GLOBAL SUPPLY CHAIN STUDY

PRESENTED BY: ERM WITH CONTRIBUTIONS FROM NORWEP

PRESENTED TO: THE FEDERATION OF NORWEGIAN INDUSTRIES, OFFSHORE NORWAY AND RENEWABLES NORWAY

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Document Details

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Acronyms and Key Definitions

Acronyms

AMER – North and South America

APAC – Asia Pacific

CFD – Contract for Difference

COD – Commercial Operational Date

EMEA – Europe, the Middle East and Africa

ESA - EFTA Surveillance Authority

FBOW – Fixed bottom offshore wind

FIV-Foundation Installation Vessel

FOU – Floating Offshore Unit

FOW – Floating Offshore Wind

GRIP - Global Renewable Infrastructure Projects (ERM tool)

HV – High Voltage

HVAC – High voltage alternating current

HVDC – High voltage direct current

LCOE - Levelised cost of energy

MP – Monopile

NDRC - National Development and Reform Commission

NoA - National Oceanic Administration

O&G – Oil and Gas

OREC – Offshore Renewable Energy Certificate

OSS – Offshore Substation

OSW - Offshore Wind

PoA - Provincial Oceanic Administration

PPA – Power Purchase Agreement

SNII - Sørlige Nordsjø II

TLP – Tension Leg Platform

TRL – Technical Readiness Level

WTIV-Wind Turbine Installation Vessel

DP2-Dynamic Positioning

BE – Belgium

BS – Bahamas

CY – Cyprus

DE – Germany

DK – Denmark

JP – Japan

LU – Luxembourg

MT – Malta

NL – Netherlands

NO - Norway

PA – Panama

SG – Singapore

TW – Taiwan

UK – United Kingdom

US – United States of America

Definitions

Operational includes projects where all components have been commissioned and the project is supplying power at its full capability.

Secured means a project has secured an offtake contract for power purchase, the mechanism differs by country (CFD, PPAs, ORECs, etc.), but has not completed commissioning.

Development considers all projects which have *not* secured an offtake contract, including those in the early stages of development through to those in planning or consents. It should be noted that in some cases a development pipeline is considered 'inflated' where there may be overlapping projects areas for example which will be reduced when a project secures and offtake.

Installed power is the sum of the nominal capacity of the energy generation source. This is not the power to be supplied in practice.

Electricity generation is the gross electricity produced by electricity plants, combined heat and power plants, and distributed generators measured at the output terminals of generation. It includes on-grid and off-grid generation, and it also includes the electricity self-consumed in energy industries; not only the electricity fed into the grid (net electricity production).

Export cable or submarine cable or subsea cable: Includes submarine cables that connect offshore and onshore substations to transmit power from the wind farm to shore. It does not include array cables.

HVAC: High voltage alternating current with a power greater than 66 kV and equal to or less than 220 kV.

HVDC: High voltage direct current with power between 100 kV and 800 kV.

XXL Monopiles: can weigh in excess of 3,000 tonnes and be over 120m long.

Subsea cable supply assumption: Chinese suppliers' primary market will be China with some expected sales abroad. Only where Chinese suppliers have international presence, have they been included in the study. Where project numbers have been listed for the various Chinese suppliers, this may be conservative as it is based on limited public information

Vessel supply assumption: For most of this study a heavy-lift vessel will be assumed to be exclusively used for foundation installation and a jack-up vessel with legs that can be lowered to the ocean bottom will be assumed to be used exclusively to install wind turbines. As there are cases where jack up vessels install monopiles and heavy lift vessels install turbines, additional comments have been made to include vessels with capabilities in addition to the base assumption. It should be noted that Chinese vessels have been excluded from the study.

Contents

Executive Summary

Executive Summary

Overview and objectives of the report

In this “Global Supply Chain” study, ERM and Brinckmann assessed the offshore wind demand until 2033 considering whether supply can meet the demand for major offshore wind components and assets.

The report analyzed the following:

- Potential offshore wind market size to 2033 broken down by foundation technology type and number of turbines;
- Global turbine supply capacity, turbine demand and evaluation of turbine sizes;
- Fixed and floating foundation fabrication capabilities and foundation demand;
- Export cable suppliers, supplier capacities and export cable demand; and,
- Foundation and turbine installation vessel capabilities and vessel demand.

The report outlines the potential supply chain bottlenecks for projects reaching commercial operation starting from 2023 until 2033.

Summary of Findings

Between 2023 and 2033, an additional 226 GW of global offshore wind capacity (excluding China) is projected to come into operation.

Europe, Middle East, and Africa (EMEA) is expected to contribute circa 146 GW of installed capacity by 2033, with the UK, Germany, Netherlands, and Denmark leading large-scale commissioning.

Asia-Pacific (APAC) projects could contribute over 43 GW, primarily led by Taiwan, South Korea, and Japan from 2028 onwards. As a predominantly insular market, China has been excluded as less relevant to the Norwegian supply chain market.

The Americas are anticipated to ramp up offshore wind operations from 2026 onwards, contributing 36 GW by 2033, driven predominantly by the US.

There will be a surge in global offshore demand after 2028, necessitating significant additions to **turbine** production capacity. Western turbine OEMs dominate international markets, with Chinese OEMs facing challenges in penetrating mature markets due to technology changes and reliability concerns.

Export cable supply may face shortages from 2027 onwards, necessitating capacity expansions or entry of new suppliers into the market.

