as the existing supply chain and infrastructure, drivetrain optimisation, foundation design, materials constraints, the logistical constraints for both transportation and installation as well as permitting. To further unlock the potential of offshore wind, technology innovation will remain key and advances in this area are expected to continue.

Case study: How do you avoid connector corrosion in offshore wind turbines?

Provided by: HARTING

Offshore wind turbines are exposed to harsh environmental conditions such as high humidity and corrosive salt throughout their lifetime. Although there are no statistics available for the offshore wind industry, the economic losses due to corrosion in industrialised countries can represent up to 6% of the gross national product[1]. Therefore, a complete corrosion protection of the turbines' metallic surfaces must function optimally over their planned operational life of 25 years or more to keep the Levelised Cost of Energy (LCOE) from offshore wind under control.

Many corrosion protection methods have been adopted for the offshore wind industry. For the external surfaces of the foundations under and near sea water, the corrosion protection is prescribed in current industry guidelines based on experiences from the oil and gas industry. Cathodic protection (CP) of offshore structures with galvanic anodes is a well-established corrosion prevention technique[2]. Inside the nacelle and tower, the active desalter and dehumidifier create a relatively constant overpressure with dry air to block the salt corrosion process on the metallic surfaces. Additionally, the surface coating is widely applied for the metallic subsystems and components, such as generators, converters, motors and cabinets.

Connectors have become an indispensable element of the modern wind industry. They speed up the assembly and disassembly of individual components, encourage modular designs, and thus significantly reduce costs over the entire service life. The metallic connector hoods and housings from HARTING and many other suppliers are generally made of aluminium using a die-casting process to ensure a very demanding electromagnetic casting (EMC) functionality and to provide robust mechanical strength. However, precise guidelines for corrosion protection of connectors in the wind turbine are not provided in current industry standards.

HARTING recently issued a white paper that takes a closer look at the use of connectors and the issue of corrosion. Possible types of corrosion and the resulting problems and requirements for connectors are also considered. Finally, different strategies are discussed for minimising the risks of corrosion and ensuring corrosion protection that lasts for the entire service life of the connector.

Find out more: https://www.harting.com/UK/en-gb/markets/wind-energy

1. Corrosion: a challenge for materials science, Crespy, Daniel; Landfester, Katharina, Yearly Book of Max-Planck-Gesellschaft 2014/2015.
2. Corrosion Risks and Mitigation Strategies for Offshore Wind Turbine Foundations, Kathy Riggs Larsen, Materials Performance, 05.04.2021

Green hydrogen and Power-to-X

Generating electricity from renewables and reducing energy demand are two key planks of the transition to net zero. In the hard-to-abate sectors where direct electrification is challenging, additional technologies will be required to achieve decarbonisation.

As offshore wind power generation increases, a proportion of the energy generated may not reach the power grid due to cost or technical constraints. Locating electrolysers near offshore wind farms would enable the production of green hydrogen – an attractive proposition especially for far-from-shore projects in deep waters.

As a clean-burning gas that emits only water at the point of combustion, green hydrogen can become an important piece in the jigsaw puzzle of a net zero energy system. Today's prevalent "grey hydrogen" is produced from fossil fuels such as methane and coal, emitting large amounts of CO_2. "Blue hydrogen" relies on the same production process but pairs it with carbon capture and storage (CCS) technologies, adding significant cost and a degree of inefficiency regarding capture rates.

Green hydrogen is produced via electrolysis, fed by renewable energy sourced from an adjacent asset or the grid. Wind-to-green hydrogen can be compressed and stored in a tank system for offloading when needed. Through an offshore hydrogenation platform, liquid hydrogen (LH2) can be converted to synthetic natural gas (SNG), better known as methane, before being shipped to end-users for multiple purposes.

Applications of Power-to-X

Offshore wind energy can also power electrolysers located on oil and gas platforms to produce green hydrogen using seawater. The green hydrogen is blended into the gas and transported to land via the existing infrastructure. It is estimated that up to 20% of hydrogen by volume can be mixed into existing gas pipeline flows.[1]

Stored electricity can also be combined with captured CO_2 to make carbon-neutral liquid fuels or to generate heat through heat pumps or electric boilers (Power-to-Heat), or contained in underground formations such as salt domes and fed back to the grid when needed (Power-to-Power). Each sector will require targeted approaches, especially given the varying costs and conversion efficiency rates attached to each application.

Power-to-X is particularly capable of providing solutions, feedstock and green fuels for hard-to-electrify sectors such as heavy road transport, shipping and aviation, as well as steel and cement production and chemicals manufacturing.

While different types of hydrogen can bolster energy security by reducing import dependence, mitigating exposure to fossil fuel prices and boosting system flexibility, green hydrogen is naturally best suited to support the journey to net zero.

Several countries have ambitious hydrogen roadmaps in place, with IRENA identifying China, the EU, India, Japan, Korea and the US as early adopters. For instance, with annual consumption of more than 24 million tonnes, China is the world's largest user and producer of hydrogen. Although China's

1. GWEC, Global Offshore Wind Report 2021.

hydrogen production is predominantly coal-based, China has more than 30 green hydrogen projects in the works. The current Five-Year Plan (2021-2025) lists hydrogen as one of China's six industries of the future, and a number of provinces and cities have launched hydrogen strategies.

India launched its National Hydrogen Mission in August 2021, with the ambition of becoming "a global hub for green hydrogen production and export". The government is considering making it mandatory for refineries and fertiliser plants to use some green hydrogen. India is also the world's largest ammonia importer, a key input for fertiliser production.

Assessing the competitiveness of green hydrogen

Some experts argue that generating green hydrogen from surplus renewable energy does not make sense in a highly connected, continent-scale energy system. While offshore wind is highly compatible with green hydrogen production, it may be unable to compete on cost with production based on a combination of cheaper solar and onshore wind – especially in the geographies where these two energy sources are widely available.

At an estimated cost of around $1/kg by 2050, green hydrogen is on the path to becoming cost-competitive with grey or blue hydrogen.[2] This is especially the case in light of shifting price dynamics around high-cost gas generation. BloombergNEF has found that, in the aftermath of Russia's invasion of Ukraine, the cost differential between grey and green hydrogen has already reached the tipping point. The levelised cost of grey hydrogen from fossil gas stands at $6.71/kg in the EMEA region, while green hydrogen produced using European electrolysers costs $4.84-6.68/kg. In China, green hydrogen is priced at $3.22/kg, against $5.28/kg for grey hydrogen.

IRENA has calculated that, driven by R&D and economies of scale in manufacturing facilities, electrolysers could become 40% cheaper by 2030, making green hydrogen cost-competitive with blue hydrogen by the same date. By 2050, the IEA's Net Zero 2050 roadmap suggests that hydrogen production will be almost entirely based on low-carbon technologies, with green hydrogen accounting for two thirds of global production.

But whether green hydrogen can ultimately play the wide-ranging role that its proponents envisage is still uncertain, especially as renewable electrification and storage technologies continue to advance.

As renewable electricity and electrolyser costs fall and availability rises, green hydrogen could easily replace grey hydrogen in refineries and for producing ammonia and methanol. It could also be used to produce chemicals and manufacture steel, with pilot projects already happening in Germany's Saxony-Anhalt "chemical triangle" region and in Australia, where steelmaker BlueScope aims to work with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to replace coal with coke oven gas, which contains 60% hydrogen, subsequently adding green hydrogen.

The case for powering heat pumps appears weaker, considering how expensive carbon would have to be in order to make green hydrogen competitive with natural gas or green electricity.

In the transport sector, the use of hydrogen in passenger road vehicles is unlikely, given cost-competitiveness and convenience

2. https://about.bnef.com/blog/hydrogen-economy-offers-promising-path-to-decarbonization/

considerations, but the prospects are rosier for long-distance shipping and aviation, where electrification is unlikely to provide all the answers.

At the power system level, it has been argued that green hydrogen, stored at strategic locations and moved around as needed, could provide resilience when up to 90% of generation comes from variable renewable energy sources.

According to the IEA, global electrolyser capacity stood at 0.3 GW in 2020, mostly using grid electricity to produce hydrogen. The agency estimates electrolyser capacity to reach almost 17 GW by 2026, based on an announced pipeline of 260 GW globally. Almost half of the planned expansion is expected to use existing renewable capacity, with most announced projects ranging from 1 MW to 10 MW in size and being located close to industrial sites and ports.

Larger projects of 10-100 MW are expected to rely on some 18 GW of additional renewable capacity during 2021-26, most of which could come from China, Chile, Spain and Australia.

Supply chain pressures in the renewables sector (see Part One: Supply Chain), however, could disrupt a trend of falling costs and slow down growth of green hydrogen. Low electricity prices are essential for producing competitive green hydrogen.

Scaling green hydrogen on the global level

Countries with the potential to generate large amounts of low-cost renewable energy are prime candidates for becoming producers of green hydrogen, especially if they also have access to water and the capability to export to large demand centres.

Several countries with widely differing locations and conditions could become leaders in the green hydrogen production race. Scotland, for example, with its vast offshore wind resources and existing oil and gas infrastructure, is well placed to play a major role. On the other side of the globe, Australia has immense potential for cheap wind and solar generation. With a more favourable political outlook for net zero policies than it has enjoyed for decades, it could gain a prime position. Several countries in Africa and the Middle East, such as Egypt and the UAE, are exploring opportunities to become hydrogen exporters.

Whatever the pace of green hydrogen expansion, offshore wind will be a major source of power for it. For instance, following the North Sea Summit in May, Danish developer Copenhagen Infrastructure Partners (CIP) shared plans to build an artificial "hydrogen island" in the Danish North Sea. Electricity from 10 GW of offshore wind capacity would power electrolysers to produce nearly 1 million tonnes of green hydrogen annually for export to neighbouring northern European countries via 275 kilometres of pipelines.

It is no surprise that intense international collaboration is ongoing to both advance technological developments and support hydrogen production in countries with significant renewable energy generation opportunities. More than 30 countries already have hydrogen strategies that include import or export plans, according to IRENA, and cross-border hydrogen trade looks set to grow considerably in the coming years.

But whether the technical potential to produce hydrogen at export scale can be realised will also depend on factors like government support, the investment climate and political stability.

Floating offshore wind — a global opportunity

Floating offshore wind has the potential to expand rapidly to deliver the renewable energy capacity the world needs, and 2021 witnessed further breakthroughs in the sector. In 2021 the UK's Kincardine floating offshore wind farm came online, taking global floating offshore wind capacity to 139 MW, while Equinor has now commenced construction of its Hywind Tampen floating project. Development activity has continued to accelerate in a number of different markets, with leasing activity in France, the UK and California, and early-stage development activity in a wide variety of countries, including South Korea, Ireland, Japan, Norway, Colombia and Italy.

An important feature of floating offshore wind is the significant presence of several large European oil and gas companies. These companies have unparalleled offshore engineering skills and financial strengths. Their deep-water experience, combined with knowledge from fixed offshore wind developers, will take floating wind from the current demonstration stage into full commercialisation by the middle of this decade.

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. There are now floating offshore wind farms operating successfully in the UK and Portugal, as well as a significant pipeline of projects in different markets across the globe. The success of the UK's ScotWind leasing round, where 15 GW out of 25 GW of sites awarded leasing contracts are for floating projects, highlights the sector's appetite to move rapidly to the delivery of large GW-scale projects.

However, over the remainder of this decade, the sector will need to shift from a pre-commercial to fully commercial model, and to do this successfully it will need to grapple with a number of supply chain and installation challenges. Over the next five years we expect to see the delivery of a number of projects between 100 and 500 MW, and this learning applied to de-risk delivery of the first multi-GW floating projects by the end of the decade in both Europe and East Asia. GWEC's forecast is for total installations to reach 18.9 GW by 2030 (see graph on page 97). Rapid growth will come late in the decade however, with 73% of this capacity coming in 2028, 2029 and 2030.

By the end of the decade, we expect South Korea, the UK, the US, Spain and Ireland to be the top five global floating markets. It is expected that Europe will retain its dominant position in leading floating offshore wind development with 59% global market share, closely followed by Asia (29%) and then North America (12%).

Floating wind's current contribution to total offshore wind installations is only 0.2%, but it will play an increasingly important role toward the end of this decade, accounting for 6.0% of total installed offshore wind capacity in 2030. Looking ahead, post-2030, it is expected that this proportion will continue to rise for two reasons. First, as mature and maturing markets like the UK and US start to experience constraints

Drivers and constraints considered for the next floating wind markets

Site conditions
Wind speeds and bathymetry are key factors to determine the technical potential of a market and gauge the attractiveness of sites.

Policy environment
Government targets and dependability of the regulatory framework for renewable energy influence market maturity and attractiveness.

Support regime
Available subsidies and precedence from previous renewable projects affect ease of financing for offshore wind projects.

Permitting regime
Governance, requirements and clarity of permitting process determine project development lead-time and cost.

Supply chain and infrastructure. (ports)
Current port capacities, domestic industrial capabilities and potential synergies from existing industries influence cost of installation.

Transmission grid
Substations close to connection point, current transmission grid capabilities, as well as planned buildout affect the offtake situation

on fixed offshore wind growth, floating offshore wind offers a route to development of new areas. Second, as costs continue to fall, new markets where fixed offshore wind was not an option will rapidly open up.

This means that while floating offshore wind growth across the current decade is impressive, these early commercial schemes are essentially pathfinders, with industry using this experience to bring down costs, ramp up supply chain capacity and capability and shift from bespoke to mass production of critical components like platforms, anchors, mooring systems and dynamic cables.

At the start of 2022, GWEC published a report titled, Floating Offshore Wind – a Global Opportunity. This report looked at where we might see the next generation of floating offshore wind growth, as other countries seek to emulate pioneer floating markets like the UK, France, South Korea and Japan. We identified 30 markets with the right conditions and profiled five geographies in different global regions to look at what conditions needed to be in place and what constraints had to be overcome.

Drivers and constraints considered for the next floating wind markets

Our report highlighted opportunities in California, Ireland, Italy, Morocco and the Philippines. For these geographies to become hubs of floating offshore wind activity depends on one critical factor: policy ambition. Governments need to act as the catalyst for kickstarting successful floating offshore wind deployment, which can bring economic advantage and rapid action in emissions reduction. Policy and regulatory action are needed to support port infrastructure, supply chain, grid access and a route to market/revenue.

While we have identified five geographies that could become a "chasing pack" behind more mature markets, there is a much larger group of countries where the conditions are right for successful floating offshore wind growth. What's more, as understanding of this technology increases through commercial deployment, costs will fall and make floating offshore wind a clear option for many more countries around the globe.

Long timeframes between inception and energisation mean that to see floating offshore wind growth from now into the 2030s, we need market frameworks over the next few years. Our experience of supporting market growth in countries like Japan, Vietnam, Brazil, Colombia and the Philippines shows that there is growing appetite across the globe, as well as an understanding of the readiness of floating offshore wind to support national goals to decarbonise and meet growing electricity demand.

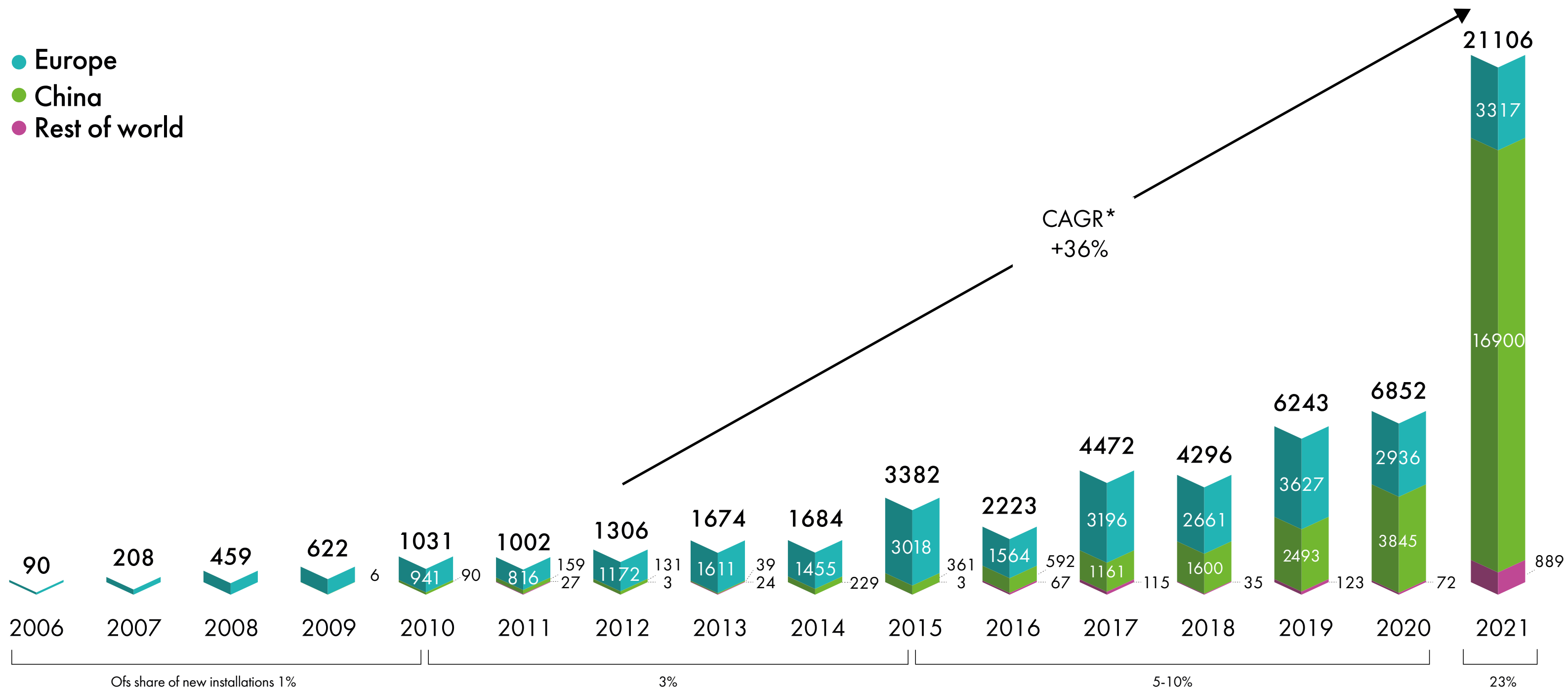
MARKET STATUS 2021

Annual installations

2021 saw 21.1 GW offshore wind become grid connected worldwide, setting a new record in the offshore wind industry.

- China led the world in annual offshore wind installations for the fourth year in a row with nearly 17 GW of new capacity connected in 2021. This astounding level of growth was driven by the expiry of Feed-in-Tariffs (FiTs) for offshore wind at the end of 2021 - the same policy shifts that created a huge rush in onshore wind installations in 2020.
- With 3.3 GW of offshore wind capacity added in 2021, Europe accounted for the majority of the remaining new installed capacity.
- With projects awarded in the Contracts for Difference (CfD) Round 2 in 2017 coming online, the UK installed 2.3 GW of new offshore wind last year, making it the largest European offshore wind market in 2021, followed by Denmark (608 MW) and the Netherlands (392 MW).
- No offshore wind turbines were installed in Germany during 2021, although there was one small

New offshore installations 2006-2021 (MW)



*Compound Annual Growth Rate.
Source: GWEC Market Intelligence, June 2022

offshore wind project under construction. The slow-down was primarily caused by previously unfavourable market conditions and a low level of ready-to-build offshore wind projects in the pipeline.

- In 2021 Norway commissioned the 3.6 MW TetraSpar floating foundation demonstration project at the Metcenter Test site. Together with the five units of 9.5 MW floating wind turbines connected at the Kincardine floating wind farm in Scotland and the one 5.5 MW floating prototype unit installed at the Yangxi Shapa III offshore wind farm in China, a total of 57 MW of floating wind capacity was commissioned in 2021.
- Outside of China and Europe, two other countries recorded new offshore wind installations in 2021: Vietnam (779 MW, intertidal only) and Taiwan (109 MW).
- Driven by the 1st of November FiT deadline, 20 intertidal projects in Vietnam fully or partially reached their commercial operation dates (COD) last year according to EVN (Vietnam Electricity), making it the third largest market in new installations in 2021.
- Taiwan was due to commission more than 1 GW of offshore wind capacity from three projects last year based on the project COD plans, but only the 109 MW Changhua demonstration project came online. The delays are primarily caused by COVID-19 related disruptions.
- The United States is the only market with an offshore wind project in operation in the Americas, but no offshore projects were built in 2021.

Cumulative installations

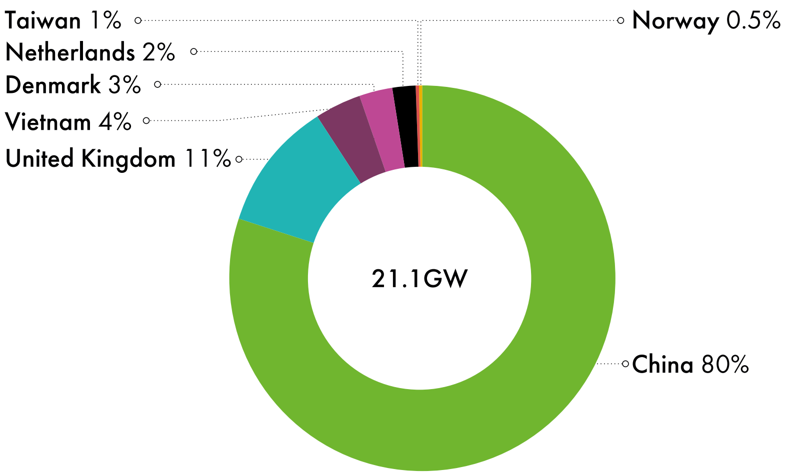
The global offshore market grew on average by 36% per year in the past decade, bringing total installations to 56 GW, which accounted for nearly 7% of total global wind capacity as the end of 2021.