Fixed-bottom foundations dominate forecasts, with around 210 GW projected between 2023 and 2033, led by EMEA. While monopiles are expected to be the main fixed foundation type, jackets might be the most suitable technology for Norwegian waters and sufficient jacket foundation capacity is expected for projects reaching COD by 2033. **Floating foundations** (FOW) are maturing but face challenges, with only 18 GW forecasted by 2033, primarily led by Norway. FOW do not yet have a dedicated supply chain for serial manufacture; however, there is an opportunity for yards with expertise in large steel structures to capitalise on this gap, assuming a healthy, financially viable FOW project pipeline, which is not expected until the end of this decade.

The industry expects larger monopiles and turbines, leading to the need for **vessel** upgrades and potential changes to fleet distribution. Regulatory constraints, such as the Jones Act in the US, may affect vessel deployment strategies. Increasing water depths and turbine sizes will lead to larger monopiles. Only 6 vessels will be capable of XXL monopile installation by end of 2024 with a potential bottleneck starting from 2029. The Americas and APAC will likely see shortages as the fleet is mostly European, potentially leading to some of the European fleet moving abroad.

Overall, the **offshore wind industry is poised for significant growth globally**, with regions and sectors facing both opportunities and challenges in meeting demand while scaling up infrastructure to meet their offshore wind generation.

Market Sizing

Global Outlook

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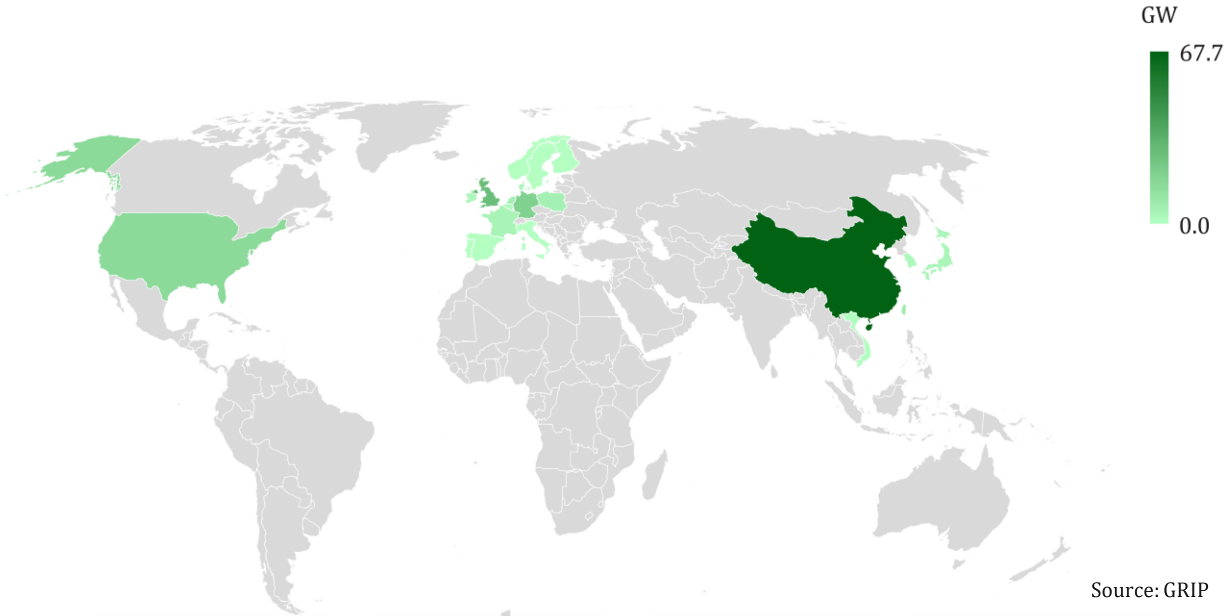
Global Offshore Wind Update

The global offshore wind operational capacity has reached 67.8 GW, with an additional 106 GW secured route-to-market either under construction or at the pre-construction stage.

Total operational + route to market secured, GW



Source: GRIP

67.8 GW Operational

106.0 GW Secured

1,430.6 GW In Development**

1,604.5 GW Total Portfolio

Top 15 countries, operational + route to market secured, MW*

#	Country	Operational	Secured	Development**
1	**China**	33,539	34,193	90,521
2	**United Kingdom**	14,802	13,196	84,538
3	**Germany**	8,251	11,499	40,727
4	**USA**	42	15,652	117,871
5	**Taiwan**	613	7,288	40,499
6	**The Netherlands**	3,745	3,192	21,400
7	**Poland**	-	5,930	9,896
8	**France**	482	4,171	5,753
9	**Japan**	311	3,662	51,168
10	**Denmark**	2,473	1,176	13,272
11	**Ireland**	25	3,330	85,318
12	**South Korea**	106	2,433	56,423
13	**Belgium**	2,261	-	3,500
14	**Vietnam**	777	312	65,349
15	**Sweden**	191	-	113,269

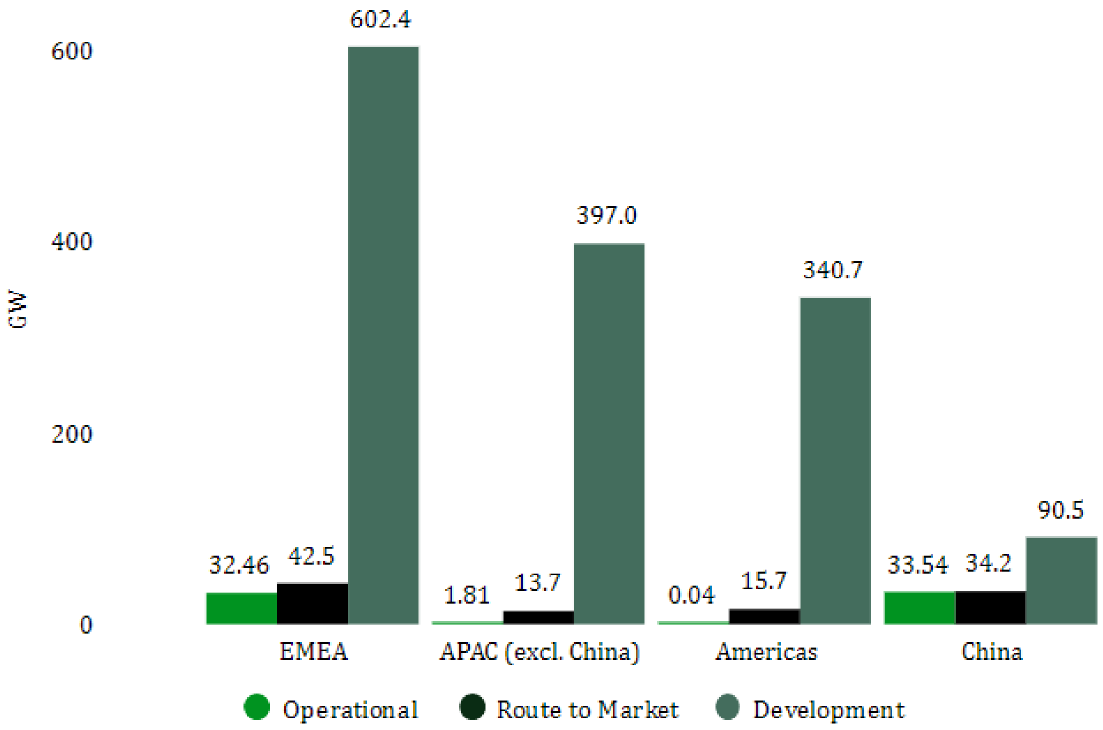
Source: GRIP

See slide 4 for detailed terminology descriptions for operational, secured (route-to-market) and development.
*Ranking is based on operational capacity plus addition to capacity with a route-to-market secured.
**Development capacity includes early-stage development projects, some of which have overlapping areas, leading to an over inflated portfolio.

Regional Breakdown

Nearly 100 GW have secured a route-to-market, while ongoing development projects surpass a staggering 1,400 GW.

Breakdown for the major regions



Source: GRIP

*Includes capacity scheduled for auction that is yet to be allocated.

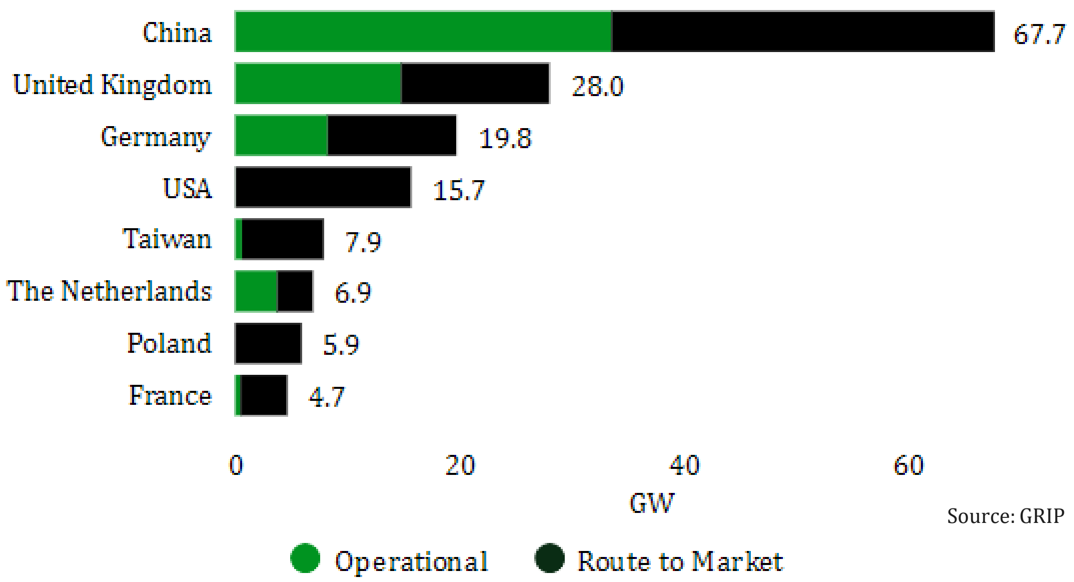
Updates

- As of January 2024, there are 67.8 GW of offshore wind capacity in operation globally. China leads with the greatest operational capacity, closely followed by the EMEA region. Projects which became fully operational in Q4 2023 are - 256 MW Arcadis Ost 1 in Germany, 759 MW Hollandse Kust (Noord) in The Netherlands, 570 MW Seagreen Bravo in the UK as well as 1 GW Guangdong Yangjiang Qingzhou 1 & 2 in China.
- Route-to-market secured capacity includes projects with firm offtake contracts (mechanism differs by country e.g., CFD, PPAs, ORECs). Maturer markets have clearer route-to-markets often via offtake auctions, which encourages offshore wind development. The capacity awarded in offtake contracts has dipped recently due to a mismatch between market prices and government expectations, e.g., UK's Allocation Round 5 in 2023 where no OSW capacity was awarded. Future offtake contracts are expected to reflect inflation and supply chain constraints.
- Over 1,400 GW of offshore wind is in development. We expect the actual capacity which reached operation to be much reduced for a myriad of factors including overlapping development project boundaries and markets where there is not yet a defined route-to-market for offtake.