- In total installations, the top spot has been held by the UK since 2009, but as GWEC predicted, China took over the leading position by the end of 2021. The other markets in the global top-five are: Germany, the Netherlands and Denmark.
- Europe remains the largest offshore wind regional market as of the end of 2021. The region was responsible for 50.4% of total cumulative global offshore wind installations, 18% lower than the previous year. The sharp drop of its market share is primarily due to the remarkable growth of the offshore sectors in China and Vietnam in 2021.
- As the world's second largest regional market, Asia is trailing behind Europe by less than 1% in cumulative installations. China is the largest market in the region, followed by Vietnam, Taiwan, South Korea and Japan.
- Outside Europe and Asia, North America has 42 MW offshore wind in operation as of the end of last year from the Block Island wind farm located in the US.

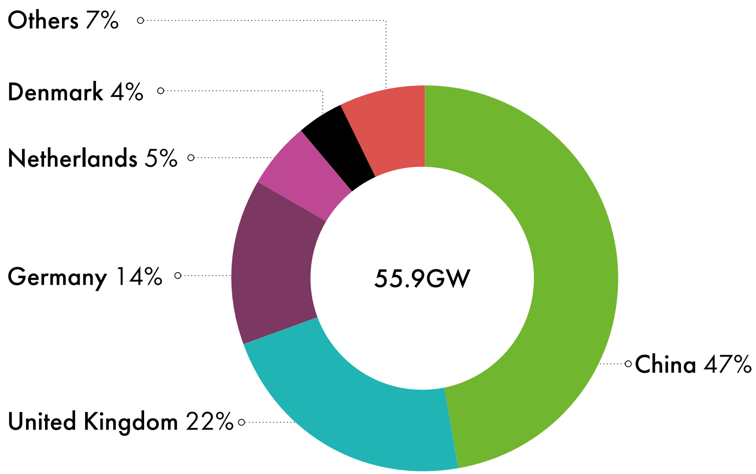
Floating wind

- 57.1 MW of floating wind was installed in 2021, of which 48 MW was in the UK, 5.5 MW in China and 3.6 MW in Norway.
- Two floaters were decommissioned last year. One unit, of 5 MW, in Japan and another, of 2 MW, in the UK.
- As of 2021, a total of 121.4 MW of net floating wind is installed globally, of which 78 MW is located in the UK, 25 MW in Portugal, 5.9 in Norway, 5.5 MW in China, 5 MW in Japan and 2 MW in France.

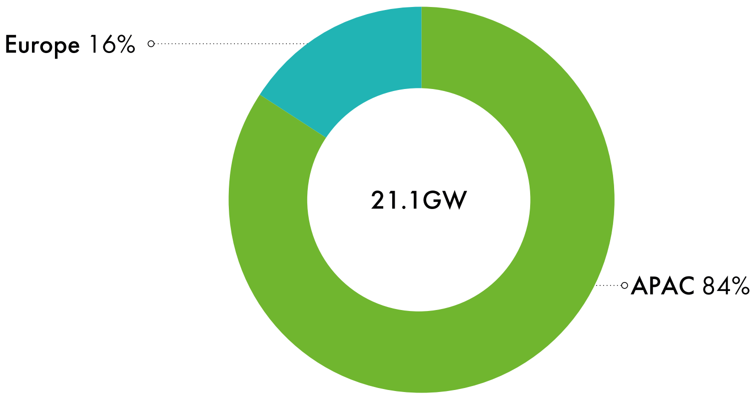
New offshore wind installations by market



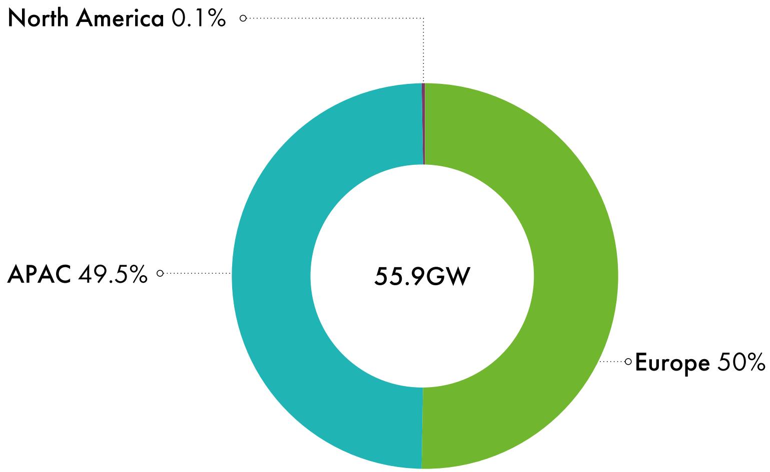
Total offshore wind installations by market



New offshore wind installations by region



Total offshore wind installations by region



Source: GWEC Market Intelligence, June 2022

MARKETS TO WATCH

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 - is expected to be approved within 2022. This plan, which was changed substantially after COP26, is a significant piece of legislation that enables the country to move towards a green economy with better grid stability and a larger share of renewable energy generation.

The offshore wind target was increased from 2GW in the first draft to 7GW by 2030 in the most recent draft released in April. This draft plan was approved by an appraisal committee and is waiting for a final decision from the Prime Minister at the time of writing this report. The ambitious target will not only cement Vietnam as a regional offshore wind leader, but also marks Vietnam as a global energy leader. In order to meet this ambitious target, a clear and transparent legal framework needs to be issued no later than the end of 2023.

PDP 8 development to date

At COP26, Vietnam made a strong commitment to become net zero by 2050. This led to a significant increase in the wind target in PDP8 target to 7GW of offshore wind by 2030 and 16GW of ONS, meaning wind will reach 15.8% of the total installed capacity by 2030.

At the same time, PDP8 still includes the coal projects which were in PDP7 but have not been built. These projects are likely to be further delayed due to the challenge of obtaining finance for coal projects worldwide. Once these projects are late, there a big chance that the government will look at renewable energy, including offshore wind, to replace them.

The higher ambition of wind and renewable energy is in-line with the Politburo's Resolution No. 55-NQ/TW to diversify[1] the energy mix and to ensure the country is ready for energy transition.

It is clear that renewable energy is the key to Vietnam's energy transition. However, the increasing penetration of renewable energy into the system also brings a need for grid upgrades. A regional target was proposed in the PDP8 draft to lower the cost needed for grid upgrades. Recently, the national assembly has passed a law to allow private sector to make investment in the national grid system. All these factors pave the way for Vietnam to meet its net zero target by 2050.

Offshore wind route to market

Prior to the announcement of Draft PDP8, 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 into the country's huge offshore wind potential.

The WBG estimated that the offshore wind technical potential for Vietnam is 599 GW (261 GW for fixed foundation and 338 GW for floating foundation)[2] and DEA's estimation indicated that after a constraints analysis, Vietnam will be left with a highly realisable technical potential of 160GW.[3]

The 7GW target of offshore wind by 2030 set in PDP8 is very ambitious for a new market like Vietnam, yet it is achievable if the regulatory

1. https://www.bakermckenzie.com/en/insight/publications/2020/02/vietnam-national-energy-development-strategy
2. https://documents1.worldbank.org/curated/en/340451572465613444/pdf/Technical-Potential-for-Offshore-Wind-in-Vietnam-Map.pdf
3. 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

framework is put in place swiftly. To meet that target, a route to market process to enable the installation of 7+ GW offshore wind by 2030 needs to be issued quickly.

Currently, Vietnam does not have any true offshore wind installed. Given the typical development and construction timeline of 5-7 years for projects after all the permitting hurdles are cleared, getting the first generation of offshore wind connected by 2030 will require consultation and establishment of policy and regulatory frameworks to begin today. Key components include:

- A simple remuneration mechanism which is quick to implement: Given how long it takes to develop and run an effective auction for offshore wind (typically 3-4 years), the first 4-5 GW of projects should be developed through a transitional mechanism made available in the next 1-3 years;

- A clear timeline for the implementation of an auction by middle of the decade which can provide a clear signal of procurement schedules for long-term investment[4] and sufficient time to create suitable guidance, regulations, evaluation criteria and other elements of auction design.

- A clear, coordinated and streamlined permitting process to ensure projects can be implemented on time and secure seabed exclusivity for development work; this also requires a centralized and well-organized development/permitting office within the government which can oversee the necessary licenses and approvals from various public bodies, with a focus on implementing, collecting and coordinating consultations and comments;

- A marine spatial planning (MSP) approach which allows for a light mechanism to ensure projects can get underway in the next few years, while a more robust framework is developed to ensure smooth mid-term offshore wind planning and mitigation of conflict between ocean users;

- Improved PPA bankability to attract international finance, which will be required to bring in the large investment volumes required for offshore wind. Domestic banks and institutions may not be able to provide sufficient capital to a new sector such as offshore wind, particularly given current lending limits.

- Grid planning and operational upgrades to facilitate the integration of offshore wind, with consideration of location (the proximity to power load centre, e.g. north and south), well-managed timelines to ensure deliverability on-schedule and concrete guidance on the requirements for successful developers; the Government may also wish to consider mechanisms on encouraging private-sector investment in transmission to solve upcoming transmission challenges.

Besides these issues, the Vietnamese government also needs other policy to develop a strong local supply chain and infrastructure to supply for the offshore wind industry in Vietnam.

4. GWEC elaborates on the best practices to transition from an initial procurement scheme to a competitive auction for offshore wind in this report on offshore wind in Vietnam from 2021: https://gwec.net/vietnams-future-transition-to-offshore-wind-auctions-international-best-practices-and-lessons-learned/.

Photo: Orsted

Taiwan

Taiwan is the third-largest offshore wind market in the Asia-Pacific region, after mainland China and Vietnam. With ambitious targets and a significant and clear pipeline laid out, the market has attracted eager interest from leading offshore wind developers and technology providers.

As of today, two offshore wind projects under the Demonstration Incentive Program have come online: Formosa 1, totalling 128 MW, and Changhua Demonstration project, totalling 109 MW. This will be followed by a series of projects including Greater Changhua 1 & 2a (900 MW), Formosa II (376 MW), Yunlin (640 MW) and Changfang Phase 1 (100MW). Greater Changhua 1 & 2a delivered first power in April 2022 and is expected to be completed by the end of 2022. Formosa II and Yunlin are both under construction and should make significant progress in 2022.

Increased Round 3 offshore wind target showing green ambition

Offshore wind is a key component of Taiwan's green economy vision, which includes a scenario to

Progression of Taiwan's wind procurement mechanisms

Round 1
(Demonstration Phase)
Two demonstration projects (128 MW and 109 MW)

Round 2 (2020-2025)
Selection process allocated 3,836 MW COD 2020-2025

Auction process allocated 1,664 MW COD 2020-2025
Both selection and auction process

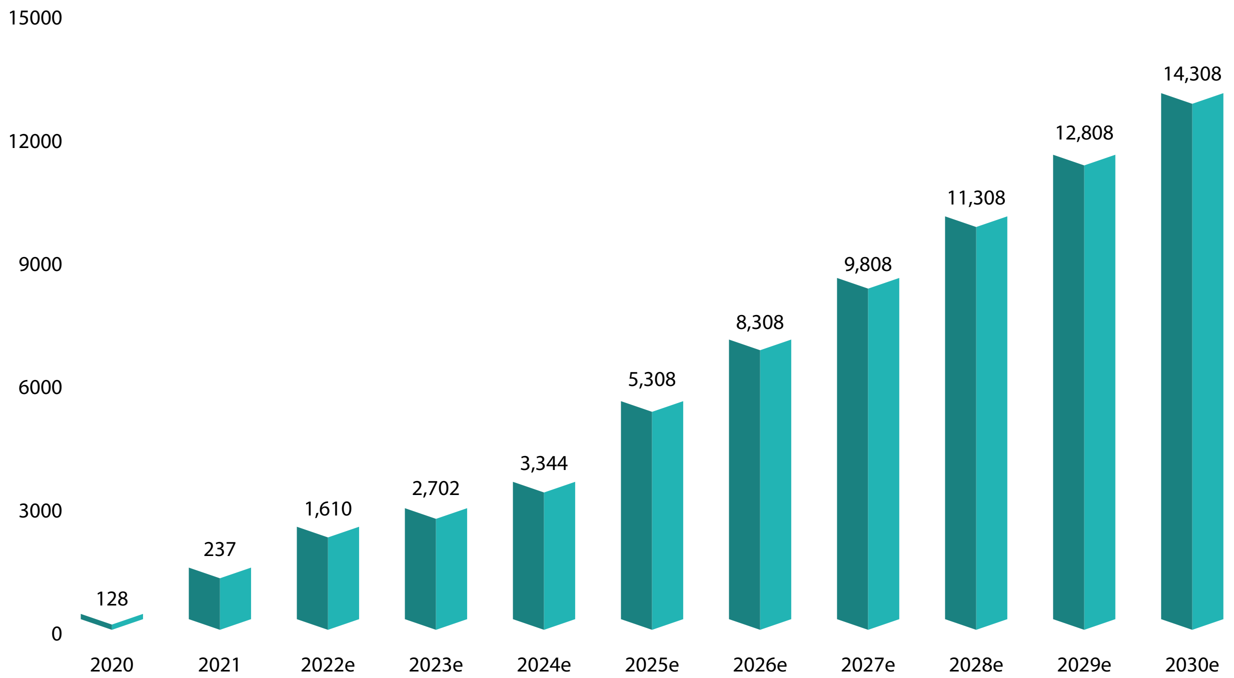
Round 3
Phase 1 (2026-2031)
1.5GW/year
Totalling 9 GW to be connected from 2026-2031

Auction taking place in 2022, 2023 and 2024 with each auction allocated 3 GW (covering two years)
Priority to projects with EIA and at <50m water depth

Round 3
Phase 2 (2032-2035)
Totalling 6 GW to be grid connected regulations to be released based on the results from Round 3 Phase 1

Source: MOEA, May 2022

Market outlook for cumulative installed offshore wind capacity in Taiwan (MW)



Source: GWEC Market Intelligence, June 2022

generate 20% of electricity through renewable energy by 2025 (which the government is now saying will likely happen in 2026 or 2027). In May 2021 the government announced that it would increase its offshore wind ambitions to 15 GW over the 2026-2035 period. While the original 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, was published by The Ministry of Economic Affairs (MOEA) in May 2022 with the final rules expected by mid-year.

The MOEA is aiming to allocate 1.5GW of offshore wind development each year from 2026 to 2031 for a total of 9 GW. Round 3 Phase 1 capacity will be allocated through three (3) auctions. The auction of 3GW for 2026-2027 ("Phase 1-1") is scheduled to be held later in 2022, the auction for 2027-2028 capacity ("Phase 1-2") will be held in 2023 and that for 2030-2031 ("Phase 1- 3") in 2024.

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.

In the Round 3 documents, the Industrial Development Bureau (IDB) has specified a total of 26 items as "key development items". A bidder will have to commit to procure locally all these key development items for at least 60% of its proposed capacity. There will also be opportunities to go beyond the 60% and receive additional points in the scoring system. 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

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

avoidance cost[1] of Taipower. The government was inspired by the example of zero-subsidies auction in Europe, as well as the burgeoning Corporate PPA market. 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

Significant supply chain investments have already been undertaken in Taiwan with further progress made in the past 12 months. Following the inauguration of Siemens Gamesa's nacelle assembly facility in Taichung in September 2021, the Vestas-Tien Li blade manufacturing facility located at the same city built their first blade for V174-9.5 MW offshore turbine in April 2022.

In addition to local produced nacelles and components that also include transformers, switchgears, rotor hub, towers, foundations and cables, CDWE, a joint venture between the Taiwanese shipbuilder CSBC and DEME Offshore, and Dong Fang Offshore are working on the first Taiwanese flag offshore wind installation vessel and cable-laying vessel respectively with the delivery expected to take place next year.

Within the next decade, Taiwan will achieve more than 12 GW of installed offshore wind capacity, becoming the second largest offshore wind market in Asia after mainland China, with an established domestic supply chain. The sector was 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.

India

India's offshore wind sector has gained momentum as a result of the Prime Minister's announcement of net zero targets at COP26 and the country's strengthened strategic ties with bilateral institutions for harnessing green energy. In a multi-pronged approach to bolster climate action at COP26, India also announced its increased ambitions of installing 500 GW of non-fossil fuels-based power generation capacity by 2030, inclusive of 30 GW offshore wind capacity.

Auctions to 2030 to include offshore wind blocks

In March 2022, the Ministry of New and Renewable Energy (MNRE) held an industry-wide consultation on its discussion paper "Establishment of Offshore Wind Energy Projects to achieve a target of 30 GW by 2030. On behalf of the offshore wind industry, GWEC presented and submitted inputs to the MNRE outlining enabling features and prospective gaps.

After a detailed review, in June 2022, the MNRE announced India's offshore wind bid trajectory as per below:[1]

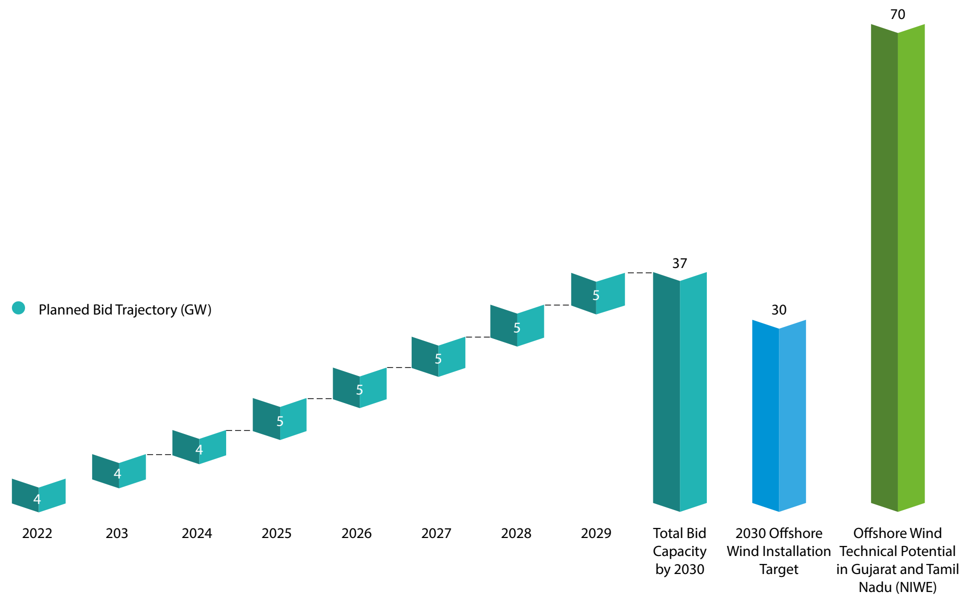
- Beginning with financial year (FY) 2022-2023, offshore wind bids of 4 GW capacity per year for a period of three years to be rolled out off the coast of Tamil Nadu and Gujarat for sale of power through open access/captive/bi-lateral third-party sale/merchant sale.
- For the subsequent five years, an annual bid volume of 5 GW planned until FY 2029-2030.
- Power from all offshore wind capacities that will be bid out up to FY 2029-2030 shall be evacuated and transmitted from offshore pooling substations to onshore transmission networks free of cost.
- The first 8 GW of capacity bids shall be eligible for the benefits of green attributes such as carbon credits.

These figures convey that India would award bids totalling 37 GW of capacity from 2022-2029, which can offset the impact of unfulfilled target of 5 GW by 2022. It is not yet clear how much of the capacity allocated through bids would be installed by 2030, against the target of 30 GW of installations by the end of the decade. While this development invites enthusiasm, the following must be prioritised ahead of any capacity bidding:

- Result of Floating LiDAR by NIWE: NIWE is yet to award the E-tender for supply, installation, and commissioning of integrated floating buoys for mounting LiDARs at three locations in Gulf of Mannar, off the Tamil Nadu coast.[2] The E-tender has been opened up three times, with the last occasion noting closure in early March 2022 and an award by April 2022.
- Approval of Viability Gap Funding by the Ministry of Finance: Viability gap funding or other financial incentives can help to build confidence and drive stakeholder participation.
- Policy and regulatory clarity: GWEC's India Offshore Wind Working Group is working with government and industry stakeholders to share global experience and advocate for

1. https://pib.gov.in/PressReleseDetailm.aspx?PRID=1832708
2. (Zone B1, Zone C1 & Zone E2)

Offshore wind planned bid trajectory vs installation target vs earmarked potential



Credit: MNRE, NIWE, GWEC Market Intelligence required policy clarity, cost reduction strategy, and offshore wind roadmap.

Important aspects to outline include: socioeconomic awareness among indigenous/fishing communities; developing a robust MSP framework; building out port and grid infrastructure; ensuring vessel availability; and offshore wind-tailored regulation and standards. Timely approval of permits and allocation of clearances, power evacuation and transmission infrastructure commissioning and adherence to PPA signing timelines will also be required to ensure an expedient installation timeline.

Through strategic alliances and institutional partnerships, the Governmentt of India is already strengthening its existing expertise of offshore wind:

- Renewable Energy Catapult and NIWE have announced a Joint Declaration of Intent (JDI) to establish a 5-year collaboration programme to support the UK and India's offshore wind industry.[3]
- Under the MoU between India and Denmark, a knowledge hub called the Centre of Excellence for Offshore Wind and Renewable Energy (CoE) was launched in September 2021 for the adoption of a comprehensive and coherent approach leading to cost-effective offshore wind power, with a view to mobilising significant investment. An initial report in May 2022 estimated the lowest possible LCOE by 2025 and 2030 could be in the range of 11.2-7.4 INR/kWh and 7.8-5.2 INR/kWh, respectively.[4]

The Indian public sector undertakings (PSUs) have also been encouraged by the government to scale up their renewable energy portfolio by participating in the forthcoming offshore wind bids. This has opened a door for win-win partnerships between international offshore wind players and PSUs.

In recent years, oil and gas company ONGC and the National Thermal Power Corporation (and largest power generator utility NTPC) have entered into a Memorandum of Understanding (MoU) to explore offshore wind opportunities.

3. https://www.ukri.org/news/ukri-india-announces-new-initiatives-during-uk-pms-visit-to-india/
4. These revised estimates are based on recent market changes compared to the 2021 FIMOI report version-1. See: https://coe-osw.org/first-indian-technology-catalogue-with-offshore-wind-data/.
5. Global Wind Report 2022, GWEC

Germany-based RWE Renewables and utility Tata Power Renewable Energy have signed a MoU to jointly develop offshore wind projects.

Offshore wind is critical to net zero by 2070 goal

Meeting India's net zero target requires a massive push for decarbonisation and renewable energy capacity. This will support the transition from fossil fuels to clean energy as well as meet evolving power demands. While utility-scale renewable energy technologies such as wind and solar face land allocation delays for project development, offshore wind has an opportunity to mitigate or even avoid this legacy challenge.

The MNRE could exploit India's massive offshore wind potential in the medium to long-term to strengthen efforts for climate resilience and energy security. Learnings from countries in Europe showcase the promising role of offshore wind towards supporting India's National Green Hydrogen mission, clean power demand from the commercial and industrial segment and energy exports.

Enabling offshore wind policies will thus be pivotal for driving investor participation and project risk mitigation. A long-term non-solar RPO trajectory specific to offshore wind and a production-linked incentives scheme for domestic offshore wind manufacturing could support a thriving offshore wind industry in the country. Alongside other renewable energy technologies, offshore wind must be provided "deemed generation" status.

Furthermore, a growing pool of innovative financing mechanisms such as blended finance and Green/Masala Bonds for the initial phase of offshore wind market development could be leveraged to support early project financing.

Brazil

Brazil is positioning itself as a highly promising offshore wind market with an opportunity for regional and global leadership. Offshore wind is seen as one of the most promising new renewable energy technologies in the country, contributing to a just energy transition and benefiting from green recovery packages, in which more than R$250 billion ($49 billion) has been provisionally allocated over the next 10 years to invest in the generation and transmission infrastructure of renewable energy.

The growth of the offshore wind sector is associated with having positive socioeconomic benefits, such as job creation, which will in turn reduce the social income gap that exists in Brazil. Job creation will play a positive part in increasing the average income of those in the workforce by a greater proportion than that of any other existing renewable energy technology.

Critical regulatory breakthroughs

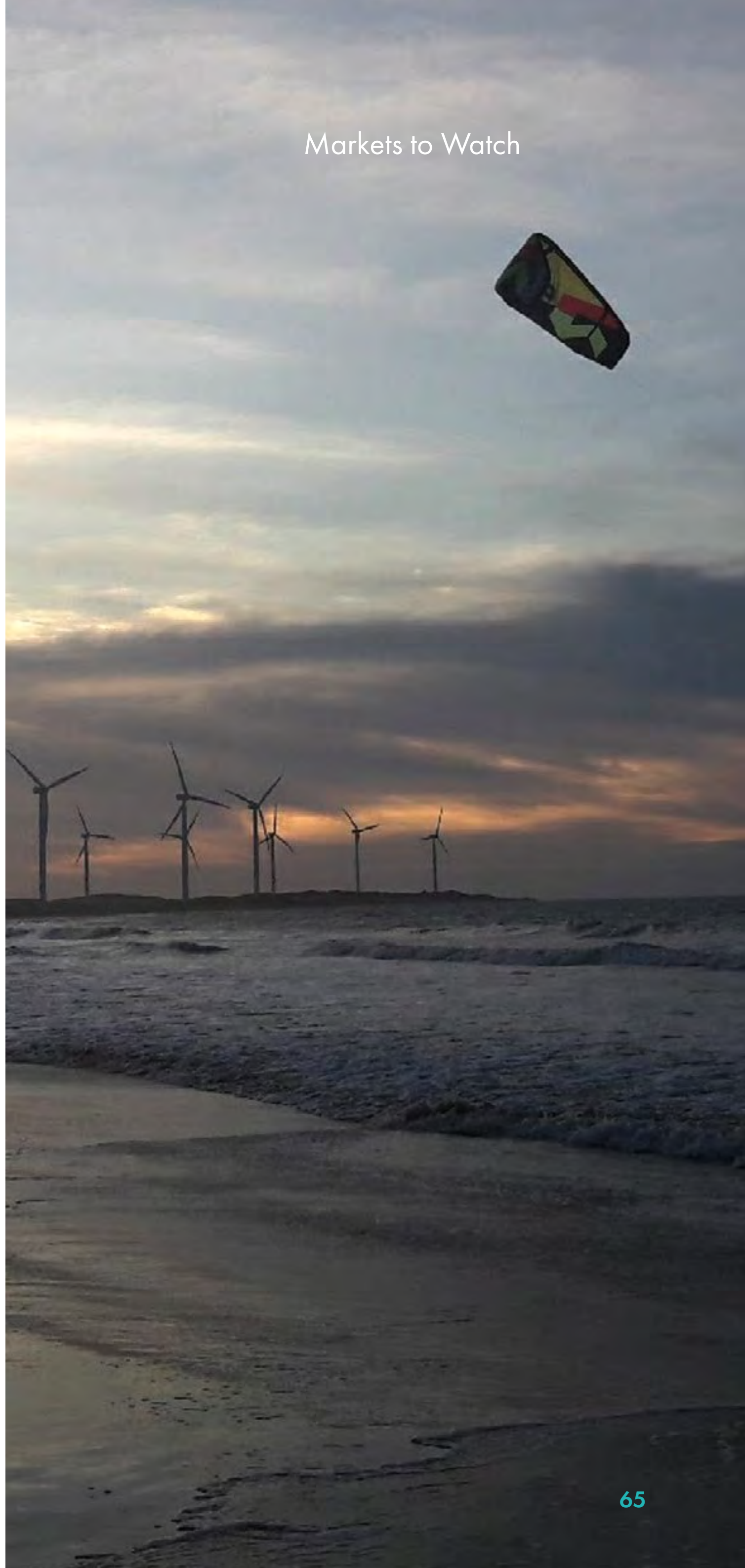
2021 was a decisive year in Brazil's offshore wind history. ABEEÓlica (Associação Brasileira de Energia Eólica and New Technologies) led the charge for the creation and establishment of a regulatory framework, culminating in a highly successful meeting with then-Minister of Mines and Energy Bento Albuquerque and Senator Jean Paul Prates in April 2021. As a result of this engagement, in the first weeks of 2022, the long-awaited Decree N° 10.946/2022 was published, setting out the main guidelines for offshore wind projects in Brazil.

> The country already has more than 100 GW of offshore wind energy projects registered for environmental impact assessment by IBAMA and is striving to establish its regulatory apparatus

The decree provides a framework for the assessment of seabed for the development of offshore wind projects, and shows that the stages of planning and permitting are being defined to ensure the effective rollout of this technology is being facilitated.

Another positive regulatory signal is the PL 576/2021. This bill is not limited to the development of offshore wind solely, but also details the scope to produce renewable energy at sea, which opens up possibilities for new technologies in the future, such as floating offshore wind. PL 576/2021 creates a regulatory framework for the process of granting offshore wind farms with auctions, and charges the payment of special participations to the Union, states and municipalities – resources that are not provided for in the presidential decree. Discussions are ongoing and the prospect of approval is still undetermined and dependent on several Senate assessments.

When addressing the challenges of offshore wind in the country, it is important to highlight Brazil's proactive regulatory approach to this emerging industry. At a national level, environmental legislation and regulations have already been developed in line with increased market demand. The country already has more than 100 GW of offshore wind energy projects registered for environmental impact assessment by IBAMA and is striving to establish its regulatory apparatus, which should be specified later in 2022, in the details of Decree No. 10,946/2022.



Despite this positive momentum, the offshore wind industry will still face significant challenges, such as how to develop a domestic supply chain. Brazil will also need to accommodate and organise its structure of maritime routes and ports, incorporating the port-industry concept. There are also challenges regarding transmission infrastructure, which will need to be overcome. Lastly there is the consideration of cost and value competitiveness within the Brazilian market, as offshore wind will need to compete with other more mature and highly competitive supply chains, such as onshore wind and solar projects.

What's next on the horizon

A first step has already been taken with the publication of the decree and the regulation of the transfer of use for sea areas, which should be released later in 2022. This is the starting point for defining other regulatory issues. One of the most relevant aspects for investors are the rules that will be established for energy auctions. After the regulation of the assignment of areas, the next step is to hold the first offshore wind energy auction in the country.

ABEEólica has collaborated with the main governmental and regulatory institutions to obtain these guidelines in 2022, thus directing the path for carrying out an energy auction in the coming years. It is anticipated that by the end of this decade the country will have its first wind turbines operating at sea. This would allow for a strong market expansion due to its capacity to supply other renewable generation chains, such as green hydrogen.

There is no doubt that offshore wind is already a source of investment opportunities, growth and modernisation for the Brazilian economy. There is an opportunity for the country to be one of Latin America's hubs for investment in renewable energy technology and offshore wind. For this future to materialize, it is essential that the offshore wind industry be viewed under the concept of new industrial planning integrated with energy planning.

United States

Since the ambitious 30 GW by 2023 offshore wind target was released by the Biden–Harris Administration, there has been a noticeably positive attitude towards pushing the rollout of offshore wind on the political agenda. Although no new offshore wind turbines were installed in the US in 2022, the US offshore wind market continues to gain strong momentum in both state and federal waters.

Raised action at federal level

The Bureau of Ocean Energy Management (BOEM) is the US organisation that manages and is responsible for the offshore wind market in federal waters. Since the issue of the Outer Continental Shelf (OCS) Renewable Energy Program, which made the production and transmission of renewable energy sources like offshore wind much easier to procure, BOEM has issued 25 commercial and 10 competitive offshore wind energy leases in the Atlantic Ocean, ranging from Massachusetts to North Carolina. To position the domestic offshore wind industry to meet the 2030 target, BOEM has been extremely active in the past 12 months, working to identify areas of unexplored wind energy potential. This has been paired with fast paced leasing auctions in a bid to align output with ambition.

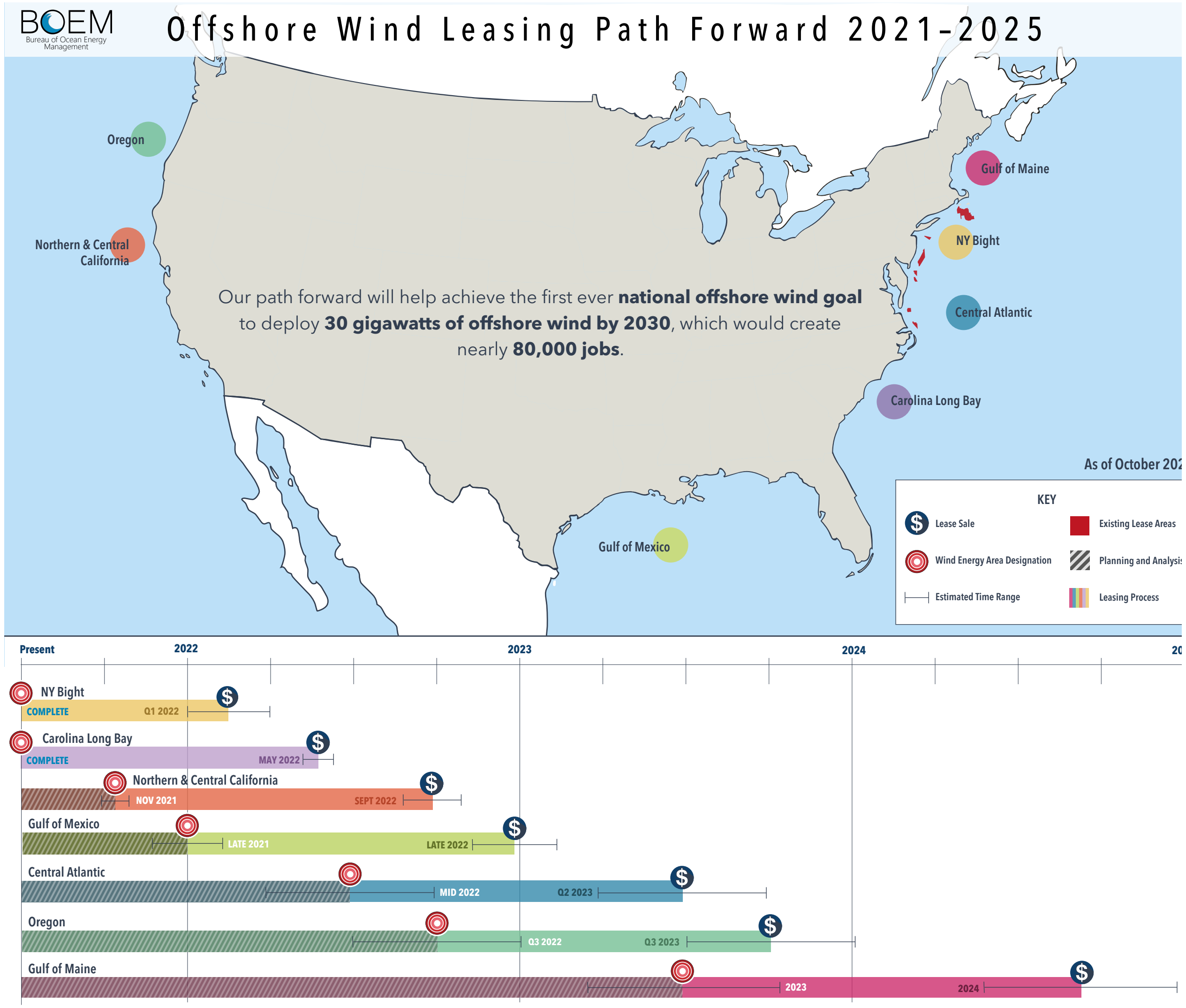
The collaborative efforts by BOEM and a flood of developers in the New York Bight leasing round led to this being the largest ever offshore wind industry auction in US history. With the proposal being made in January 2022, and the auction being held in February 2022, there was a shortened timeline which saw this auction closed in Q1 of 2022. This leasing round saw the auction of circa 448,000 acres of seabed off the coast of New York up to New Jersey allocating 5.6 GW of offshore wind capacity to six bidders. With a record USD 4.37 billion being generated in revenue, the auction set new records.

Coming in second to this auction was the announcement of the wind energy auction in Carolina Long Bay which saw the auction of two leasing areas off the coast of North and South Carolina. At full capacity this region has the potential to produce an output of 1.3 GW of offshore wind energy which could power 500,000 homes. The two winning developers of the auction round generated a revenue of USD 315 million.

Following the Carolina Long Bay lease, completed by BOEM in May, a now clear schedule for the Californian offshore wind market will see the leasing of 373,268 acres of seabed in federal waters of the Humboldt Call and Morro Bay Call areas. This boasts a potential of 4.5 GW of installed wind power generation. This auction, which follows the Call for Information and Nominations for offshore wind areas in California in 2018, is planned to take place in Q4 of 2022 and will be the first US project to award offshore floating wind. BOEM is expected to publish a Proposed Sale Notice in Q3 of 2022 that will allow for a public consultation, welcoming comments on the details about the two proposed lease areas.2

Looking ahead to what can be expected from the US and the efforts of BOEM, the pathway shown in figure 1 indicates that the next area for offshore wind growth is due to be the Gulf of Mexico. BOEM has issued a Call for Information and Nominations to assess the commercial interest and viability in this region. In light of this, BOEM is scheduled to issue a draft Environmental Assessment for the

US Offshore Wind Leasing Path Forward 2021-2025



Source: BOEM

Gulf of New Mexico in the middle of 2022. Other areas of interest with planned auctions include Central Atlantic and Oregon in 2023 and the Gulf of Maine in 2024.

In addition to the Department of Interior's approval of the construction and operation plan of the Vineyard Wind project - the first large-scale offshore wind farm in the United States - in May 2021, BOEM has also started a series of environmental reviews of offshore wind projects on the east coast. These include Revolution Wind project, Ocean Wind project, Kitty Hawk offshore wind project, Dominion Energy's Coastal Virginia Offshore Wind project and US Wind's wind project offshore Maryland. The end of last year also saw the announcement of the Record of Decision (ROD) by BOEM for the South Fork Wind project. Similar to the Vineyard wind project, this project is due to come online delivering power to New York in 2023.

Growing ambition including floating at state level

At the state level the US has experienced a rise in declared ambition, with this year's standout announcement of an additional 3 GW of offshore floating wind installations by 2030 by the California Energy

Commission (CEC). Floating wind is establishing its place in the offshore wind industry as a solution to exploit the vast wind potential being offered by sites with deeper waters. This new technology is enabling even greater ambition than ever before. In addition to the target in California, a new bill outlining a plan to develop 3 GW of floating offshore wind capacity in Oregon by 2030 has been introduced in the state's House of Representatives. If enacted, the bill will enable planning the development of 3 GW of commercial scale floating wind projects within federal waters off Oregon's coast by 2030.

Louisiana also announced a 5GW target of installed offshore wind capacity by the year 2035, making this the states first ever policy based Climate Action Plan. This plan details around eighty four actions that must be conducted to enable socioeconomic growth in the state.

Massachusetts also passed an increased offshore wind target of 5.6GW by 2027 at state level in late Q1 of 2022, which is the second time that the state raised its offshore wind target. So far the state has procured 3.2GW of installed offshore wind capacity and so the trajectory is positive and within reach.

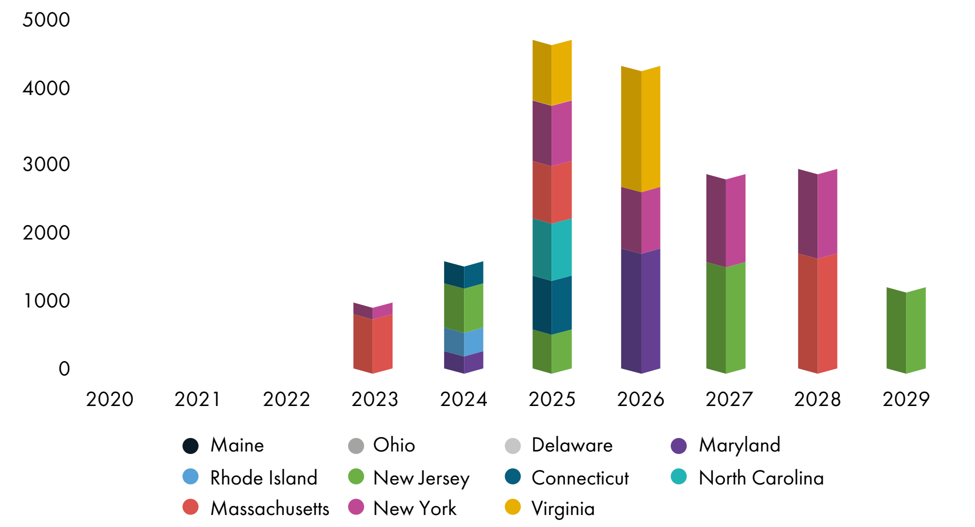
After taking into consideration the progress made at state level, the total announced offshore wind procurement targets are now 49.5 GW. This is a 28.6% increase in state level commitments from the previous year where the target was positioned at 38.5GW. If these targets are met this will propel the US to be able to make significant changes in global emission contributions.

Strong market growth expected from 2025 onwards

According to the GWEC Market Intelligence global offshore wind database as of June 2022, the US offshore wind pipeline total has reached 40 GW for both federal and state waters. This includes 21 offshore wind projects which have secured offtake or won state solicitations and announced an anticipated year of operation. Developers expect a total of 18 GW of offshore wind to be online between 2023 and 2029 (see figure 3). Of the 18 GW of offshore wind capacity, 23.4% is likely to be built in New York, followed by New Jersey (20.5%), Massachusetts (17.7%), Virginia (14.4 %) and Maryland (11.2%), making these the top 5 offshore wind states in expected new installations. With regards to project ownership, the situation is the same as last year and the majority of assets, planned to be built in 2023-2029, are controlled by European developers including Ørsted, Avangrid Renewables (a subsidiary of Spain's Iberdrola), EDPR, Ocean Wind and CIP as well as oil and gas companies like Equinor, BP and Shell.

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 2024 and 2025. The primary reason for this is the change of project commission date for some projects. Additionally, in GWEC's updated US offshore outlook we included two projects that won the second offshore wind solicitations in Maryland and another two that won the third solicitations in Massachusetts at the end of 2021. As a result, GWEC Market Intelligence believes that the strong offshore wind growth is likely to take place from 2025 instead of 2024.

Expected annual offshore wind installation by state, 2022-2029 (MW)



Note: This forecast is solely based on projects with commission date announced. For the entire 10-year forecast (2022-2031), please see Page 94 in Market Outlook section. Source:GWEC Market intelligence, June 2022

As of June 2022, offshore developers have selected or announced preferred turbine suppliers for ten 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. Vestas took over GE as the second largest supplier after Empire Offshore Wind - a joint venture between Equinor and BP named the Danish turbine manufacturer as the preferred supplier for the 2.1 GW Empire Wind 1 and Empire Wind 2 offshore wind projects in New York last October. Although, GE Renewable Energy's order backlog in the US is just 1% lower than Vestas. As of today, the most popular models selected for US offshore wind projects are SGRE's SG15-222 DD, Vestas V236-15.0 MW turbines and GE's Haliade X- 13MW DD.