Key Offshore Wind Markets

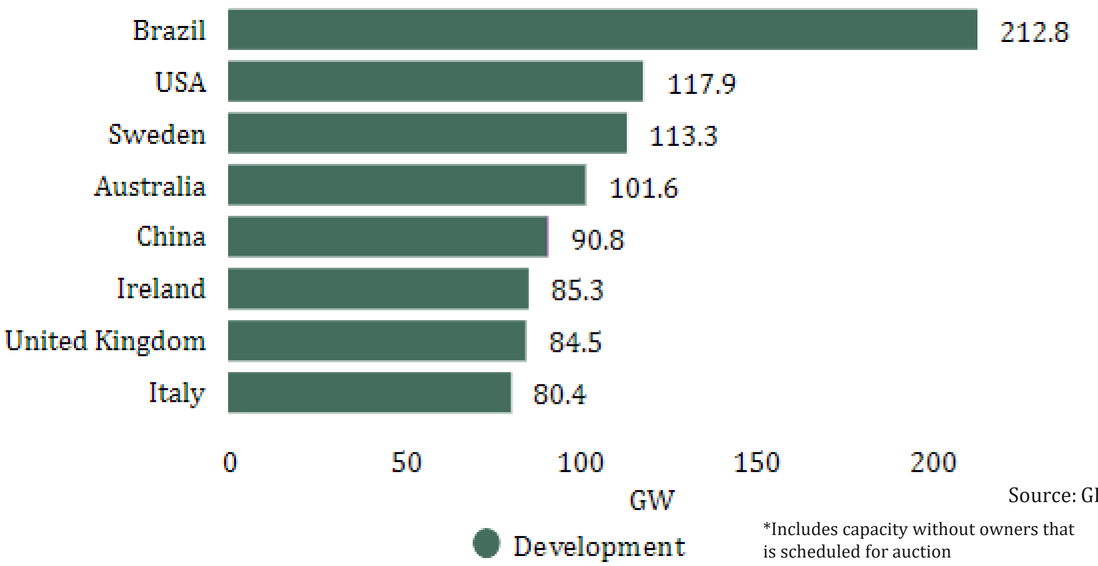
Five projects became operational Q4 2023, Arcadis Ost 1, Hollandse Kust (Noord), Seagreen Bravo and Guangdong Yangjiang Qingzhou 1 & 2 bringing the total operational capacity to 67.8 GW by the end of 2023.

Key markets, total operational and secured capacity



Source: GRIP

Key markets, development*



Source: GRIP

*Includes capacity without owners that is scheduled for auction

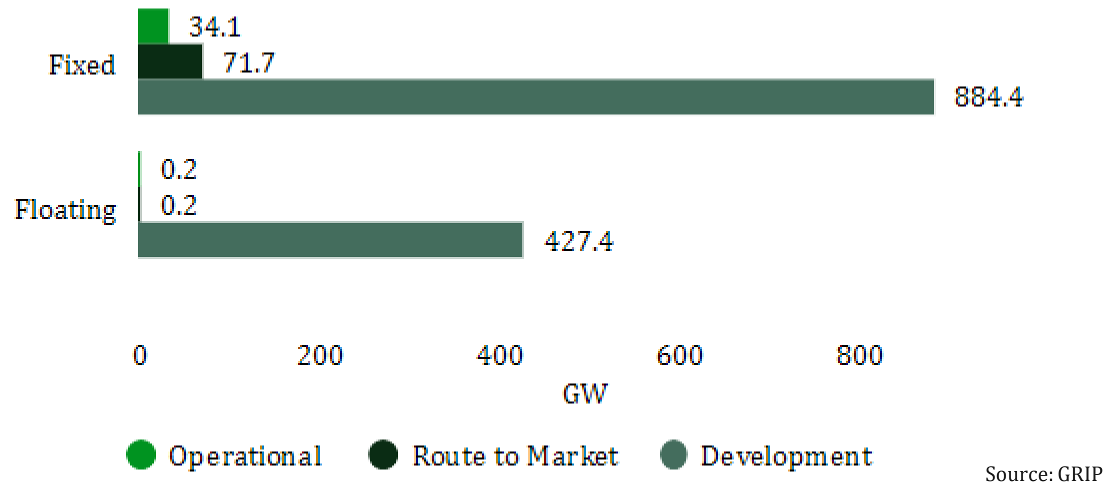
- China has consistently led the offshore wind market in recent years. In 2023, China increased operational and route-to-market secured capacity by almost 15 GW.
- The UK dominates the European market in terms of operational and route-to-market secured capacity.
- The remaining key markets have maintained their rankings over the last year, with all the markets progressing lease and offtake auctions.

- Development capacity in Brazil has experienced a substantial rise over the last few years, increasing by over 40 GW in the last year alone. Due to overlapping boundaries, many projects currently under development will not be realised.
- Sweden and Australia boast very large development portfolios but are yet to display a track record in securing these commercial scale projects with a route-to-market.