Overcoming challenges in the US supply chain

Following the breakthroughs made on the federal and state levels, further progress has been made to address the four challenges that we assessed last year. Authorities are making ample effort to take advantage of the expertise of Europeans companies and markets to leverage wind potential in a project-based approach.

Local supply chain – Balance of plant

The US embarked on the construction of its first offshore wind tower manufacturing plant as of 2022, a contract awarded by the Port of Albany. A US based OEM won a USD 42.7 million contract as part of a joint venture with a view to manufacturing homegrown wind towers by late 2023.

Another component that is developing in the US supply chain is that of cables. At the end of last year, the UK based Prysmian Group secured USD 880 million in offshore wind cabling projects, awarded by Vineyard Wind. As a result, they will be building a cable plant in the US to accommodate the commission of the three core cables (HVAC 275 kV) with XLPE insulation and single wire armouring.

Local supply chain – Vessels

The Jones Act still stands as a dominant bottleneck adding to the lengthy timelines of project rollouts in the US offshore wind market. However, the market has adjusted to this to deliver projects which are, in many cases, supported by European based companies.

The market is, however, experiencing raised private sector efforts to work around these restrictions including the joint venture by Equinor and BP to support the Empire Wind offshore wind farm project. Together they have awarded a long-term service operation vessel (SOV) charter agreement to Edison Chouest Offshore (ECO), a US-based company, in order to be compliant with the Jones Act. This SOV will be the first in US waters to be hybrid with capability to operate partially on battery power.

The Danish subsidiary Maersk Supply Service has this year chartered a wind turbine installation vessel (WTIV), which will be used in the installation of the 15 MW Vestas manufactured turbines in both Empire one and two. This vessel is expected to come into operation around 2025. Maersk mitigated concerns regarding a breach in the Jones Act by chartering this vessel as it is constructed with barges and tugs supplied and managed by Kirby Offshore Wind, a US-based company.

Infrastructure – Ports

Investments in port infrastructure is a critical component of enabling the offshore wind sector to play it's part in reaching decarbonisation targets.

Projects in support of accommodating the development of the nations ports include:

- The Port of Humboldt Bay has received USD 10.5 million in investment for the ports renovation in order to support the intended 1.6GW of offshore wind development in the Humboldt call area.

- There are positive investment signals in the growth of offshore wind coming from regions like Massachusetts where the Baker – Politio Administration announced plans to invest USD 100 million towards supporting offshore wind ports in the state.

- The Port of Albany has received USD 29.5 million to invest in the necessary development of the ports infrastructure to allow it to be transformed into an offshore wind tower manufacturing facility.

- In August 2021 the Port of Virginia leased an area of the Portsmouth Marine Terminal to Dominion Energy to aid the development of the country's largest offshore wind project.

- Port of Davisville and the South Quay Marine Terminal in Rhode Island have also been awarded USD 95 million in state support to allow for upgrades to the infrastructure for upcoming projects along the East Coast. This dormant site will be upgraded to enable offshore wind related facilities to be developed in line with wind energy related business activities in the area.

Infrastructure – Grid

A State Agreement Approach (SAA) has been approved by the Federal Energy Regulatory Commission (FERC) to implement the wind transmission grid solicited in New Jersey. The SAA permits the New Jersey Board of Public Utilities (NJBPU) and PJM Interconnection to use a competitive planning process for the selection of a provider of a transmission solution. The joint SAA received 80 proposals from utility companies and developers indicating an appetite for finding transmission solutions on the supply side. It is anticipated that a decision on the outcome of any recommendations or decisions will be confirmed later this year.

Workforce Development

Dedicated resources for the growth and development of human capital is essential in enabling the offshore wind sector to reach it reach its full capacity.

- The BOEM Carolina Long Bay Offshore wind auction saw a new framework being introduced whereby bidders are awarded a 20% monetary credit which must be committed to the support of workforce training programs to enable the development of the local supply chain. For this auction round the total credit awarded for investment in workforce development is around USD 42 million.

- The North America Building Trade Union (NABTU) and Ørsted have collaborated to provide the announcement of a Project Labour Agreement (PLA) which strives to help the US workforce develop to accommodate the requirements of the offshore wind farm supply chain.

Japan

Considering Japan as an archipelago with strong wind speeds – even stronger and steadier offshore – the development of offshore wind is indispensable to increasing renewable energy supplies. Japan has approximately 128 GW of fixed-bottom offshore wind potential and 424 GW of floating offshore wind potential.[1] Despite the huge wind potential, Japan does not have any large-scale commercial wind operations but times are changing.

With rising fossil fuel costs and a goal to achieve carbon neutrality in 2050, the Government of Japan has recognised offshore wind as a power source that can be introduced in large scale without putting significant burden on the economy and with significant cost reduction potential. Both the public and private sectors are now looking to utilise the country's abundant offshore wind resource and to stay self-reliant.

In November 2021, Japan's biggest refiner, Eneos Holdings, announced its decision to buy Japan Renewable Energy (JRE) for about JPY 200 billion ($1.8 billion), joining the list of major global companies moving away from fossil fuels and expand their low-carbon business.[2] This will mark the first big purchase of a renewables firm by a top Japanese oil company. Last December, the first commercial-scale wind farm, located at Noshiro, Akita, started taking shape as it received its turbine components with a goal of commencing commercial operation in 2022.[3]

Comparison of Fifth & Sixth Strategic Energy Plan Energy Mix by 2030

	Sixth Strategic Energy Plan (Approved in October, 2021)	Former Fifth Basic Energy Plan (prepared in 2015)
Photovoltaic	103.5 ~ 117.6 GW (129 ~146 GWh)	64 GW
Wind (onshore)	17.9 GW	9.2 GW
Wind (offshore)	5.7 GW	0.8 GW
Geothermal	1.5 GW	1.4 ~ 1.6 GW
Hydropower	50.7 GW	48.5 ~ 49.3 GW
Biomass	8.0 GW	6 ~ 7 GW
Electric Power to be generated	336.0 ~ 353.0 GWh	236.6 ~251.5 GWh

Note: 5.7 GW of offshore wind represents an expected installed capacity. The target of 10 GW by 2030 is defined as awarded by auction projects set out by the First Vision for Offshore Wind Power Industry.
Source: JWPA, Dec 2021

Making offshore wind the main renewable power source in Japan

Since the release of the "Act on Promoting the Utilization of Sea Areas for the Development of Marine Renewable Energy Power Generation Facilities" (hereinafter referred to as the "Act on Promoting Utilization of Sea Areas for Renewable Energy Generation") in April 2019, Japan has been steadily working to expand offshore wind power generation by creating a certification system and licensed use of designated promotional sea areas while maintaining harmonisation with local communities.

Building on the Act, other key policy documents and regulations such as the Vision for Offshore Wind Power Industry (released in Dec 2020), the Green Growth Strategy Through Achieving Carbon Neutrality in 2050 (updated and announced in June 2021) and the Sixth Strategic Energy

1. NEDO Offshore Wind Condition Map
2. https://www.reuters.com/business/energy/eneos-says-buy-japan-renewable-energy-177-bln-2021-10-11/
3. https://constructionreviewonline.com/biggest-projects/the-akita-noshiro-offshore-wind-farm-project-timeline/

Japan Offshore Auction Progress List

Stage of Progress	Round 1 (FY2019)		Round 1.1 (FY2020)		Round 2 (FY2021)	
	Initial (July 2019)	Progress (July 2020)	Initial (July 2020)	Progress (November 2020)	Initial (Sep 2021)	Progress (March 2022)
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		Gann-u and Minami-Shiribeshi, Hokkaido Hiyama, Hokkaido Mutsu bay, Aomori Kisakata, Akita-city, Akita Yusa, Yamagata Murakami & Tainai, Niigata		Ishikari-city, Hokkaido Shimamaki, Hokkaido Matsumae, Hokkaido Kuji-cuty, Iwate Aware-city, Fukui Hibikinada Kitakyshu, Fukuoka Karatsu-city, Saga Gann-u and Minami-Shiribeshi, Hokkaido Hiyama, Hokkaido Mutsu bay, Aomori	
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		Kisakata, Akita-city, Akita Yusa, Yamagata Murakami & Tainai, Niigata Isumi-city, Chiba Japan Sea Side North, Aomori Japan Sea Side South, Aomori Enoshima Saikai-city, Nagasaki	
Areas with auction already launched		Goto, Nagasaki		Noshiro, Akita Yurihonjo North & South, Akita Choshi, Chiba		*NOTE: Happou-cho & Noshiro, Akita Round 2 Auction schedule is being postponed (Previou bid submission deadline was set to be June 2022)
Successfully Auctioned					Goto, Nagasaki - 16.8 MW (Won by a consortium of six companies led by Toda Corporation)	Noshiro, Akita Pref - 478.8 MW Yurihonjo North & South, Akita Pref - 819 MW Choshi, Chiba Pref - 390.6 MW (All 3 sites on by Mitsubishi Corporation Consortium)

Source: JWPA, Dec 2021

Plan (approved by the Cabinet in Oct 2021) were updated and launched with the goal of making offshore wind one of the main power sources in Japan.

The First Vision for Offshore Wind Power Industry, based on a cost reduction study by GWEC and the Japan Wind Power Association (JWPA), was created to boost local and international investment confidence and facilitate investment decisions. This is done by providing a visible offshore wind project pipeline, a cost-effective power supply chain and a conducive business environment as the government set out to designate 1 GW of promotional zones for auction annually for the next 10 years to reach an awarded capacity of 10 GW by 2030 and 30-45 GW by 2040, including floating offshore wind.

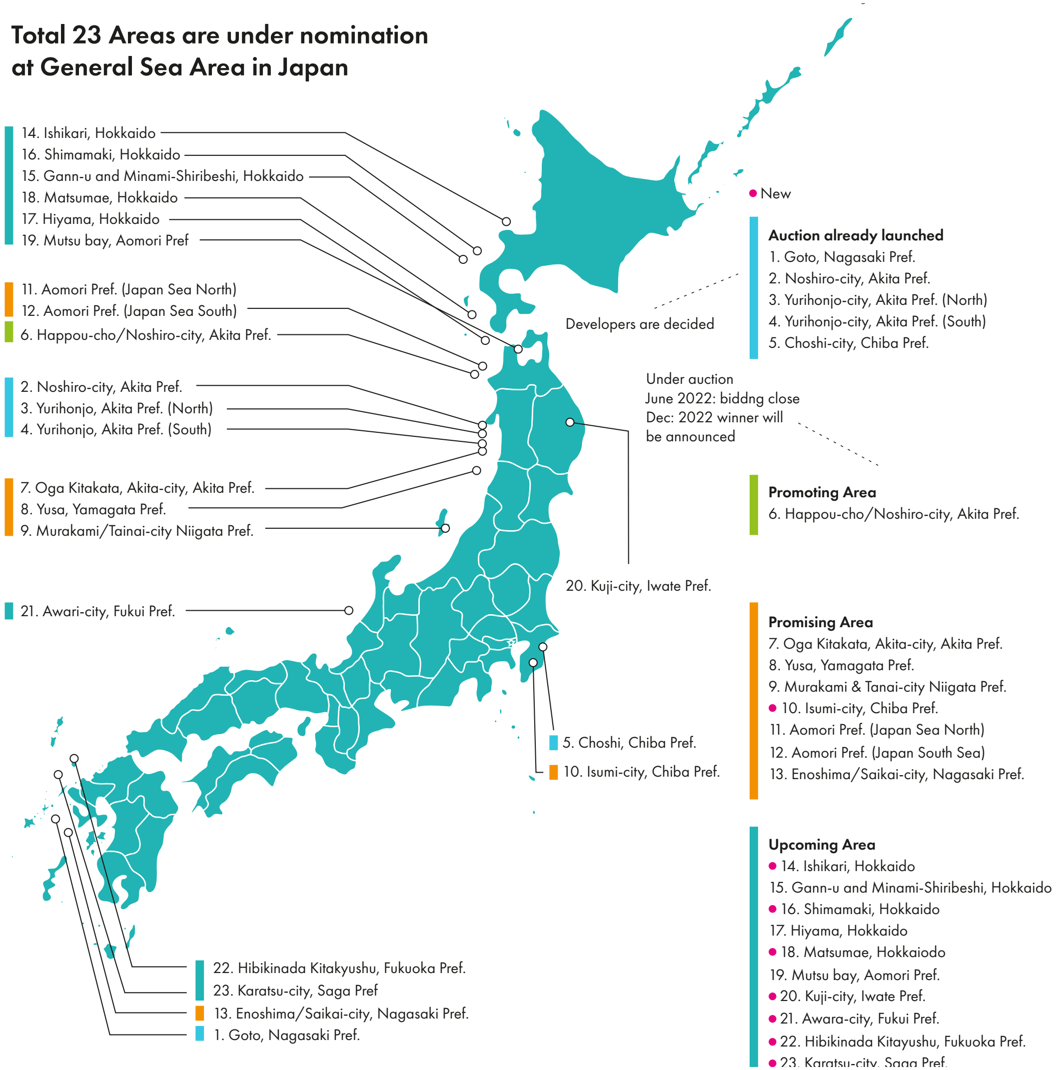
In the same period, the Green Innovation Fund for Offshore Wind was launched to accelerate the next-generation technology development with a focus on floating offshore wind. By October 2021, the Ministry of Economy, Trade, and Industry (METI) allocated JYP 119.5 billion ($940 million) for various cost reduction projects with a maximum subsidy period of 12 years (3-5 years for component technology development and a maximum 8 years for testing and demonstration). These projects aim to achieve a generation cost of JPY 8-9/kWh (EUR 0.06-0.07/kWh) with seafloor-mounted turbine by 2030.

Most importantly, in the Sixth Strategic Energy Plan announced in October 2021, the government reviewed its energy policy progress in the decade after the incident at Fukushima Daiichi Nuclear Power Station and increased the share of renewable installed capacity by more than 10% from 22-24% in the Fifth Strategic Energy Plan to 36-38% by 2030. The total of installed wind energy now accounts for about 5% of Japan's electricity supply, with 17.9 GW from onshore wind and 5.7 GW from offshore wind.

Making a centralised system a reality

Recognising the lack of high-quality project development data and the inefficiency of having many

Nominated Offshore Wind Areas at General Sea Area in Japan



Source: JWPA, June 2022

stakeholders involved in early-stage site surveys, the government aims to establish a centralised bidding system where it will work with local government during the initial stage of site development to efficiently conduct wind and other surveys and secure the power grid in a timely manner. Improvements and updates on relevant Acts will be made by the government to accelerate the implementation of projects such as a new scheme for the temporary right to grid connection.

In July 2021, three government-led, centrally-coordinated research projects, including Gann-u and Minami-Shiribeshi in the Hokkaido prefecture, Sakata in the Yamagata prefecture and Hirono-cho in the Iwate prefecture (floating offshore wind) were initiated as the first batch of test projects under the government-led centralised system. Wind resource measurements, seabed surveys, environmental impact assessments and local community surveys for these three projects will be completed by the government before 2025 and made ready for future auction rounds

A clear centralised bidding system scheme will be established within a couple of years and with the recent Round 1 Auction result, which highlighted the lack of relevant wind development data, the process is likely to be accelerated.

Round 1 Auction lessons learnt and the way forward

In June 2021, a consortium of six companies led by Toda Corporation was selected to build a 16.8 MW floating wind project offshore Goto City, in the Nagasaki Prefecture. Soon after, in December 2021, consortia led by Mitsubishi Corporation successfully won the development right for all three fixed-bottom offshore wind projects in Noshiro, Yurihonjo North and South, and Choshi with exceptionally low tariff prices of: JYP 11.99/KWh (Euro 87.85/MWh), JYP 13.26/kWh (Euro 97.15/MWh) and JYP 16.49/kWh (Euro 120.82/MWh) respectively. With many developers still unclear on the precise price and non-price bidding points assessment, the Mitsubishi-led consortia dominated the Round 1 auction by bidding the cheapest electricity price in each project.

The result raised concerns on bidding procedures and led to the postponement of the Round 2 auction (Happo-Noshiro zone) bidding application deadline which was originally set for June 2022. Japan's government and the Public-Private Council are now working with the wind industry to review and adjust the existing auction bidding framework. The JWPA and wider wind industry have also submitted a proposal detailing various improvements necessary to improve the existing auction system and achieve a good balance of cost reduction, local content and meeting the target. The suggestions include the implementation of appropriate information disclosure, two-stage developer selection, more reasonable price and non-price point allocation and early introduction of a centralised auction system.

All eyes on Japan's floating offshore wind

With Japan's floating offshore wind potential at more than three times its fixed-bottom potential, this is where the bulk of the wind resources lie. Floating offshore wind is still in the early stages of development and cost remains high. It was only in 2017 that the Norwegian energy major, Equinor, opened Hywind Scotland, a 30 MW first full-scale floating offshore wind farm. However, there is a need for the industry to accelerate the development of floating offshore wind and move beyond demonstration projects, by drawing on both local and international experience and expertise.

South Korea

South Korea has made headlines in offshore wind in recent years. First, its Green New Deal announced in 2020 set out a target to achieve net zero emissions by 2050, with a $52 billion green economy investment package. This included $7.7 billion worth of investments in wind, solar and hydrogen technologies by 2025, and the establishment of a major target of 12 GW offshore wind by 2030. Its net zero target was passed in a bill in September 2021, and a Nationally Determined Contribution (NDC) submitted to the UNFCCC in December 2021 also aimed to reduce greenhouse gas emissions by 40% from 2018 levels to 2030.[1]

In early 2021, South Korea announced the world's largest offshore wind project of 8.2 GW off the coast of Shinan, which would provide power to 12 million residents in nearby Seoul and Incheon by 2030. The project is being developed by a consortium of 33 public and private entities, including the utility Korea Electric Power Corp (KEPCO) and local OEMs like Doosan Heavy Industries & Construction.[2] In May 2021, the government also announced a 6 GW floating offshore wind complex off the coast of Ulsan by 2030, bringing together local and foreign developers.

Most recently in 2022, the country's largest offshore wind turbine was installed at the Korea Wind Power Demonstration Center in South Jeolla. The 8 MW prototype, developed by Doosan as part of an industry/academia/research project, has a 100m blade and total height of 232.5m.[3]

Changing dynamics in national energy policy

While strides in ambition, public-private cooperation and technology development have been made, there are several considerations for the trajectory of offshore wind growth in South Korea.

Generally, the country's renewables deployment has lagged behind its G20 peers – wind and solar energy comprise less than 4% of the power mix as of 2020.[4] Most electricity is generated by coal, natural gas and nuclear energy. While coal phaseout is also slower than other G20 countries, coal-fired generation reduced from 41% of the power mix in 2015 to 36% in 2020; however, this has been compensated for by a rise in gas generation, which increased from 22% in 2015 to 27% in 2020. This is partly due to the muted growth of wind and solar deployment during this period.

The recent election of President Yoon Suk-yeol by a narrow margin presents another factor. His conservative administration is seen as business-friendly, but he has also publicly disagreed with the 2050 carbon neutrality goal and pledged to resume construction of the nuclear plants previously put on hold.[5] The revival of nuclear energy is likely to result in extensions of current operating permits; design, approval and commissioning of new plants faces local opposition and would not materialise until the end of the decade at least.

Political support for offshore wind

1. https://energytracker.asia/the-future-of-energy-transition-under-s-koreas-new-president-yoon-suk-yeol/; https://climateactiontracker.org/countries/south-korea/
2. https://www.offshorewind.biz/2021/02/05/south-korea-launches-eur-36-billion-offshore-wind-project/
3. https://www.offshorewind.biz/2022/01/27/koreas-largest-offshore-wind-turbine-stands-complete/#:~:text=The%208%20MW%20offshore%20wind%20turbine%2C%20which%20has%20been%20developed,largest%20wind%20turbine%20to%20date.
4. https://ember-climate.org/app/uploads/2022/02/Global-Electricity-Review-2021-South-Korea.pdf
5. http://www.koreaherald.com/view.php?ud=20220203000944

technology and foreign investment remains strong, though the changing dynamics around nuclear policy could constrain government budgets for the procurement and grid/port development needed to enable large-scale offshore wind growth. Industrial benefits and job creation linked to the offshore wind industry may also carry more political currency under the new administration, compared to the benefits for decarbonisation and displacement of fossil fuels.

Can the market catch up to national ambitions?

The 12 GW offshore wind target by 2030 is a large leap from the 188 MW of offshore wind currently installed (as of the end of 2021). Most projects under development are located off the provinces of South Jeolla, North Jeolla, Ulsan and Incheon, with some ambition in Jeju Islands and other regions. Altogether around 25 GW of potential capacity which could come online by 2035 has been identified, according to Aegir Analytics.