Key Foundation Technologies and Key Players

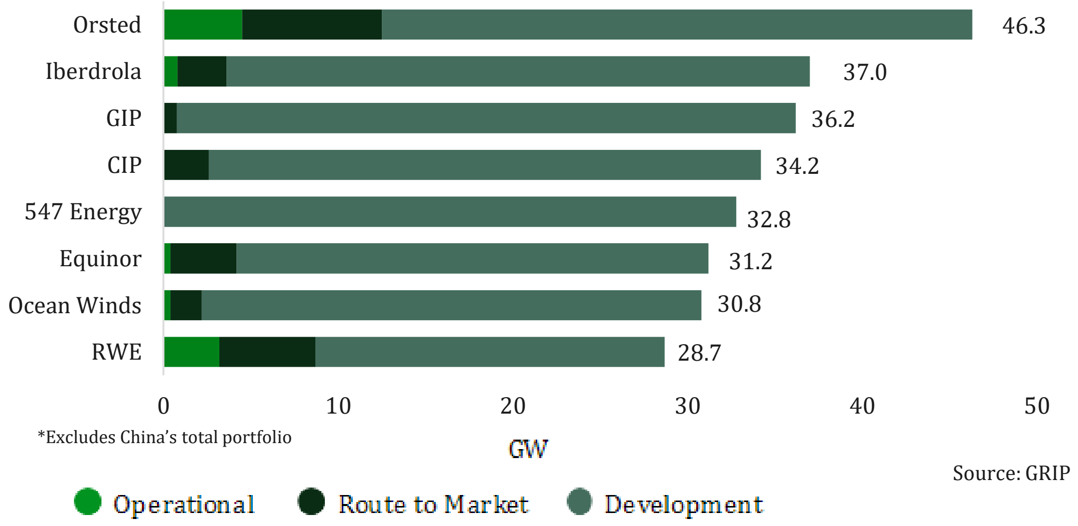
Despite adding over 130 GW in floating offshore wind capacity to the development pipeline in the last year, fixed-bottom technology maintains its dominance in the market.

Technologies (excl. China)*



*Excludes China's total portfolio
**Includes capacity without owners that is scheduled for auction.

Key owners (excl. China)*



*Excludes China's total portfolio

- Floating offshore wind technology opens new potential for offshore wind and means new markets can enter the industry which due to bathymetry were not suited to fixed-bottom offshore wind.
- The world's largest operational floating offshore wind project is Hywind Tampen at 88 MW, which came online in 2023

- Ørsted, Iberdrola, and Global Infrastructure Partners (GIP) have remained the top three offshore wind owners in recent years.
- A substantial amount of capacity exists in the global development pipeline without an assigned owner, primarily because the capacity has not yet been tendered.

China

China is the largest offshore wind market and expected to stay in the lead with more than 34 GW secured route-to-market capacity.

Why do we exclude China from market sizing?

A controversial decision to cease granting national-level subsidies for offshore wind projects is unlikely to arrest the industry's rapid growth, with experts predicting the domestic sector to continue its upward trend.

Operating capacity has reached 33 GW, and accounts for approximately 10% of China's total wind capacity, almost equal to the operating offshore capacity of all of Europe. Another 34 GW capacity secured route-to-market is expected to reach commercial operation before 2030.

The government has implemented a full range of policies and incentives to both encourage and pressure stakeholders to produce and consume renewable energy. It has also ensured financing not just for the plants themselves, but also for the supply chain and construction infrastructure necessary to build them. By taking advantage of this funding and the immense domestic market opportunities, China's suppliers have relentlessly driven down costs, making renewables development economically competitive and sustainable while achieving dominance as one of the leading manufacturers of wind turbine components.

It is hard for European suppliers to enter the Chinese market. The Chinese supply chain's primary market will be China with some export to the global market. Therefore, we consider China to be out of reach for the Norwegian supply chain, making it misleading to present opportunities in China.

Chinese suppliers have been included in other report sections where they provide relevant services outside of China and in the turbine supply report covering the contrasting product strategies of Western vs Chinese OEMs.

Policy and regulatory framework

Leasing

Currently, Chinese offshore wind leasing is conducted through price-based auctions in regions approved by the National Oceanic Administration (NoA). Once the regional plan is approved by the NoA, the Provincial Oceanic Administration (PoA) holds auctions. Auctions are set up by local governments, which set their own evaluation criteria. The central government requires capability, technology and power price all be considered.

Route to market

For projects approved between 2014 – 2018 and commissioning by 2021, power prices were set by the National Development and Reform Commission (NDRC) using national subsidies. The end of 2021 marked a major policy transition for the Chinese offshore wind industry, with the central government terminating the feed-in tariff (FIT) scheme for offshore wind. With the end of FITs in 2021, bid submissions are required to be competitive with wholesale market rates noting that some provinces provide their own subsidies. After 2019, projects compete with ceiling bid prices determined by the NDRC.

Targets

China's national goal of 5 GW of installed offshore wind by 2020, was easily surpassed. Provinces have set their own offshore wind targets, e.g., Guangdong, the leading province aims for 18 GW of offshore wind capacity to be installed by 2025. The national 14th FYP, released in March 2021 has set a target for 20% of the energy fuel mix to be sourced from renewable energy technologies by 2025.

OFFSHORE WIND FORECAST 2023-2033

Market Sizing

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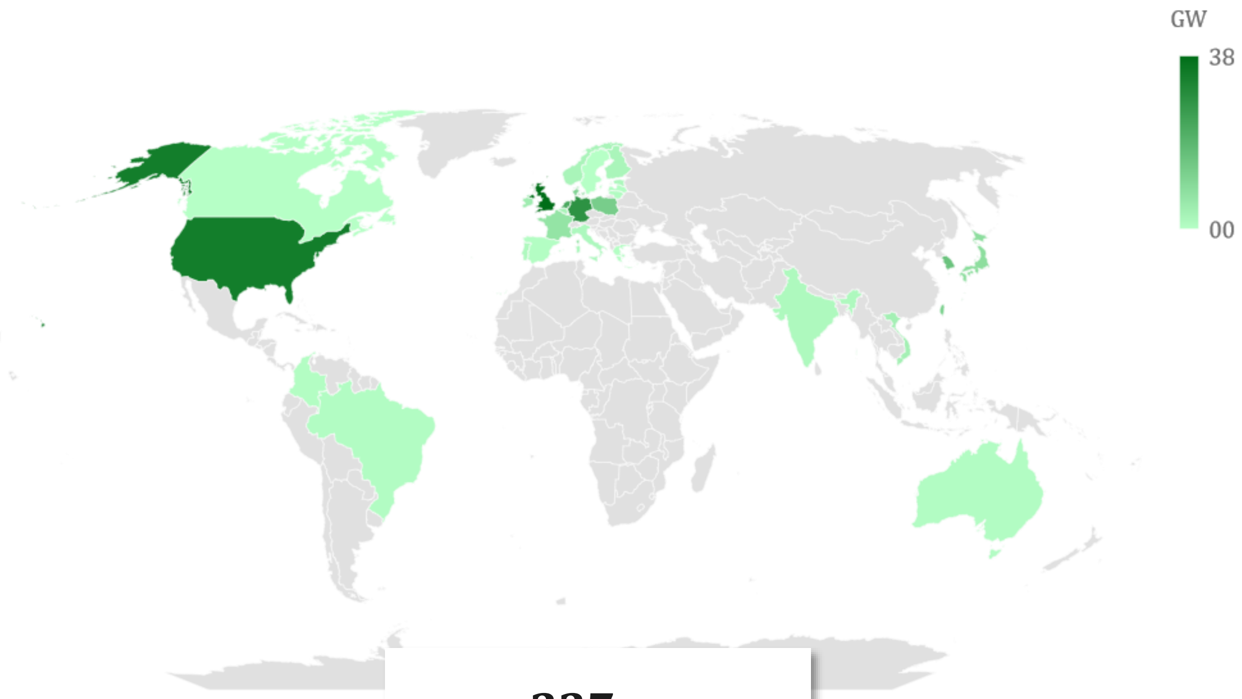
Global Market Outlook Between 2023 and 2033

An additional 226 GW of fully operational projects are poised to come online between 2023 and 2033 (excluding China) of which 210 GW will come from the top 15 countries.

Forecast global installed capacity between 2023-2033, GW



227 GW
Forecasted capacity (2023-2033)

Top 15 countries, forecasted capacity between 2023-2033, GW

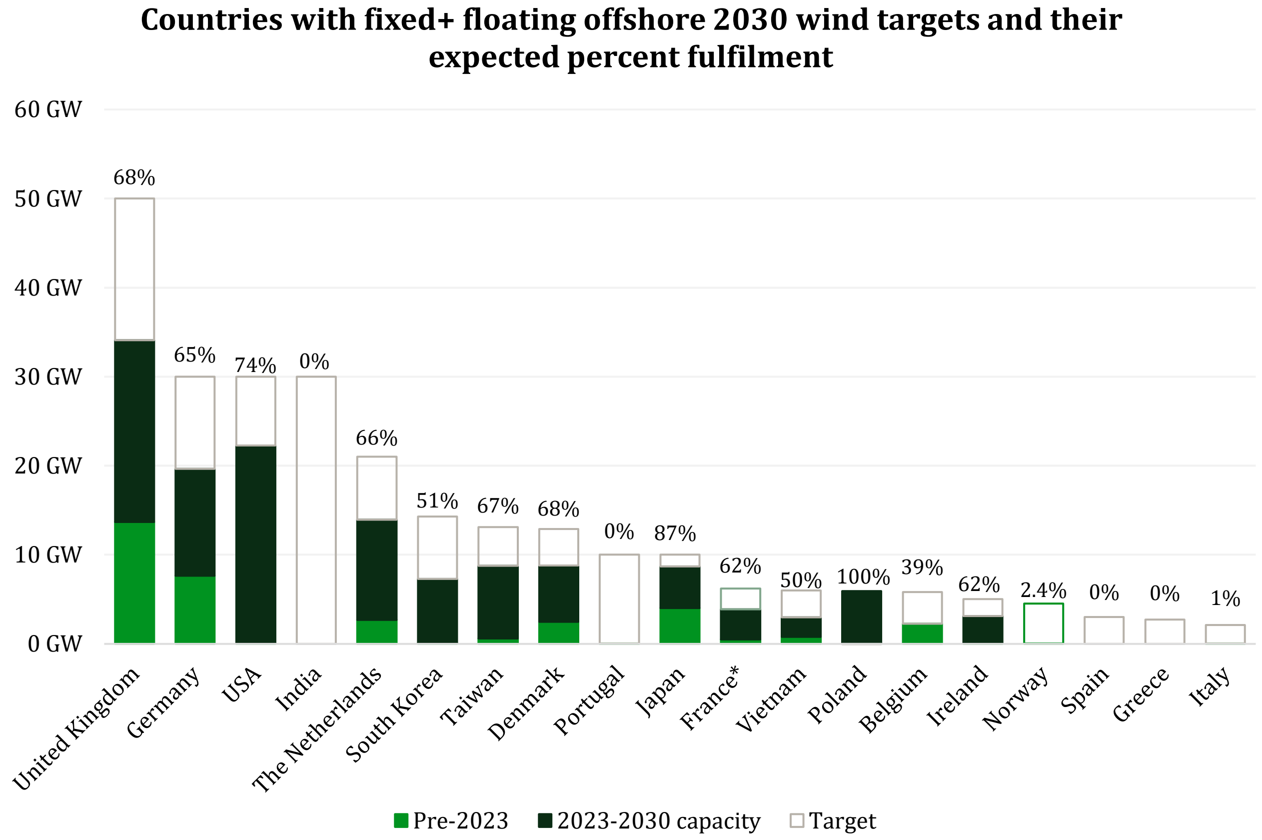
#	Country	Capacity (2023-2033)
1	United Kingdom	37.7
2	United States	33.7
3	Germany	28.5
4	Netherlands	22.4
5	South Korea	15.8
6	Poland	13.1
7	Denmark	11.8
8	Taiwan	11.7
9	Japan	8.8
10	France	7.4
11	Ireland	5.1
12	Vietnam	4.1
13	Belgium	3.5
14	Norway	3.0
15	Finland	2.9