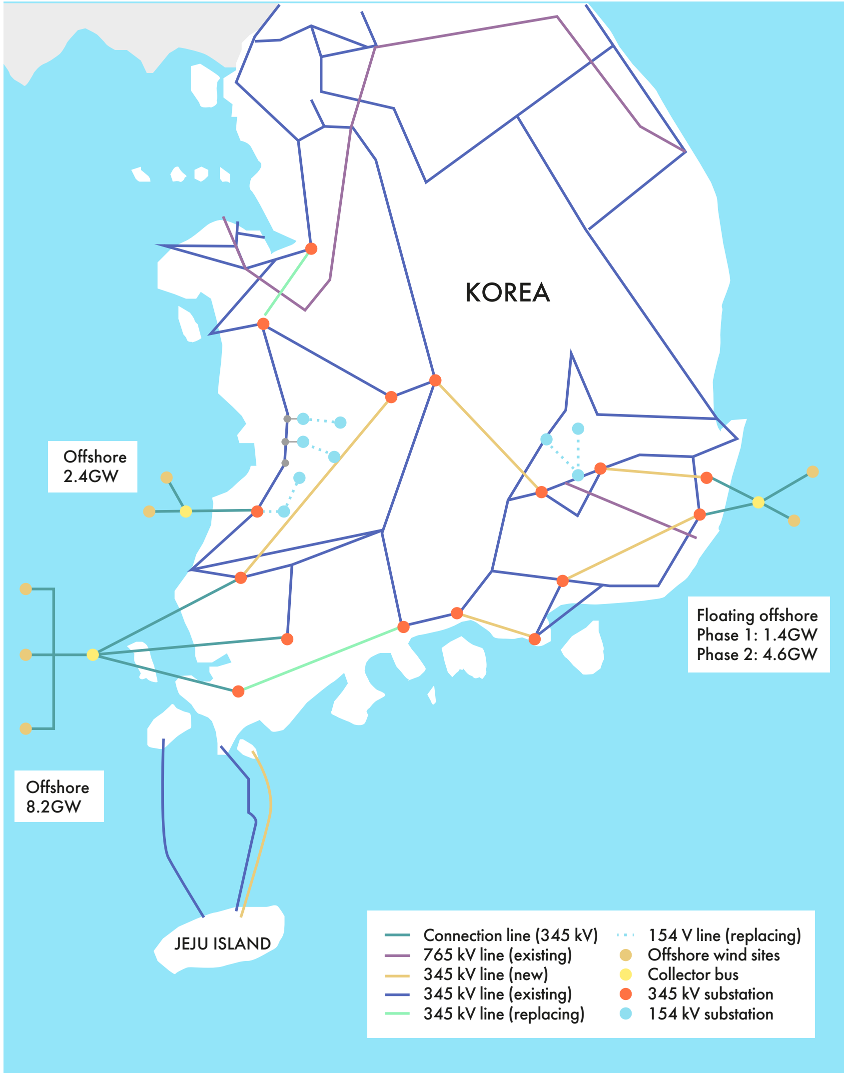
The ambitious national target and strong conditions for fixed-bottom sites (especially off South Jeolla) and floating wind (especially off Ulsan), close to large demand centres, has drawn heavy interest from local and foreign renewables companies. These include Ørsted, Corio Generation, Total Energies, Shell, Equinor, EDP, Aker Solutions, Copenhagen Infrastructure Partners and others, many of which have entered into MOUs or joint agreements with local partners. Similarly, offshore wind has also sparked the interest of domestic industrial conglomerates such as Samsung, Hyundai, Doosan and STX in renewable energy project development and equipment supply.

Meeting the 12 GW by 2030 target would require a speedy clip of buildout of around 1.3 GW on an annual basis through the remainder of the decade. But the offshore wind sector has been slow to take off, due to several factors discussed below.

Resolving current barriers on the ground

A degree of investment risk is inherent in the extensive permitting process for offshore wind. After an occupancy permit for public waters is granted for a LIDAR device (covering a 5-km radius of the device) and a roughly one-year data collection period, developers may secure an Electricity Business License (EBL). They then have a 4-year preparation period to obtain all the necessary permits and

Planned offshore wind and grid reinforcement in Korea, 2020



Source: MOTIE, Offshore wind power generation plan, 2020; IEA, Korea Electricity Security Review.

complete construction or request a permission extension. The permits are numerous and include an EIA, occupancy implementation plan, marine traffic safety examination, cultural heritage survey, onshore permits for onshore facilities, construction plan approval and more.

The Offshore Wind Collaboration Plan (OWCP) issued by government in 2020 aims to establish a "one-stop shop" permitting regime to shorten timelines. A Special Act to establish this regime has not yet been passed, partly due to opposition from commercial fishing interests.

The first generation of offshore wind projects in South Korea saw long lead times from 8-11 years from first permit to COD, largely due to opposition from local residents and members of the fishing industry. Stakeholder complaints have previously led to cancellations of projects, such as the 105 MW Handong-Pyeongdae project on Jeju Island. New models for enhanced stakeholder participation and profit-sharing are under consideration by local government, while demonstration projects for community socioeconomic benefit will be important to allay livelihood concerns.

The RPS scheme, which mandates large state-owned and private power companies to procure a portion of power from renewables, makes Renewable Energy Certificates (RECs) a common form of remuneration for generation. RECs are based on a calculation of power produced and straight-line distance to shore, which can multiply the REC value. The calculation does not consider water depth, which can be a significant factor for the economics of projects.

Although the REC weighting system was recently updated to reflect the higher development costs for offshore wind, the trading market still presents uncertainty, and a final REC weighting is not available until construction is completed. That said, recent trading prices have been buoyed by the increasing number of local companies which are committing to the RE100 campaign to procure 100% renewable energy for power consumption by 2050. For instance, spot prices for RECs jumped 45% from July 2021 to January 2022.[7] As well, the RPS standard has recently raised to 12.5% for 2022 and will increase to 25% by 2026.

Grid investment is a major challenge on the horizon for enabling large volumes of offshore wind in this decade. Reinforcement needs have been highlighted around North and South Jeolla and Ulsan, where large-scale offshore wind capacity is in development. The prospect of grid constraints, as well as the current lack of priority for grid connections for offshore wind, presents some development risk. This is especially the case as an EBL is not granted to projects until KEPCO has confirmed that the project can access sufficient grid capacity. Proactive grid planning and grid operation innovations, including an approach using "promotional zones" for renewable energy to customise transmission planning, could ease the grid challenge.[7]

In terms of supply chain, South Korea does have significant industrial experience in steel, ship building and logistics, which can translate to offshore engineering and supply chain competencies. But its domestic wind turbine supply chain is still at an early stage. While advancements in turbine technology have been made, it will be important to lower local content and trade barriers to allow developers to access best-in-class technology with cost efficiency, while still encouraging technology learning and transfer between foreign and local companies.

Looking ahead to 2030

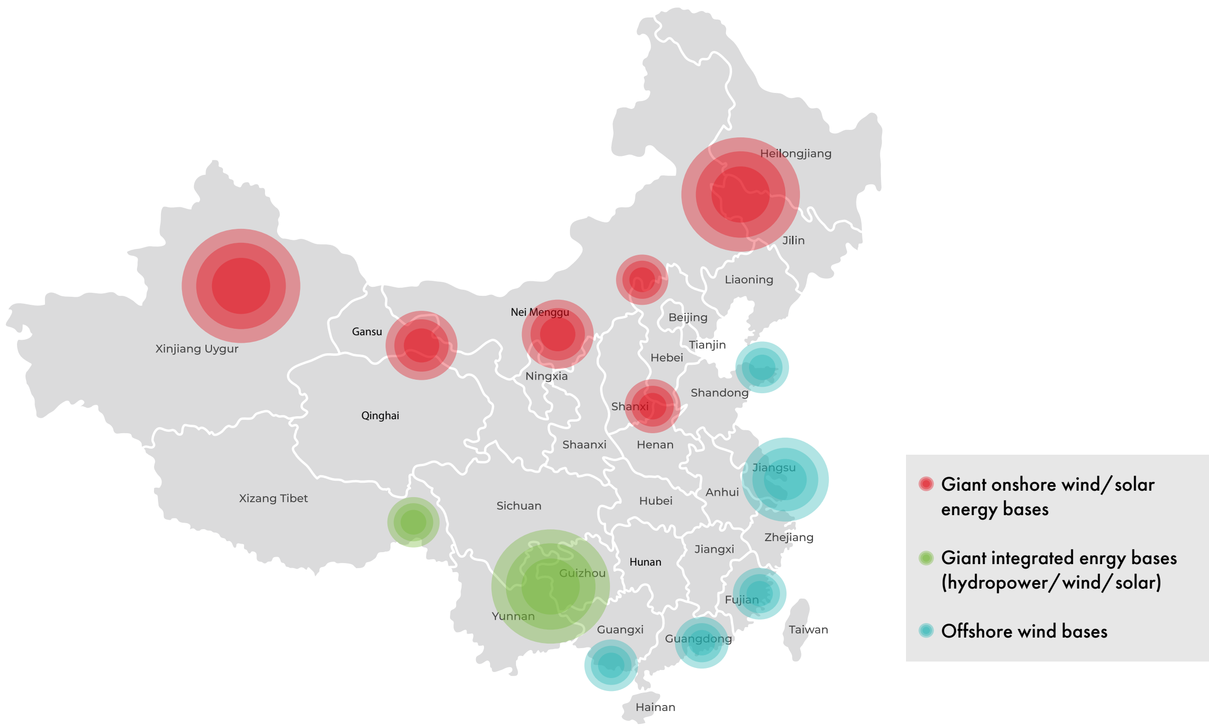
The 2030 ambitions and mega projects off Shinan and Ulsan have put South Korea on the map for global offshore wind development. By the end of the decade, the country is set to emerge as the top floating offshore wind market in East Asia. GWEC Market Intelligence forecasts a total of 6.5 GW of fixed-bottom offshore wind and 3.6 GW of floating wind will be commissioned in South Korea by 2030.

With less than eight years to go to meet a 12 GW target, it is critical that the new administration works with local governments, industry and other stakeholders to resolve the challenges around remuneration, permitting, local opposition and grid investment. This can ease the barriers for offshore wind development in Korea and pave the way for industry to deliver on national ambitions for industrial growth and decarbonisation.

6. https://www.mayerbrown.com/-/media/files/perspectives-events/publications/2022/03/offshore-wind-in-south-korea--the-path-ahead.pdf
7. https://iea.blob.core.windows.net/assets/a8539b34-fb1b-42cc-ba09-e08637a59bc1/KoreaElectricitySecurityReview.pdf

China

China's 14th Five-Year Renewable Development Plan



Source: NDRC, NEA, 2021

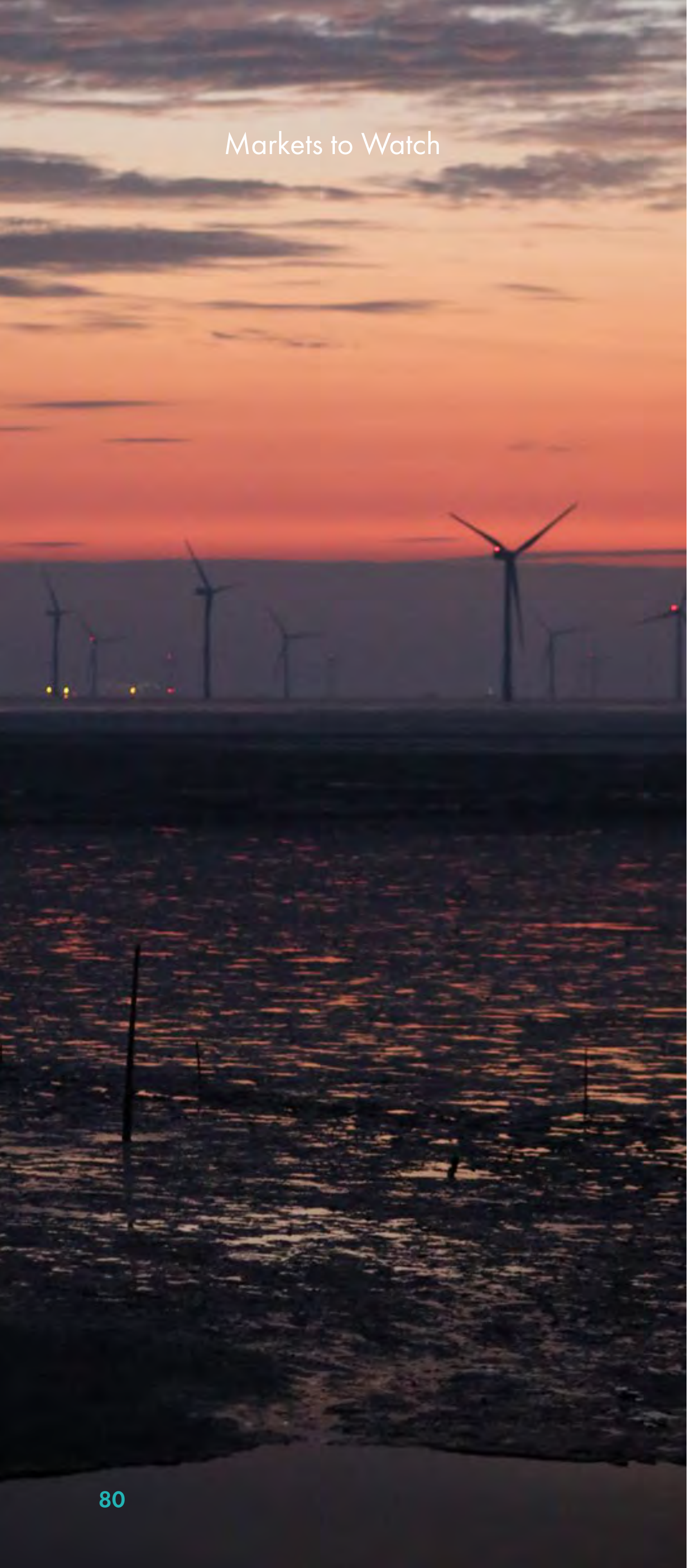
China installed its first offshore turbine, a 1.5 MW direct drive machine, in the Bohai Sea in 2007. China's first commercial offshore project, Donghai Bridge offshore wind farm, was commissioned in 2010. The market, however, was not ready to take off until the first offshore Feed-in-Tariff (FiT) scheme was released by the National Energy Administration (NEA) in 2014 and the Management Measures for Offshore Wind Power Development and Construction was jointly released by NEA and the State Oceanic Administration (SOA) in 2016, which resolved challenges between various government bodies and stakeholders.

Offshore wind enjoyed fast development during the 13th Five-Year Period (2016-2020). China passed the 1 GW milestone for offshore wind installations at the end of 2015 and became the world's largest offshore wind market in terms of new installations in 2018. By 2020, total offshore installations reached a milestone of 10 GW.

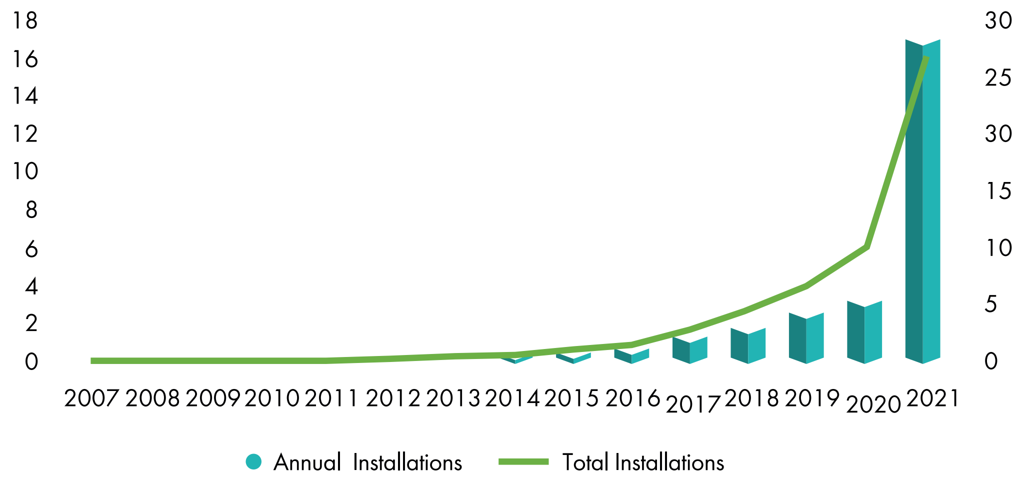
Explosive offshore growth driven by policy change

In 2021, 47.5 GW of wind capacity was grid-connected in China, of which 16.9 GW is offshore wind. This made China the leading offshore wind market globally and set a new record in global offshore wind installations in a single year. The Chinese offshore wind industry had prepared for this moment for two and a half years, with enormous investments dedicated to building the local supply chain, balance of plant, infrastructure and efficiency in offshore turbine installations.

The huge spike in installations was driven by a new policy released in May 2019 by the National Development and Reform Commission (NRDC), presenting a clear roadmap towards a phase-out in subsidies for both onshore and offshore wind. For offshore wind, projects already approved before 2019 would not receive the FiT if they are not fully grid-connected before the end of 2021. Starting from 1 January 2022, the subsidy for



Offshore wind development in China, 2007-2021 (GW)



Source: GWEC, CWEA, NEA, March 2022

offshore wind from the central government will be completely terminated.

At GWEC's Global Offshore Wind Summit – China 2019, large local developers and turbine OEMs were already discussing how to address the bottlenecks throughout the offshore wind supply chain, such as large blades, main bearings and offshore wind installation vessels, to meet the 2021 deadline.

A strong local supply chain to back up growth

China is the world's largest wind turbine manufacturing hub, accounting for 60-65% of global outputs of turbine nacelle and key components including gearboxes, generators and blades. There are eight established offshore wind turbine manufacturers in China as of 2020, with another two OEMs announced to enter the offshore sector in 2021. Assembly factories for offshore turbines have been built in coastal provinces throughout the past years.

Cities such as Yangjiang (Guangdong Province) or Yancheng (Jiangsu Province) have made themselves into bases for offshore wind farm manufacturing with tailor-made offshore wind ports available. With recently invested offshore wind turbine assembly facilities located in Zhejiang, Shandong, Liaoning and Hainan Provinces coming online in the next two years, the annual offshore wind turbine manufacturing capacity in China is likely to reach 20 GW from today's 16 GW.

The last two years also witnessed how quickly Chinese local developers and offshore EPC contractors mobilised installation vessels to meet the 2021 grid-connection deadline. According to GWEC Market Intelligence's Global Offshore Wind Turbine Installation Vessel Database 2020, China had 24 jack-up vessels/barges and 10+ heavy lift vessels for offshore wind turbine installation purpose. One year later, 40 jack-up vessels/barges, of which more than 10 were newly constructed and delivered, and 30 heavy lift vessels were identified in China. In addition, at least 10 jack-up installation vessels are under construction, of which 7 will be capable of installing 10MW+ offshore wind turbines.

Aside from these newly built turbine installation vessels, some drilling platforms and semi-submersible vessels were upgraded and converted for offshore wind construction purposes. A handful of foreign vessels from Europe, Middle East and Singapore have also been transported and leased to China to support the final offshore wind installation rush in 2021.

China in pole position for global offshore wind power growth

Looking ahead, during the current (14th) Five-Year Period (2021-2025), China will construct large-scale offshore bases (10 GW-level) in the eastern coastal areas. The five selected offshore bases are Shandong Peninsula, Yangtze River Delta, Southern Fujian, Eastern Guangdong and Beibu Gulf . Summing up the targets released by all coastal provinces in their 14th Five-Year Plans, China will add a total of 40-50 GW of offshore capacity during the 2021 to 2025 period.

China will add a total of 40-50 GW of offshore capacity during the 2021 to 2025 period.

In addition, during this period, the Chinese government plans to provide support on emerging technologies and demonstration projects, such as deep-water wind farms and flexible DC transmission, digitalised O&M for offshore wind, renewable hydrogen, energy islands and integrated energy solutions.

From 2022, the central government will cease subsidies for offshore wind, but a small portion of financial support from provincial authorities is still available in provinces like Guangdong, Shandong and Zhejiang for the next 3-4 years to support the local offshore wind industry to reach grid-parity by 2025.

Although annual offshore wind installations are expected to slow down in 2022 and 2023 after a record year, with further technology innovation and cost reductions, the market is likely to bounce back from 2024 with new installations potentially to reach 10 GW the year after. GWEC Market Intelligence predicts 98 GW of new offshore wind capacity will be built in China in 2022-2031, contributing to 31% of the global offshore wind additions in this period.

Exploring new markets

GWEC Market Intelligence is monitoring activities in 46 countries on a regular basis to document the opportunities and progress of taking wind global as well as supporting governments in developing appropriate policy frameworks.

The four selected countries – Ireland, Colombia, Australia and the Philippines – represent markets with high offshore wind potential but varying political support and targets to date. Still, in all four countries there is an increasing awareness that offshore wind can provide a scalable, cost-competitive and efficient solution for renewable energy.

Ireland

Development stage
Awarding the first batch of Maritime Area Consent (MAC) applications from a set of seven qualified offshore renewable energy projects would enable the first Offshore Renewable Energy Support Scheme (ORESS 1) auction to open in Q4 2022. Consultation for the auction opened in October 2021. In September 2021 a tender was launched to create a Strategic Environmental Assessment for the new Offshore Renewable Energy Development Plan (OREDP II). At least 15 floating offshore wind projects of more than 7 GW capacity are at different stages of early development. The Rosslare Europort will be upgraded as an Offshore Renewable Energy Hub with EUR 200 million in investment.

Political support
A 5 GW target by 2030 has been set under the 'Programme for Government,' which also plans to tap ~30 GW floating offshore wind in Atlantic waters in the long term. The Maritime Area Planning Bill 2021 simplified permitting processes for offshore wind development, followed by the Department of Transport setting out the strategy for commercial ports development. A Maritime Area Regulatory Authority (MARA)[9] will be established in 2023 for assessment and consents for offshore wind projects.

Challenge
Lack of availability of indigenous and economically sustainable local supply chain including suitable port infrastructure. Need to speed up the lease and licensing process, establish clear regulations around grid connection and streamline planning and consenting.