Notes: Additional capacity forecasted to reach commercial operation between 2023-2033. As of end 2022, the operational capacity was 31 GW excluding China.

Note: all figures and rankings presented exclude China. Sources: GRIP database, public figures, ERM analysis.

Expectations of Countries Hitting Their Offshore Wind Targets

Only Poland is expected to meet its 2030 offshore wind target.



Notes: 1) All countries but France have a 2030 target, *France's target is 6.2 GW installed capacity target by 2028. 2) Forecast assumptions that planned auctions will go ahead on time, average of 10 years required from development to commercial operations of a wind farm and that development can rely on an adequate supply chain capacity.
Sources: GRIP database, public figures, ERM analysis.

According to ERM's forecast, only Poland is on track to meet its 2030 target. While Poland currently lacks installed offshore wind capacity, projects that secured leases in 2021 are anticipated to become operational by 2026.

Poland is expected to increase its target with an update of the Polish Energy Policy 2040; however, as this has not been officially announced, Poland is meeting its current target of 5.9 GW target.

Japan is next closest to reaching its 2030 target (87%), followed by USA (74%), Denmark (68%) and the UK (68%). Italy, Spain, Portugal, Greece, and India are forecasted to install almost no capacity before 2030.

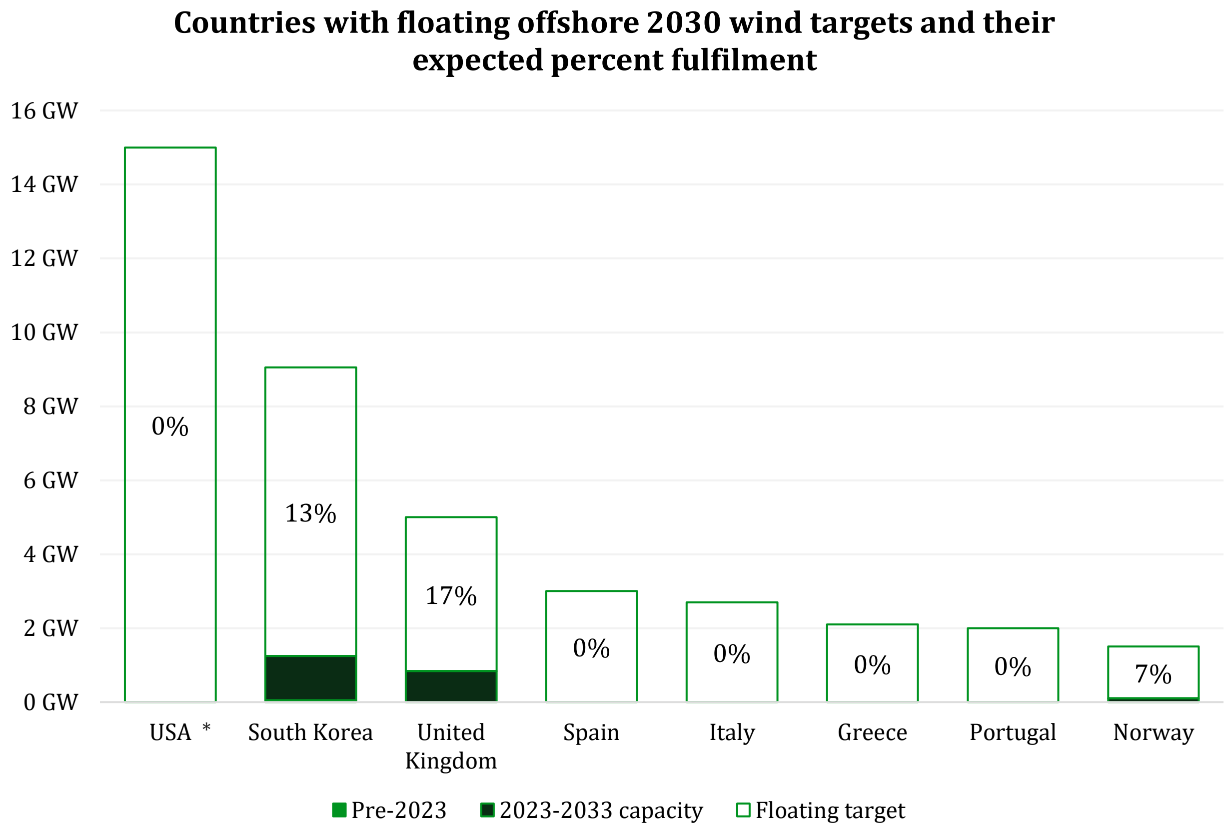
France does not have stated 2030 targets. However, the country targets 6.2 GW installed capacity by 2028, only 62% of this target is forecasted to be installed by 2030.