Next Milestone
Investment planning is required to grow the local supply chain and enhance grid capacity. Setting a policy framework which can address the anticipated impacts of current supply chain challenges on LCOE and supply chain development

Colombia

Development stage
An MoU has been signed to build the first farm of 350 MW capacity in Barranquilla by developer Copenhagen Infrastructure Partners and Public Lighting of Barranquilla to power green ammonia production. Another project, Vientos Alisios, is being developed by BlueFloat Energy for which pre-feasibility status is granted and grid connection secured. According to the Offshore Wind Roadmap for Colombia, there is potential for installing almost 50 GW of capacity with ~27 GW for fixed-bottom and 21 GW for floating foundations.

Political support
The President of Colombia has officially launched the offshore wind roadmap and published a proposal of regulations for the allocation of seabed for public consultation. The first allocation round will be called once the proposal is enacted. There is an ambitious plan to increase the share of non-conventional renewable energy to 17% by 2030. The Colombian government has also pledged to halve GHG emissions by 2030 as part of the long-term strategy to reach net zero by 2050.

Challenge
Medium-term challenges hinder offshore wind project development such as onshore grid connection timelines, logistical issues, need for port upgrades and operation planning.

Next milestone
There is a need to speed up the process of issuing relevant executive regulations as deliberated under the roadmap. The government should start with establishing short-term to long-term targets, which can strategically support the National Hydrogen Strategy and Roadmap.

Australia

Development stage
The Bass Strait off Gippsland in Victoria has been identified as the first priority area to be assessed for offshore wind suitability. Progress continues on the 2.2 GW Star of the South offshore wind farm as the work on Environmental Impact Statement and the Environment Effects Statement has started. There are 20+ projects at different stages of early development, including two floating projects[8] by Spain-based BlueFloat Energy and Australia's Energy Estate. Also, Oceanex Energy has shared a plan for four floating offshore wind projects.

Political support
The newly elected prime minister has a strong position on renewables for responding to the climate emergency and supports a new target to reduce carbon emissions by 43% by 2030 and achieve net zero by 2035, rather than 2050. The Victorian government set a 9 GW target by 2040, with first installation in 2028. The Offshore Electricity Infrastructure Bill introduced in 2021 is set to allow seabed leasing by mid-2022. There is a public consultation on draft regulations for the Offshore Electricity Infrastructure Framework.

Challenge
There has been a patchy track record on policy measures to back renewable energy generation, especially with respect to long-term certainty for measures such as a Feed-in-Tariff scheme and grid infrastructure availability.

Next milestone
With vast offshore wind potential of >2 TW[10] and ambitious targets, formation of the policy and regulatory framework is now required. A combined national offshore wind target could firm up political commitment.

The Philippines

Development stage
An Offshore Wind Roadmap by the Department of Energy (DOE) and World Bank Group shows potential to install 21 GW by 2040. The DOE has issued a clearance to undertake a system impact study with the National Grid Corporation for more than 15 projects and awarded exclusive rights to develop the first offshore wind projects to Triconti Windkraft Group. The DOE also has an agreement with Iberdrola to plan five projects of 3.5 GW total capacity. An exclusivity right has been secured for the Bulalacao site development for 1.2 GW by Blue Circle and CleanTech Global Renewables, Inc. PetroGreen Energy Corporation, a subsidiary of oil and gas company PetroEnergy, is planning three GW-scale farms.

Political support
The country has a target of a 35% share of renewable energy in the power generation mix by 2030 and a 50% share by 2040, translating to 92 GW of renewable energy capacity, as per the Philippine Energy Plan (PEP) 2020-2040.

Challenge
A drawn-out permitting and leasing process, which is now being addressed by a virtual one-stop shop scheme. Transmission bottlenecks also require planning and investment.

Next milestone
There is huge untapped potential of 170 GW. Setting strong policy commitments with targets, improved permitting and leasing process and transmission system upgrades can make the country an offshore wind frontrunner in Southeast Asia.

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8 Hunter Coast floating wind farm (1.4 GW) and Wollongong Offshore Wind Project (1.6 GW) for aluminium smelter and produce green hydrogen
9 Currently, Maritime Area Consent (MAC) to grant the consents for the first phase of offshore wind projects.
10 https://www.afr.com/companies/energy/australia-s-offshore-wind-sector-primed-for-lift-off-20220114-p59o9v#:~:text=Australia's%20offshore%20wind%20resources%20could,the%20country's%20entire%20electricity%20generation.

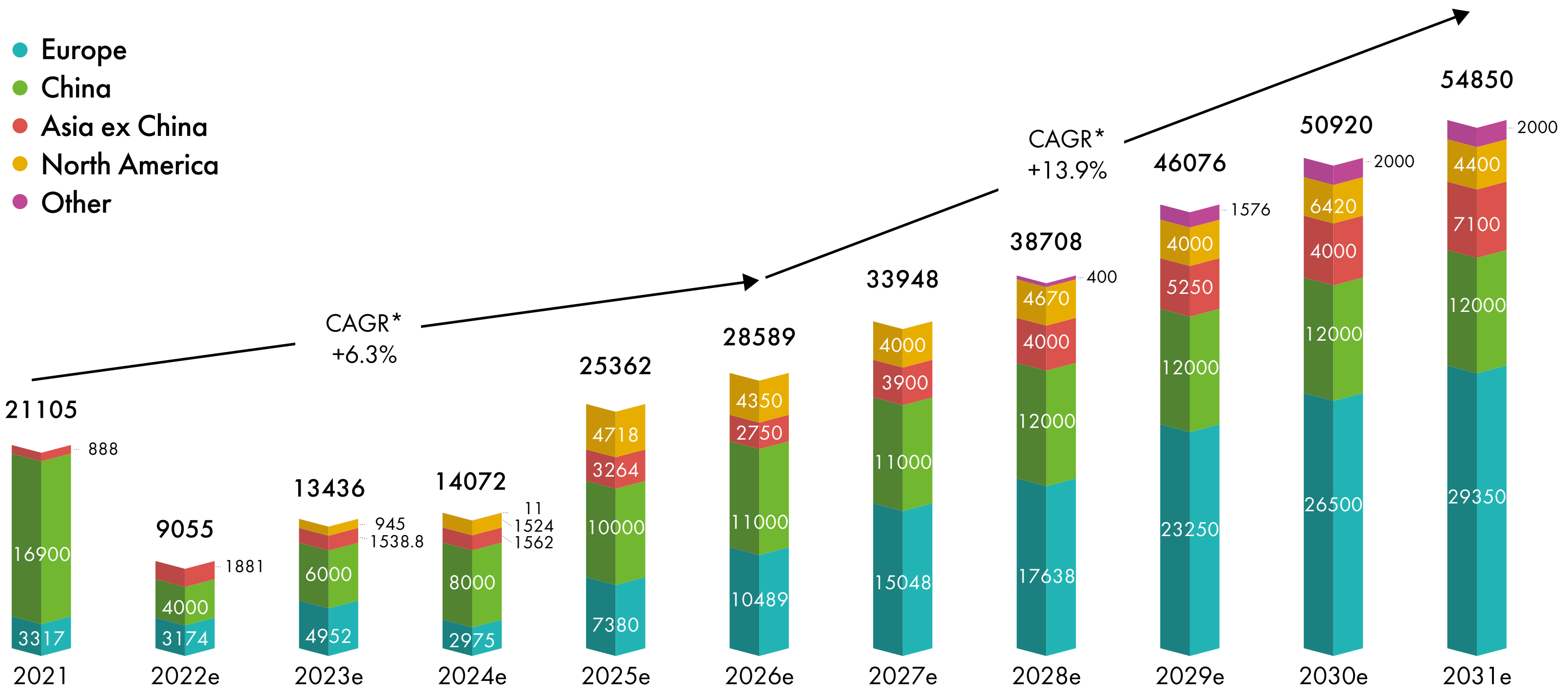
MARKET OUTLOOK 2022-2031

Global Offshore Market Outlook to 2031

2021 saw commitments to net zero gather global momentum at COP26. Coupled with renewed policy urgency for achieving energy independence from Russian oil and gas - and fossil fuel volatility in general - triggered by Russia's invasion of Ukraine, the global offshore wind market outlook in the medium and long-term looks extremely promising.

With an expected compound average annual growth rate of 6.3% until 2026 and 13.9% up to the beginning of next decade, new installations are expected to sail past the milestones of 30 GW in 2027 and 50 GW by the end of this decade.

New offshore installations, global (MW)



*Compound Annual Growth Rate.
Source: GWEC Market Intelligence, June 2022

This outlook reflects current declared national and regional targets. It is highly likely that these targets will increase further. On the other hand, there is currently an implementation gap between declared targets and the rate of annual installations.

GWEC Market Intelligence expects that over 315 GW of new offshore wind capacity will be added over the next decade (2022-2031), bringing the total offshore wind capacity to 370 GW by the end of 2031. 29% of this new volume will be installed in the first half of the decade (2022-2026) with the remaining to be connected in the latter half (2027-2031). The volume of annual offshore wind installations is expected to more than double from 21.1 GW in 2021 to 54.9 GW in 2031, bringing offshore's share of global new installations from 23% in 2021 to 32% by 2031.

Although Asia will replace Europe as the world's largest regional offshore wind market by cumulative installations by the end of 2022, Europe is expected to recapture this title from 2031. To ensure energy security, while achieving climate change targets, Europe is likely to continue increasing annual offshore wind installations, surpassing the milestones of 10 GW in 2026 and 25 GW in 2030. North America will remain the third largest offshore wind market by 2031, followed by the Pacific region and Latin America.

In the near term (2021-2024), the majority of growth outside Europe will come from Asia, primarily China and Taiwan. The contribution from North America (mainly the US) will grow in importance from 2025 onwards while a sizeable volume is unlikely to emerge from Latin America (Brazil) and Pacific region (Australia) until the end of this decade.

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 offshore wind targets.

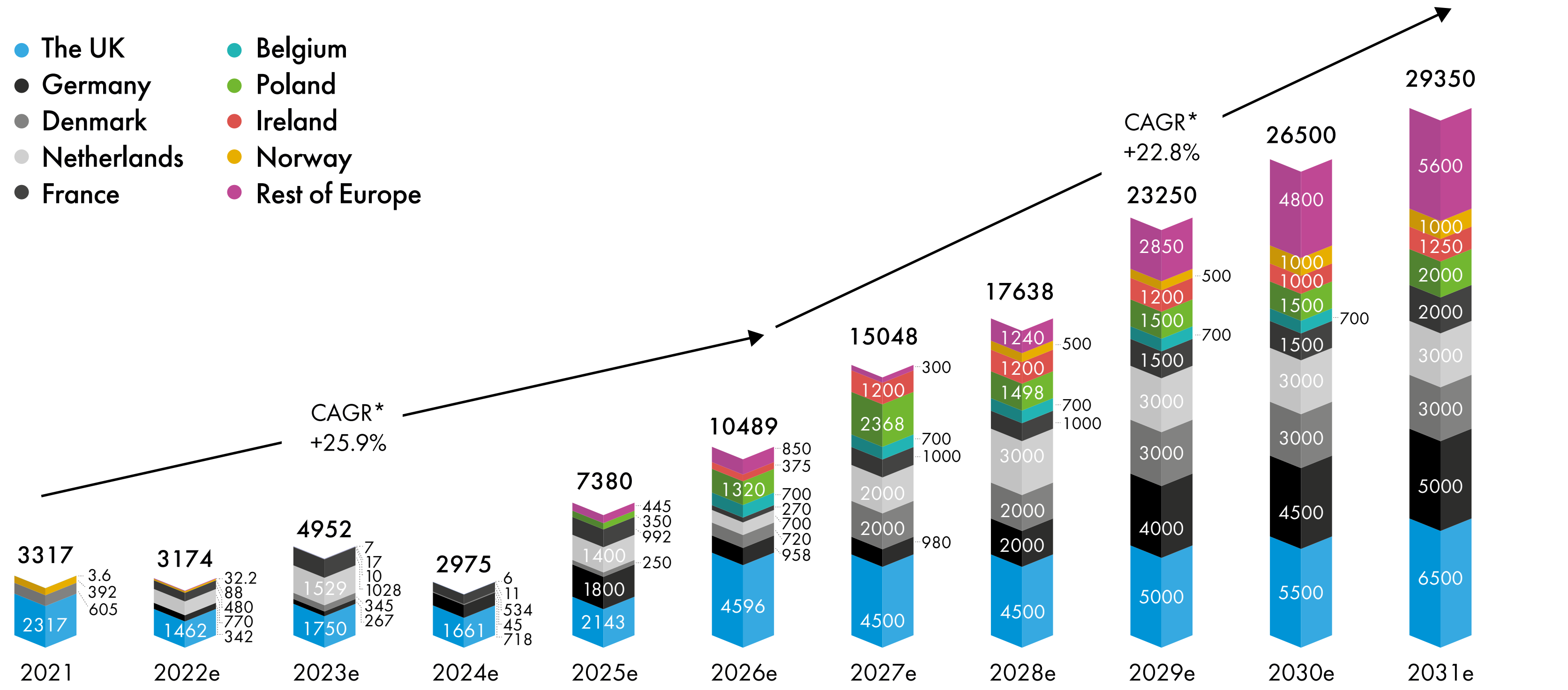
Europe

The world's first offshore wind project was installed in Denmark in 1991, making Europe the birthplace of the offshore wind industry. Through three decades of development, fixed-bottom offshore wind has become one of the most cost-competitive energy sources in Europe with a mature offshore wind supply chain established in countries neighbouring the North Sea and the Baltic Sea. In 2009, Norway commissioned the world's first floating offshore wind turbine. As of today, the continent remains the technology hub for floating wind turbines and foundations.

Europe remains the world's largest regional market in terms of total offshore wind installations as of the end of 2021, although the region already lost its leading position to Asia in new installations in 2020.

Looking at potential growth, GWEC Market Intelligence has already predicted that Europe will maintain its double digital growth rate in this decade, as: 1) fixed-bottom offshore wind has become the most competitive electricity generation technology after onshore wind and solar PV – but with considerable

New offshore installations, Europe (MW)



*Compound Annual Growth Rate.
Source: GWEC Market Intelligence, June 2022

advantages in terms of being able to be deployed at scale, 2) progress continues in the commercialisation of floating wind that will unlock potential in deep water, 3.) The European Commission presented its offshore renewable energy strategy as part of EU Green Deal in November 2020, setting a target of 300 GW of offshore wind by 2050 for the EU, which makes offshore wind a strategic energy source for achieving its 2050 net zero target, 4) Europe's Power-to-X ambitions offer further market growth opportunities for offshore wind.

Following Russia's invasion of Ukraine, the European Commission released the REPowerEU plan to make Europe independent from Russian fossil fuels well before 2030, which GWEC believes will accelerate the offshore wind and renewable hydrogen deployment across the entire convenient. The Esbjerg Declaration signed by Germany, Denmark, Belgium and the Netherlands in May 2022 to jointly develop the North Sea as a Green Power Plant of Europe, provided a further milestone for offshore wind acceleration.

However, according to GWEC Market Intelligence's latest market outlook, market growth in Europe in the near-term (2022-2024) is

The latest offshore wind targets in Europe

Unit: GW	2027	2030	2035	2040	2045	2050
EU		≥60				≥300
UK		50				
Germany		30	40		≥70	
Netherlands		22.2				
Denmark		12.9				
Belgium		5.7				
France			18			40
Poland	10.9*					
Norway				30		
Ireland		5				30
Spain		3				
Esbjerg Declaration**		≥65				≥150

* Either in operation or under development by 2027. ** Countries set joint target through Esbjerg Declaration include Germany, Denmark, Belgium and the Netherlands
Source: GWEC Market Intelligence, June 202

expected to be relatively slow, with average annual installations staying around 3.7 GW. This is mainly due to the lower level of activities in established markets such as Germany, Denmark and Belgium. However, the European offshore market is likely to accelerate from 2025 onwards when projects from the German Round 1 Auction will come online and utility scale projects are likely to become material in new markets such as France and Poland.

With more projects being released from the announced auction plans in both mature and emerging markets in Europe, new installations in the region are likely to double in 2027 and potentially quadruple in 2031 compared with 2025. Looking at the total capacity to be added in the next ten years, 79% will be built in the second half of the decade (2027-2031).

The UK

The UK has been the offshore wind market leader in Europe since 2009. Although it lost its pole position to China by end of 2021, progress made in the past 12 months shows that offshore wind growth is likely to regain strong traction. In July 2021, Crown Estate selected three floating wind demonstration projects through a leasing opportunity for early commercial-scale floating wind projects in the Celtic Sea. The eligibility window for the Round 4 CfD auction, aiming to support up to 12 GW of renewable energy projects, opened on 13 December 2021 with results expected to be announced this summer. In February 2022, the UK government announced it would hold yearly CfD auctions from 2023 onwards to scale up the country's supply of renewable energy. In the same quarter, Crown Estate Scotland announced the outcome of the Scotwind seabed leasing round launched last summer: 17 projects, totalling 25 GW including 15 GW of floating wind, were awarded leases. In addition, the Crown Estate has completed the second phase of its ongoing engagement with the market and stakeholders on plans for up to 4 GW of floating wind leasing in the Celtic Sea. To boost the UK's energy security, Prime Minister Boris Johnson presented a plan in April 2022 to increase the UK's 2030 offshore wind target from 40 GW to 50 GW, 5 GW of which is targeted for floating wind. This is the second time the UK increased the offshore wind target in the last two years.

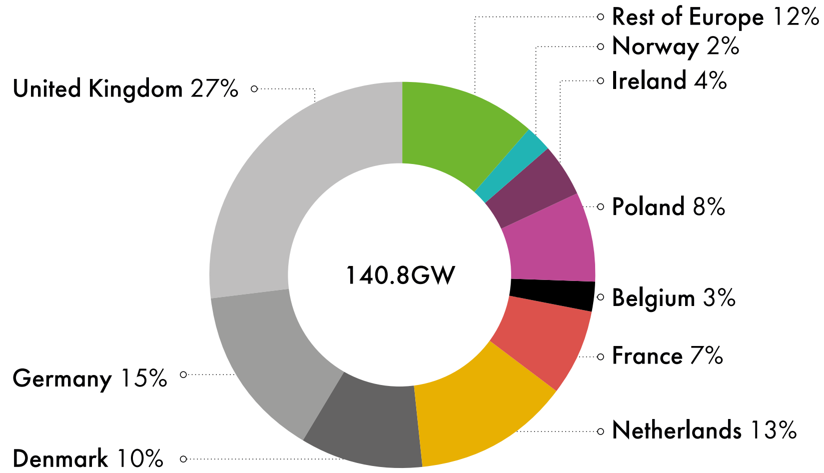
Germany

Germany used to be the world's second largest offshore wind market in total installations, but was overtaken by China in 2020 after unfavourable market conditions and a lack of mid-term visibility slowed development. The country only awarded three small "zero-subsidy" offshore wind projects, totalling 958 MW after the Round 2 offshore wind auctions were launched in 2018. However, more favourable offshore wind legislation has been adopted in the past two years. The 2020 amendment of the Offshore Wind Act (WindSeeG) increased the country's offshore wind target from 15 GW to 20 GW by 2030 and set a target of 40 GW of installed offshore capacity by 2040. The German government then changed its offshore wind legislation in April 2022 through the "Easter Package", and set a target that requires 30 GW of operational offshore wind by 2030, 40 GW by 2035, and at least 70 GW by 2045. Additionally, to replace fossil fuels from Russia, Germany signed a cooperation agreement on offshore wind development and green hydrogen with three other North Sea countries (Denmark, Belgium and the Netherlands) through the Esbjerg Declaration. The key for its offshore wind success is clear but it relies on the Germany's Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrography-BSH) speeding up the permitting and quickly opening up additional offshore wind tenders, and ensuring attractive market conditions.

Denmark

In June 2020 the Danish government approved two "energy islands," one in the North Sea and one in the Baltic Sea. The full potential for the North Sea energy island is 10 GW. In December 2021, the winner of the 1 GW Thor project was decided by a lottery draw, as more than one bidder offered to build the Thor offshore wind farm for the minimum price of DKK 0.01/kWh. In the same month the government agreed to add up to 3 GW of new offshore wind capacity to be developed before 2030 as part of the Finance Act 2022. To ensure energy independence from Russian oil and gas, Denmark hosted three other North Sea countries in May at the Esbjerg Offshore Wind Summit, from where a joint 150 GW by 2050 offshore wind target was signed through the so-called Esbjerg declaration. In June 2022, the government released the proposal to raise its 2030 offshore wind target by 45% to 12.9 GW.

Total added between 2022 and 2031



Source: GWEC Market Intelligence, June 2022

Netherlands

The Netherlands is the fourth largest offshore wind market in the world. Last November, the Dutch government increased its 2030 offshore wind target from 11.5 GW to 22.2 GW, aiming to meet the EU's current goal of reducing CO2 emissions by 55% by 2030 compared to the 1990 levels. In March 2022, the government designated three new areas and confirmed two previously designated areas in the North Sea, enabling further 10.7 GW of offshore wind to be built by the end of this decade. Following the recent geopolitical challenge, the country signed the Esbjerg Declaration with three other North Sea countries.

Belgium

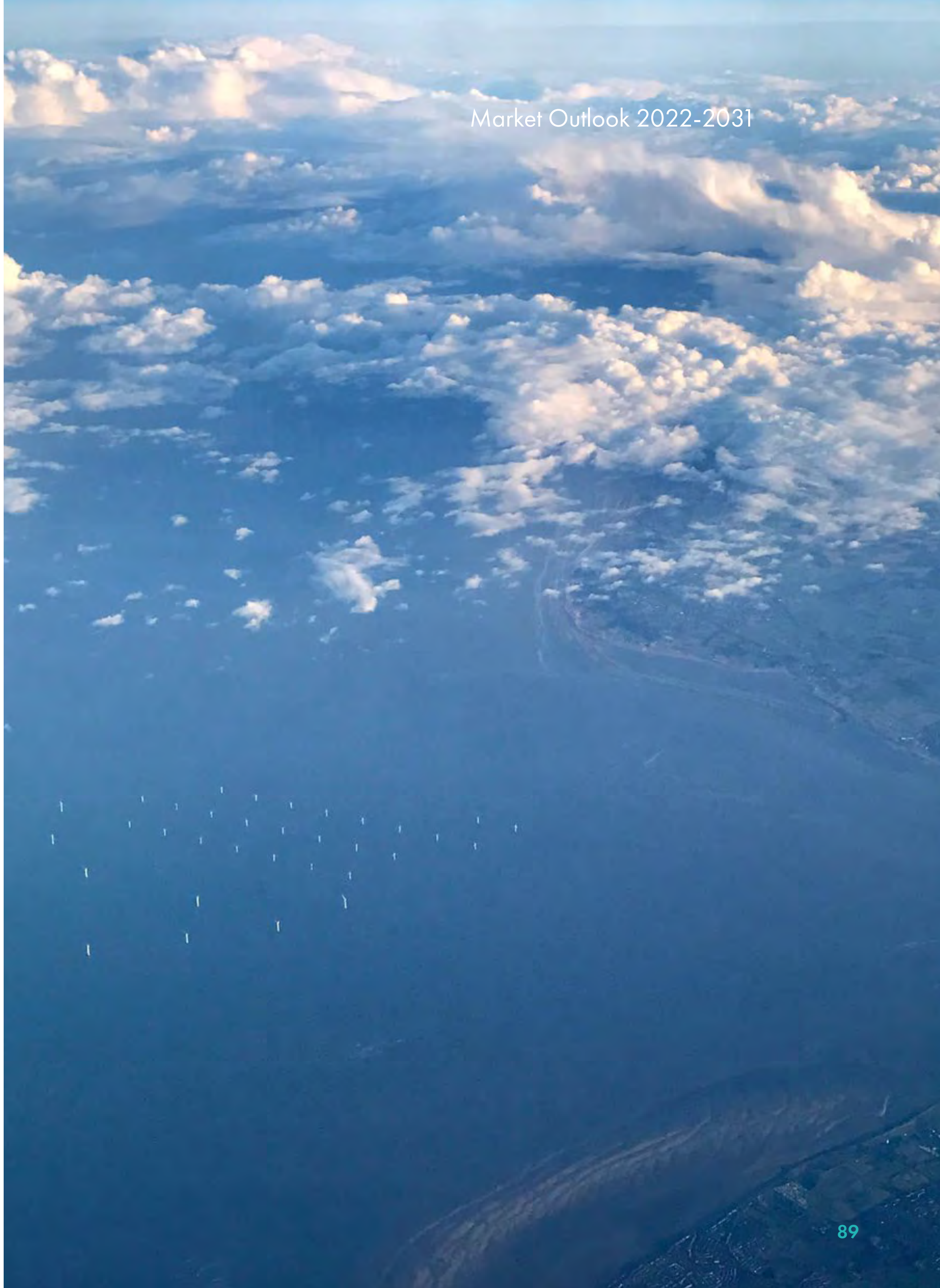
Belgium is the world's sixth largest offshore wind market in total offshore wind capacity. According to the Marine Spatial Plan 2020-2026, released in 2020, the country plans to grow its operational offshore wind capacity from the current 2.2 GW to 4.4 GW by 2030 through the development of the Princess Elisabeth Zone, which is Belgium's second offshore wind area. The government is now working on an amendment to legislative framework for having up to 3.5 GW of additional offshore wind capacity at this zone. Once grid connected by 2030, Belgium's total offshore wind capacity will reach 5.76 GW. Following the REPowerEU plan, the Minister of Energy called for Belgium to raise its 2030 offshore wind target to 8 GW. The country also jointly signed the Esbjerg Declaration in May.

France

There is only 2 MW of offshore wind power installed in France as of 2021, but around 5.5 GW of offshore wind capacity, including 0.9 GW floating wind, is either under construction or subject to an ongoing tendering procedure. According to the Multiannual Energy Programme (Programmation pluriannuelle de l'énergie - PPE) released by French government in 2020, up to 8.75 GW of offshore wind capacity will be tendered between 2020 and 2028. The latest plan shows that the government aims to allocate around 2 GW of offshore wind capacity per year from 2025 to reach 20 GW of auctioned offshore capacity by 2030 and 18 GW of operational offshore wind capacity by 2035. To reach its 2050 net zero target, President Emmanuel Macron announced in February 2022 that France will have around 40 GW of offshore wind capacity in operation by 2050.

Poland

Poland's Council of Ministers adopted a draft bill supporting the development of offshore wind energy in the Baltic Sea in late 2020. The draft bill, which was signed into law by the president in January 2021, allows for 10.9 GW of offshore wind capacity to be either operational or under development by 2027. As the end of June 2021, The Polish Energy Regulatory Office (ERO) has awarded a CfD to seven offshore wind projects, totalling 5.9 GW, the same volume as was planned in the Offshore Act. The second phase of development will include two auctions, the first in 2025



and the second in 2027, each with 2.5 GW of capacity. To support further growth, the Ministry of Infrastructure launched a procedure for granting concessions for eleven offshore wind areas in Q4 of 2021.

Norway

In June 2020, Norway opened up for full-scale floating and bottom fixed offshore wind development, totalling up to 4.5 GW, and allowed developers to apply for project licenses from January 2021. According to the Ministry of Petroleum and Energy, the 3 GW of fixed-bottom capacity at the Sørlige Nordsjø II zone will be auctioned in two 1.5 GW phases. The auction for the first 1.5 GW of capacity is expected to take place during 2022. Due to higher risk, the government has proposed the sites in the Utsira Nord lease area for floating wind to be selected based on qualitative criteria, rather than auction. In May 2022, the newly elected government launched a large-scale green investment plan aimed at allocating sea areas for developing 30 GW of offshore wind capacity by 2040. The next round of awarding licenses for offshore wind in new areas is expected to launch in 2025.

Ireland

According to Ireland's Climate Action Plan, the country aims to have 5 GW offshore wind by 2030 with a long-term plan to tap into its floating wind potential of at least 30 GW in deeper waters. Last December, Ireland awarded contracts for the creation of a Strategic Environmental Assessment (SEA) and an Appropriate Assessment (AA) for Ireland's new Offshore Renewable Energy Development Plan (OREDP II). The OREDP II, accommodated by the new Marine Planning Bill that was passed last July, establishes a framework for the sustainable development of Ireland's offshore renewable energy projects. Seven offshore wind projects, totalling more than 3 GW, have been invited to apply for Maritime Area Consents (MACs) with the first of which expected to be issued in the second half in 2022.

Spain

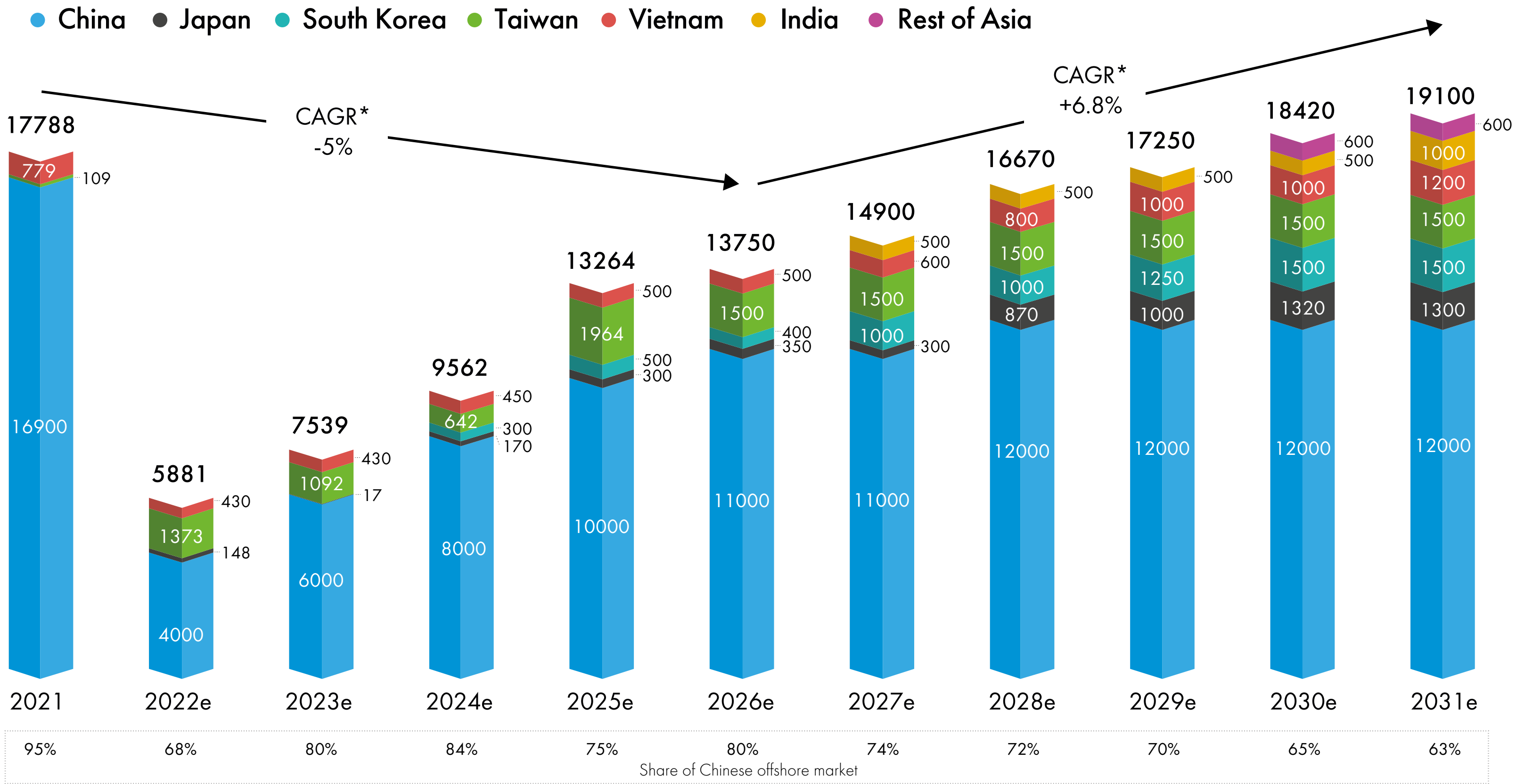
Spain only has 10 MW of offshore wind capacity installed as of today, but last December Spain's Council of Ministers approved the Roadmap for the Development of Offshore Wind and Marine Energy that will see the country to reach up to 3 GW of offshore wind by 2030. With more than 5 GW of floating wind projects at different stages of development at present, the country is expected to become one of the top five floating wind markets by 2030.

Asia

Although the first offshore wind project built in Asia has been spinning for nearly two decades, this region was quiet on offshore wind development until 2018 when China overtook the UK as the world's top market in new installations. 2020 saw Asia replacing Europe as the leading regional offshore wind market in new installations for the first time. Despite new installations in this region last year being five times greater than that in Europe, Asia is still only the second largest offshore wind market in cumulative installations with its global market share 0.9% lower than Europe.

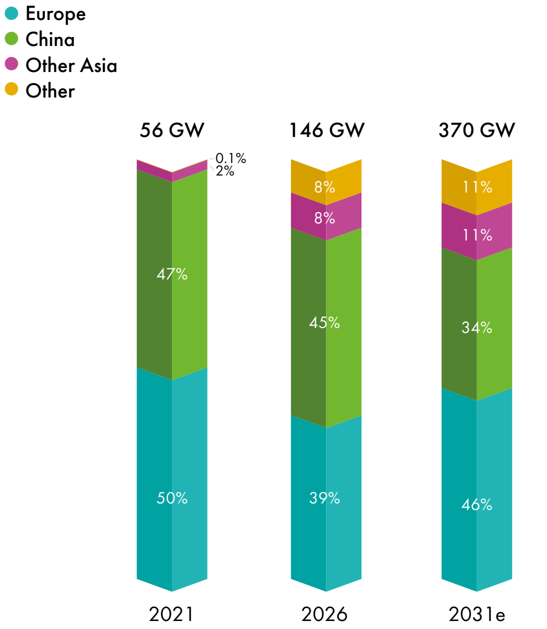
Our latest market outlook shows that China will continue to play the predominate role in this region in the

New offshore installations, Asia (MW)



*Compound Annual Growth Rate.
Source: GWEC Market Intelligence, June 2022

Total installations offshore



Source: GWEC Market Intelligence, June 2022

next five years (2022-2026), although its market share in 2022 is expected to drop to 68% after an outstanding year in 2021. Taiwan is predicted to be the largest offshore market in Asia after China in new installations in the same period.

GWEC Market Intelligence believes that the market will become more diversified in the second half of this forecast period as more utility-scale offshore wind projects are expected to come online. These will be based in Japan, South Korea and Vietnam from 2027 onwards and the first batches of offshore wind projects are also likely to take place in new markets such as India and the Philippines. As a result, China's market share in this region will decline from 80% in 2026 to 63% in 2031.

In total, 63% of the predicted offshore wind for this region is to be built in 2027-2031. Although stable growth is expected in this period, annual installations in the region are unlikely to exceed the 2021 record until 2030. The top five markets in total new additions in this region in the next ten years will be China, Taiwan, South Korea, Vietnam and Japan.

China is, to date, the most mature offshore wind market outside Europe. Driven by the installation rush that started in the second half of 2019, the domestic offshore wind supply chain and infrastructure have built up quickly along China's east and southeast coast. While progress and supply chain capacity building activities have continued in Taiwan in the past two 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 workforces. Based on the investment plans and partnerships recently announced by European players in South Korea and Japan, similar success is likely to be duplicated in these two markets. To unlock the potential of offshore wind and further lower cost in the region, regional cooperation in supply chain development is a key objective.

GWEC Market Intelligence predicts that Asia will replace Europe as the largest regional offshore wind market in total installations from 2022 and then retain that position through to the end of 2030. However, with strong growth expected to take place in Europe from 2029 onwards, Europe is likely to recapture this title by the end of 2031, though the gap between the two regions will be marginal.

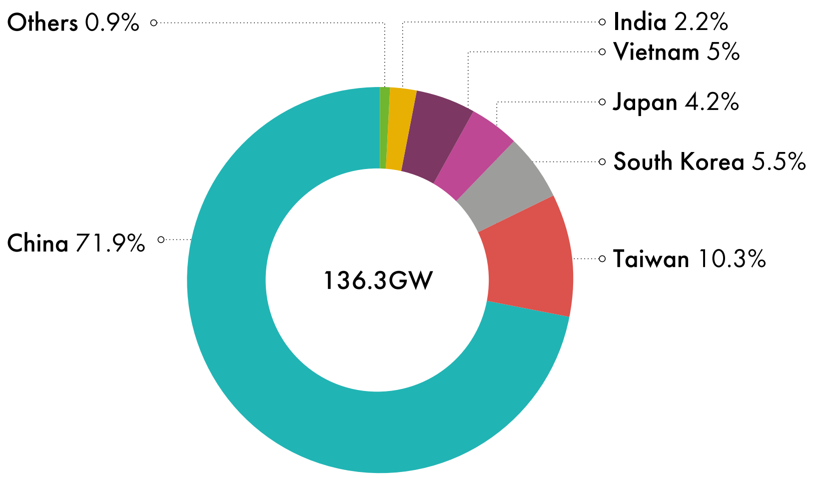
China

China grid connected nearly 17 GW of new offshore wind in 2021, overtaking the UK as the world's Number One offshore market in cumulative installation. However, following last year's astonishing level of growth, a sharp drop in new offshore installations in China in 2022 is expected, primarily due to the end of subsidies from central government from 2022. Before Chinese offshore wind reaches grid parity in 2024/2025, the pace of offshore wind growth in China will to some extent be driven by financial support provided by provincial governments, like Guangdong, Zhejiang and Shandong. Considering the total of offshore wind targets announced by coastal provinces, – either by 2025 or 2030 – has already passed 150 GW, GWEC Market Intelligence predicts that average annual offshore wind installations in China between 2025 and 2031 will surpass 10 GW, which will help the country to further consolidate its position as global leader.

Taiwan

Although only one small-scale offshore wind demonstration project was commissioned in 2021 due to COVID-19 related disruptions, GWEC Market Intelligence believes that Taiwan is well positioned to become the Number Two offshore wind market in this region. According to the Bureau of Energy's latest renewable energy development status update, 2 GW of offshore wind capacity is likely to be added in Taiwan by the end of this year, putting it on track to reach the 5.6 GW offshore wind by 2025

Total added between 2022 and 2031



Source: GWEC Market Intelligence, June 2022

target. Last August, the government officially announced its offshore wind allocation plan between 2026 and 2035. With projects expected to be allocated from the upcoming Round 3 offshore wind auction coming online, Taiwan is likely to exceed the 2030 offshore wind targets set by South Korea and Japan.

South Korea

South Korea is the fourth largest offshore wind market in the region with a target of bringing 12 GW of offshore wind online by 2030. Following its Green New Deal announced in 2020 and net zero commitment passed in 2021, offshore wind and especially floating wind has drawn heavy interest from local and foreign renewables companies. However, GWEC has downgraded our 2030 offshore wind outlook for Korea by nearly one third (from 8.7 GW to 6 GW) compared with our outlook released last September, primarily because the recent elected President Yoon Suk-yeol is seeking to change the pre-existing dynamics and goals in national energy policy. At the same time, previously identified barriers such as permitting and grid transmission still need to be addressed before the market is ready to take off.

Japan

As in the case with South Korea, Japan has made headlines in offshore wind in the past two years. Firstly, 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 offshore wind by 2030 and 30-45 GW by 2040. Secondly, the country's first ever auctions for floating and fixed bottom offshore wind were launched in 2020 following the designation of the first offshore wind development zones by the government.

Despite the progress made in past 12 months and the growing traction that offshore wind continues to gain, there have been setbacks, such as the delay of its third offshore wind auction as well as concerns generated by the outcomes of its first fixed-bottom auction. GWEC is therefore downgrading its 2030 offshore wind outlook for Japan by around 25% relative to our previous year's outlook.

Vietnam

Despite COVID-19 disruptions bringing challenges to the local industry, Vietnam had a record year in commissioning nearly GW-level intertidal projects in 2021, making it the second largest market in this region. Following the installation rush driven by the cut-off of Feed-in-Tariffs, GWEC Market Intelligence predicts that new installations in Vietnam will fall off in 2022 and most likely stay at a low level until a clear offshore wind regulatory framework (the procurement mechanism in particular) is in place. However, taking into account the net zero commitment made at COP26 as well as the 7-8 GW by 2030 offshore wind target included in the most recent draft Power Development Plan VIII (PDP8), Vietnam is poised to usher in an era of accelerated renewable energy growth and become the offshore wind market leader in Southeast Asia by end of this decade.

North America

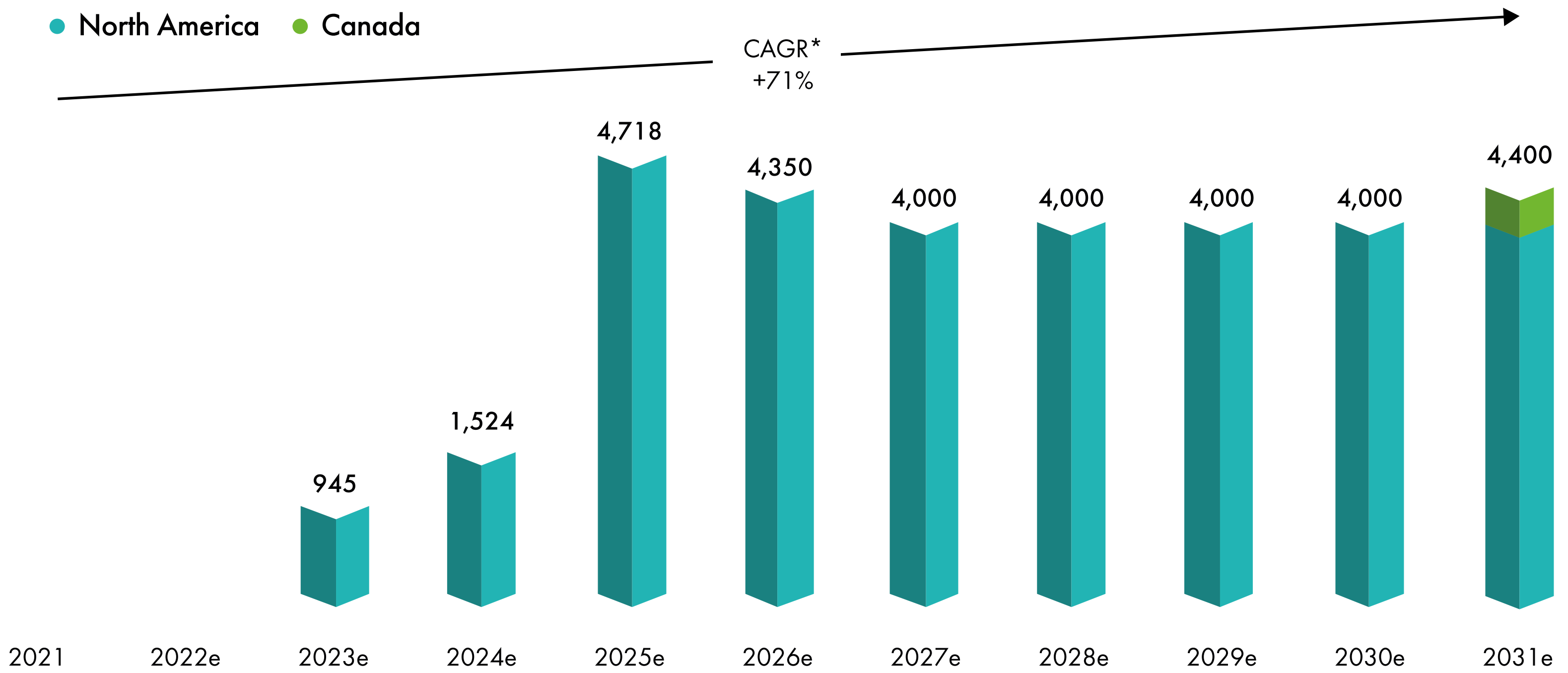
North America has only two small-scale offshore projects in operation as of the end of 2021, consisting of the 30 MW Block Island project in Rhode Island and the 12 MW Dominion Virginia demonstration project, making it the only region with operational offshore wind projects outside of Europe and Asia as of today.

Based on the latest offshore wind project development timeline, the next utility-scale offshore wind project is unlikely to come online in North America until 2023. In total, 31.9 GW of offshore wind is predicted to be built in this region in the next ten years (2022-2031), of which 99% is expected to come from the United States and only 400 MW is projected from Canada.

United States

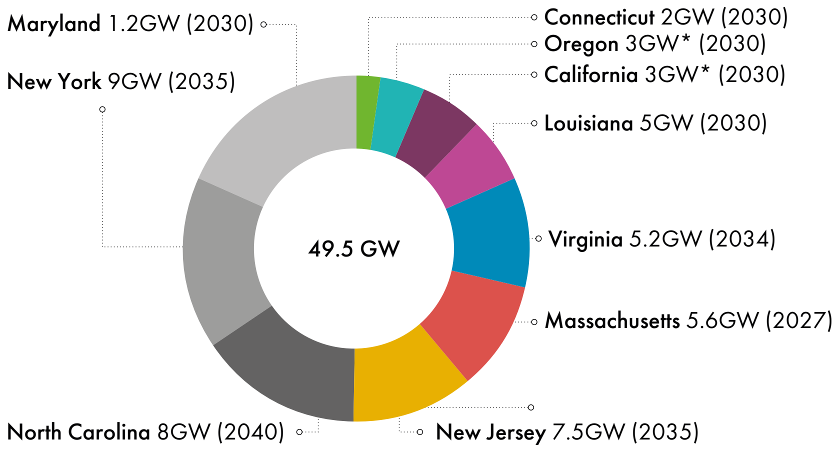
Only 42 MW of offshore wind capacity is in operation in the US as of today, but development of offshore wind market continued to gain strong momentum in the past 12 months. After the 800 MW Vineyard Wind 1 project received the final major federal approval from BOEM in May 2021, construction work started in Massachusetts in November. In the same month, the 132 MW South Fork wind project also received federal approval from BOEM

New offshore installations, North America (MW)



*Compound Annual Growth Rate.
Source: GWEC Market Intelligence, June 2022

US State-level offshore wind development targets



*Announced plan, not yet signed by law

making it the second US offshore wind project ready to enter the construction phase.

To support the Biden Administration's ambitious 30 GW by 2030 offshore wind target, BOEM has issued 25 commercial and 10 competitive offshore wind energy leases in the Atlantic Ocean, ranging from Massachusetts to North Carolina with a combined capacity of 6.9 GW most recently allocated from the New York Bight and Carolina Long Bay auctions. Following the two leasing rounds completed on the East coast, BOEM is now ready to hold the first-ever offshore wind lease sale on West Coast in the fourth quarter of 2022.

At the state level, a 5 GW offshore target was announced in Louisiana in Q1 2022, followed by a 3 GW floating wind plan announced in both California and Oregon, bringing the total of state-level offshore wind development targets up to nearly 50 GW.

GWEC Market Intelligence predicts a total of 27.5 GW of offshore wind could be built in the US by the end of 2030, the same level as we predicted for this market a year ago.

Floating Offshore Market Outlook to 2031

80% of the world's offshore wind resource potential lies in waters deeper than 60m, but as of the end of 2021 only 121.4 MW of net floating wind capacity is in operation worldwide, accounting for 0.2% of the total installed offshore wind capacity.

Nevertheless, significant progress has been made since the first MW-scale floating offshore wind turbine was grid-connected in Norway in 2009. Following a decade of testing first in Europe and then in Asia, floating wind has now passed the demonstration stage and entered the pre-commercial phase.

Since the release of our Global Offshore Wind Report 2021, further breakthroughs have been recorded in this sector. As of today, the global floating offshore wind pipeline already tops 120 GW. In the UK, for example, 15 GW of floating wind projects won the ScotWind leasing round with another 4 GW of floating wind capacity expected to be unlocked from the proposed seabed leasing in the Celtic Sea. This development, without any doubt, has paved the, much needed, way for commercialising floating wind. As developers, especially oil and gas companies, have a strong appetite for floating wind, new floating wind targets have been announced on both sides of the Atlantic Ocean in the past 12 months. Taking into account the positive political momentum behind floating wind, the increased floating wind target in the UK and the accelerated floating project development activities in Europe, Asia and North America, GWEC Market Intelligence has upgraded its global floating wind forecast and predicts that 18.9 GW is likely to be built globally by 2030, compared with 16.5 GW that we predicted a year ago.

As of today, the UK, Portugal, Japan, Norway and China are the top five markets in total (gross) floating wind installations. By the end of this decade, the UK, South Korea, United States, Spain and Ireland are likely to be the top five floating markets.

As with last year, our near-term (2022-2026) outlook is primarily based on the existing global floating offshore project pipeline. However, a top-down approach has been applied for the medium-term (2027-2030) outlook, which takes into account national floating wind targets and development plans announced by major offshore wind investors.

Considering floating wind will become fully commercialised towards the end of this decade, GWEC Market Intelligence forecasts that 28.7 GW of new floating wind capacity will be added in 2022-2031, of which less than 10% (or 2.7 GW) will be built in the first half of the decade and the majority (90%) of new volume will come online in 2027-2031.

As regards to regional distribution, we expect Europe to contribute 59.2% of total installations added in 2022-2031, followed by Asia (29.4%) and North America (11.4%). As of the end of 2031, a total of 28.8 GW of floating wind is likely to be installed worldwide, bringing its contribution to total offshore wind installations from today's 0.2% to 7.8%.

To help unlock the global floating wind potential, GWEC launched its Floating Offshore Wind Task Force in July 2020.

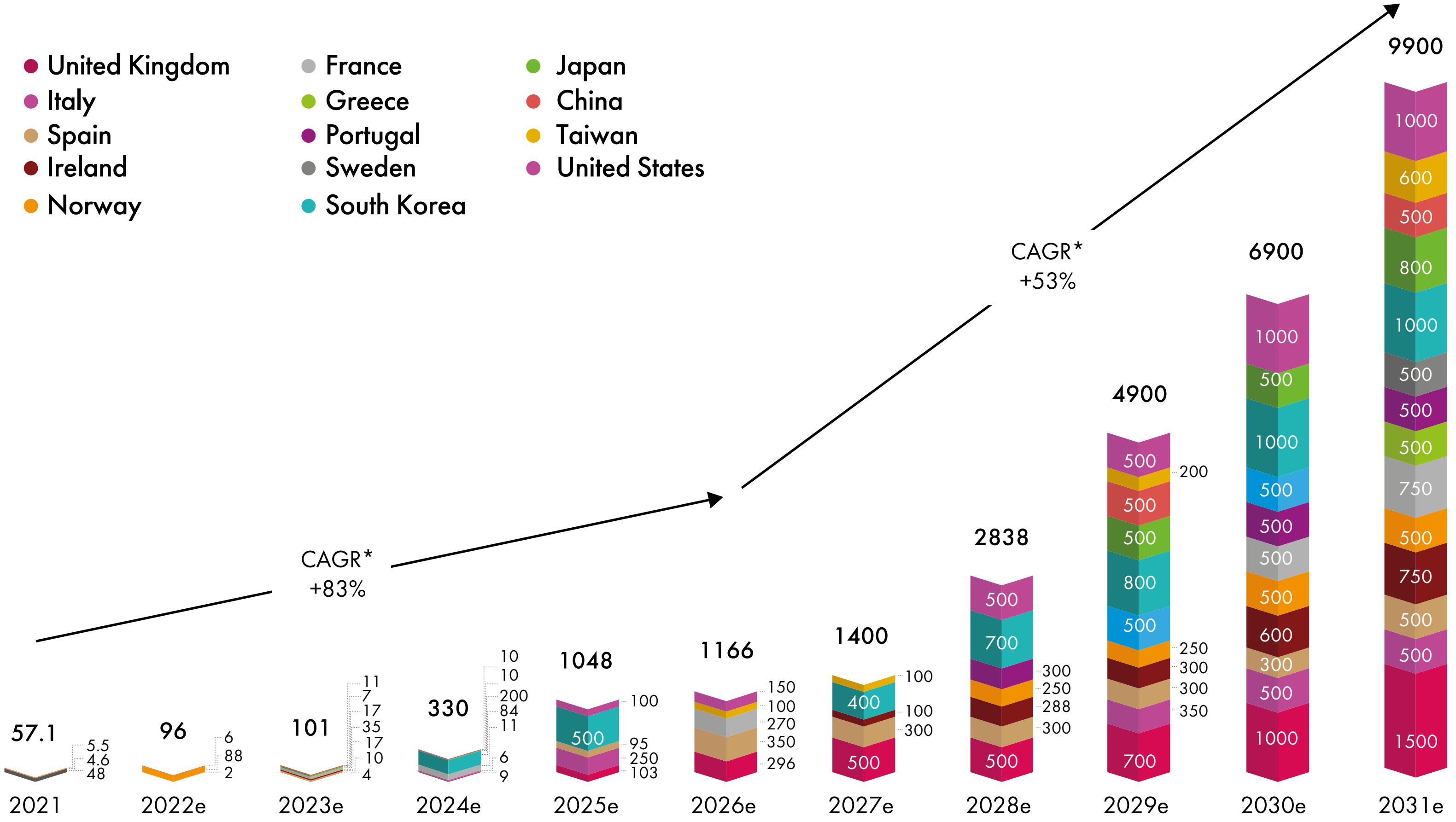
Roadmap of floating offshore wind commercialisation

Demo and trial phase (2009-2020)

Pre-commercial phase (2021-2025)

Commercial phase (from 2026 onward)

New floating wind installations, Global (MW)**



*Compound Annual Growth Rate., **Note: this floating wind outlook is already included in GWEC's global offshore wind forecast.
Source: GWEC Market Intelligence, June 2022

APPENDIX

Global Offshore Wind Report 2022 - Methodology and Terminology

Data definitions and adjustments
GWEC reports installed and fully commissioned capacity additions and total installations. New installations are gross figures not deducting decommissioned capacity. Total installations are net figures, adjusted for decommissioned capacity.

Historic installation data has been adjusted based on the input GWEC received. GWEC made the adjustments to both new and cumulative installations over the course of time.

All currency figures in $ are given in US Dollars.

Definition of regions
GWEC adjusted its definition of regions for the 2018 Global Wind Report and maintains these in the 2022 edition, 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. For the supply side data, GWEC collects directly from wind turbine OEMs.

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

Acronyms

AEP Annual Energy Production
BOEM Bureau of Ocean Management
C&I Commercial and Industrialc
CAGR Compound Annual Growth Rate
CCS Carbon Capture and Storage
CEC California Energy Commission
CfD Contracts for Difference
COD Commercial Operation Date
CSIRO Commonwealth Scientific and Industrial Research Organisation
DEA Danish Energy Agency
DNSH Do No Significant Harm
DOE Department of Energy
DOI Department of Interior
EBL Electricity Business License
EIA Environmental Impact Assessment
EPC Engineering, Procurement and Construction
EVN Vietnam Electricity
FERC Federal Energy Regulatory Commission
FiT Feed-in-Tariff
FY Financial Year
GHG Greenhouse Gas Emissions
H&S Health and Safety
IEA International Energy Agency
IRENA International Renewable Energy Agency
JWPA Japan Wind Power Association
KEPCO Korea Electric Power Corp
LCOE Levelised Cost of Energy
LIDAR Light Detection and Ranging
MAC Maritime Area Consent
METI Ministry of Economy, Trade, and Industry of Japan
MLIT Ministry of Land, Infrastructure, Transport and Tourism of Japan
MNRE Ministry of New and Renewable Energy of India
MONRE Ministry of Natural Resources and Environment of Vietnam
MSP Marine Spatial Planning
NABTU North America Building Trade Union
NDC Nationally Determined Contribution
NDRC National Development and Reform Commission of China
NEA National Energy Administration of China
OEM Original Equipment Manufacturer
OREDP Offshore Renewable Energy Development Plan
ORESS Offshore Renewable Energy Support Scheme
PDP8 Power Development Plan VIII of Vietnam
PEP Philippine Energy Plan
PMSG Permanent Magnet Synchronous Generator
PQQ Prequalification Questionnaire
PSU Public Sector Undertaking
RECs Renewable Energy Certificates
REEs Rare Earth Elements
RODA Responsible Offshore Development Alliance
RPS Renewable Portfolio Standard
RVO Netherlands Enterprise Agency
SDGs UN Sustainable Development Goals
SEA Strategic Environmental Assessment
SNG Synthetic Natural Gas
SOV Service Operation Vessel
TCE The Crown Estate
WTIV Wind Turbine Installation Vessel

About GWEC Market Intelligence

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

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

The market intelligence team consists of several strong experts with long-standing industry experience across the world.

GWEC Market Intelligence collaborates with regional and national wind associations as well as its corporate members.

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- Wind energy associations
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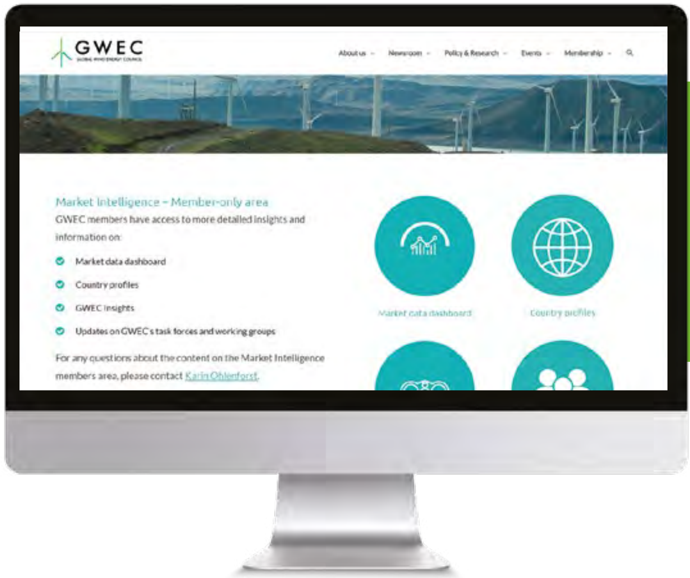
Technology/ Supply Chain
Wind turbine data, technology trends, component assessment

Energy Transition
Shift to value-focused, new wind-based solutions

O&M
ISP - OEM - Self Perform database for key markets



GWEC Market Intelligence created a Member-only area to provide more in-depth market intelligence to GWEC's members and their employees.

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GWEC Market Intelligence Products in 2022

Product	Frequency
1. Wind Energy Stats/Market Data	
Wind Stats 2021 (historic annual, accumulative, decommision data)	Annual
Global Wind Report 2022	Annual
Wind Energy Statistics (wind energy penetration rate, jobs)	Annual
2. Country Profiles/Policy Updates	
Country Profiles Onshores/Country Profiles Offshore	Quarterly/Ad-hoc
Ad-hoc Policy Updates	Ad-hoc
3. Market Outlook	
Global Wind Market Outlook 2022-2026 (Q1 and Q3) Database + Report	Semi-Annual
India Market Outlook Report 2022-2026	Annual
Global Wind Workforce Outlook 2022-2026	Annual
4. Supply Side Data	
Global Wind Turbine Supply Side Data Report 2021 (by OEM, by technology, by turbine ratings, models and drive train, etc)	Annual
5. Auctions/Tenders	
Global Wind Auction Database Annual/Quarterly Auction Trends and Learnings	Quarterly
6. Offshore Wind Market	
Global Offshore Wind Report 2022 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 and Report	Annual/Quarterly
7. Components Assessment	
Gearbox (2019), Blade (2020), Generator (2021), Gearbox (Q4 2022), followed by other components	Special Report
8. Wind Asset Owners/Operators	
Asset Owners and Operators Database (Onshore & Offshore Ranking)	Annual
Asset Owners and Operators Status Report (including strategical trends)	Annual
9. O&M	
O&M Service Provider Database (ISP - OEM - Self-perform)	Annual
O&M Service Provider Status Report (including regional trends)	Annual
10. Energy transition, Digitalisation, New Technologies	
Position papers/ studies - permitting, Corporate PPAs Special Report New solutions, GWEC policy recommendations	Special Report

GWEC Global Leaders

The Global Wind Energy Council's Global Leaders are an exclusive leadership group of decision-makers and top-tier members who form the basis of the Association's Executive Committee, which drives the work programme and plays a major role in shaping GWEC's priorities for its efforts in the short and long-term strategy.

Siemens Gamesa

Siemens Gamesa unlocks the power of wind. For more than 40 years, we have been a pioneer and leader of the wind industry, and today our team of more than 26,000 colleagues work at the center of the global energy revolution to tackle the most significant challenge of our generation – the climate crisis. With a leading position in onshore, offshore, and service, we engineer, build and deliver powerful and reliable wind energy solutions in strong partnership with our customers. A global business with local impact, we have installed more than 120 GW and provide access to clean, affordable and sustainable energy that keeps the lights on across the world, while supporting the communities where we operate.

Shell

Shell is building a global integrated power business spanning electricity generation, trading and supply. Shell entered the offshore wind business in 2000 as part of a consortium that installed the first offshore wind turbine in UK waters. Today, we have deployed, or are developing, over eight gigawatts (GW) of wind across North America, Europe, the UK, and Asia. We see offshore wind as a critical way of generating renewable electricity for our customers and moving Shell towards its target of being a net-zero emissions energy business by 2050 or sooner, in step with society.

Ørsted

The Ørsted vision is a world that runs entirely on green energy. Ørsted develops, constructs, and operates offshore and onshore wind farms, solar farms, energy storage facilities, renewable hydrogen and green fuels facilities, and bioenergy plants. Moreover, Ørsted provides energy products to its customers. Ørsted is the only energy company in the world with a science-based net-zero emissions target as validated by the Science Based Targets initiative (SBTi). Ørsted ranks as the world's most sustainable energy company in Corporate Knights' 2022 index of the Global 100 most sustainable corporations in the world and is recognised on the CDP Climate Change A List as a global leader on climate action.

Mainstream Renewable Power

Mainstream Renewable Power is a leading pure-play renewable energy company, with wind and solar assets across global markets, including in Latin America, Africa, and Asia-Pacific. Mainstream is one of the most successful developers of gigawatt-scale renewables platforms, across onshore wind, offshore wind, and solar power generation. It has successfully delivered 6.5 GW of wind and solar generation assets to financial close-ready. In May 2021, Aker Horizons acquired a 75% equity stake in the company, accelerating its plans to deliver its high-quality pipeline of over 16 gigawatts of clean energy. Mainstream has raised more than EUR3.0bn in project finance to date and employs more than 420 people across five continents.

GE Renewable Energy
GE Renewable Energy harnesses the earth's most abundant resources – the strength of the wind, the heat of the sun and the force of water; delivering green electrons to power the world's biggest economies and the most remote communities. With an innovative spirit and an entrepreneurial mindset, we engineer energy products, grid solutions and digital services that create industry-leading value for our customers around the world.

Iberdrola
With over 170 years of history behind us, Iberdrola is now a global energy leader, the number one producer of wind power, and one of the world's biggest electricity utilities in terms of market capitalisation. We have brought the energy transition forward two decades to combat climate change and provide a clean, reliable and smart business model, to continue building together each day a healthier, more accessible energy model, based on electricity.

Vestas
Vestas is the energy industry's global partner on sustainable energy solutions. We design, manufacture, install, and service wind turbines across the globe, and with +151 GW of wind turbines in 86 countries, we have installed more wind power than anyone else.

Through our industry-leading smart data capabilities and +129 GW of wind turbines under service, we use data to interpret, forecast, and exploit wind resources and deliver best-in-class wind power solutions. Together with our customers, Vestas' more than 29,000 employees are bringing the world sustainable energy solutions to power a bright future.

Equinor
We are looking for new ways to utilise our expertise in the energy industry, exploring opportunities in new energy and driving innovation in oil and gas around the world. We know that the future has to be low carbon. Our ambition is to be the world's most carbon-efficient oil and gas producer, as well as driving innovation in offshore wind and renewables. We plan to reach an installed net capacity of 12-16 GW from renewables by 2030, two-thirds of this will be from offshore wind. With five decades of ocean engineering and project management expertise, focus on safe and efficient operations, in depth knowledge of the energy markets, skilled personnel and a network of competent partners and suppliers, Equinor is uniquely positioned to take a leading role in the offshore wind industry. From building the world's first floating wind farm to building the world's biggest offshore wind farm we are well underway to deliver profitable growth in renewables be a leading company in the energy transition.

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