There is a positive correlation between countries with a clearly defined route-to-market and the likelihood of reaching their offshore wind targets.

Markets with clear tender schedules, tender criteria, and offtake mechanisms, such as the UK, Denmark, Germany, France, and the Netherlands, are more likely to actualise offshore wind capacity within the next 10 years.

Floating Offshore Wind Targets

Globally countries with floating offshore wind are lagging far behind of their targets.



Notes: 1) All countries above but the US have a 2030 target, *The US has 15Gw floating offshore wind target by 2035. 2) Forecast assumptions that planned auctions will go ahead on time, average of 10 years required from development to commercial operations of a wind farm and that development can rely on an adequate supply chain capacity.
Sources: GRIP database, public figures, ERM analysis.

Only South Korea, the UK and Norway are expected to install some floating capacity before 2030; however, this is nowhere near the respective country's ambitions. There are four key issues to resolve for the floating industry to come close to reaching their ambitious targets.

Offtake and regulatory certainty: Floating wind is a fast-developing market, but to meet targets, projects need to secure requisite funding and have a clear development framework. The majority of floating markets are newly set up without defined route-to-markets or regulatory certainty.

Levelised cost of energy (LCOE): Floating wind costs could still come down with technology advances, wind farm and turbine size increase, economies of scales and standardization.

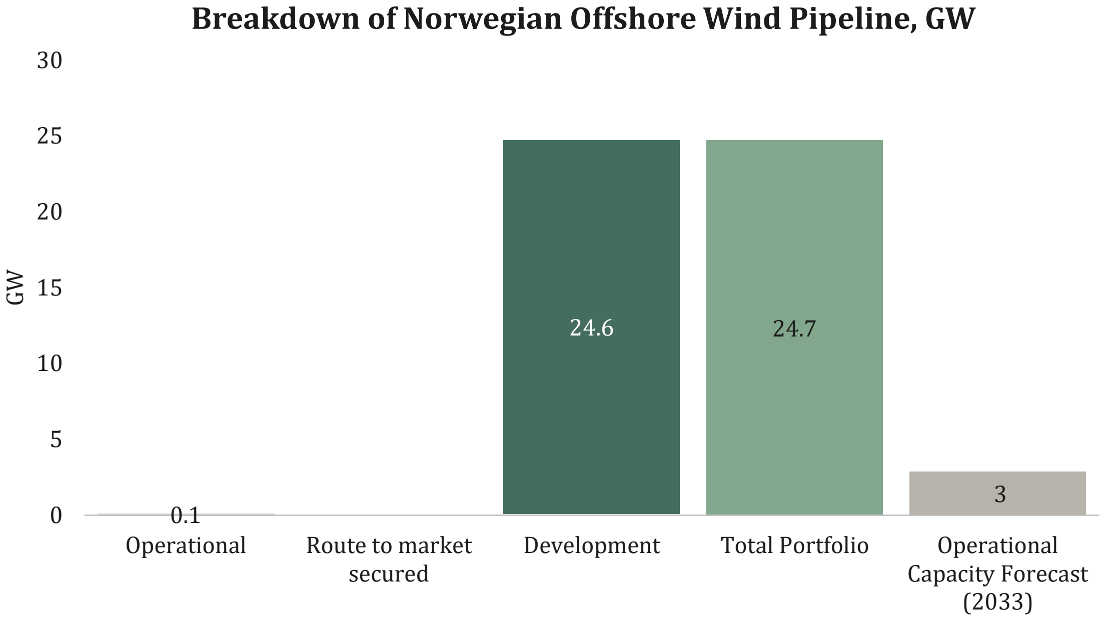
Project bankability: Floating wind is still maturing and lacks the track record that institutional investors will need to see before they are comfortable investing at scale.

Supply chain and port capacity: One pinch point for floating wind is likely to be sourcing reasonably priced steel and fabricating platforms at scale in Europe and the US. If significant investment in the supply chain is not made, many of the platforms may need to be sourced from Asia.

Norway

In the call for **Sørlige Nordsjø II** (SNII), the government has made both sustainability and positive ripple effects minimum requirements, instead of using the previous scoring system which was implemented for the categories. The requirements are now written into the future contracts for difference. Seven applications were submitted 15th November to the Ministry of Petroleum and Energy. In December 2023, the EFTA Surveillance Authority (ESA) approved up to NOK 23 billion (EUR 2.04 billion) in state aid in the form of a bilateral contracts for difference to be awarded for SNII. It was announced in February 2024 that five of the seven applicants have qualified to participate in the auction which is scheduled for 18th March 2024.

The Norwegian Ministry of Petroleum and Energy postponed the deadline for **Utsira Nord** in October 2023. The three Utsira Nord areas will be allocated based on qualitative criteria with the competition for state aid being carried out at a later point as part of the licensing process. The delay of the application deadline is due to the Ministry seeking more time with ESA and the European Commission to gain confidence that the areas can be awarded. The process must be confirmed before the ministry can receive applications.



Global Offshore Wind Forecast (1/2)

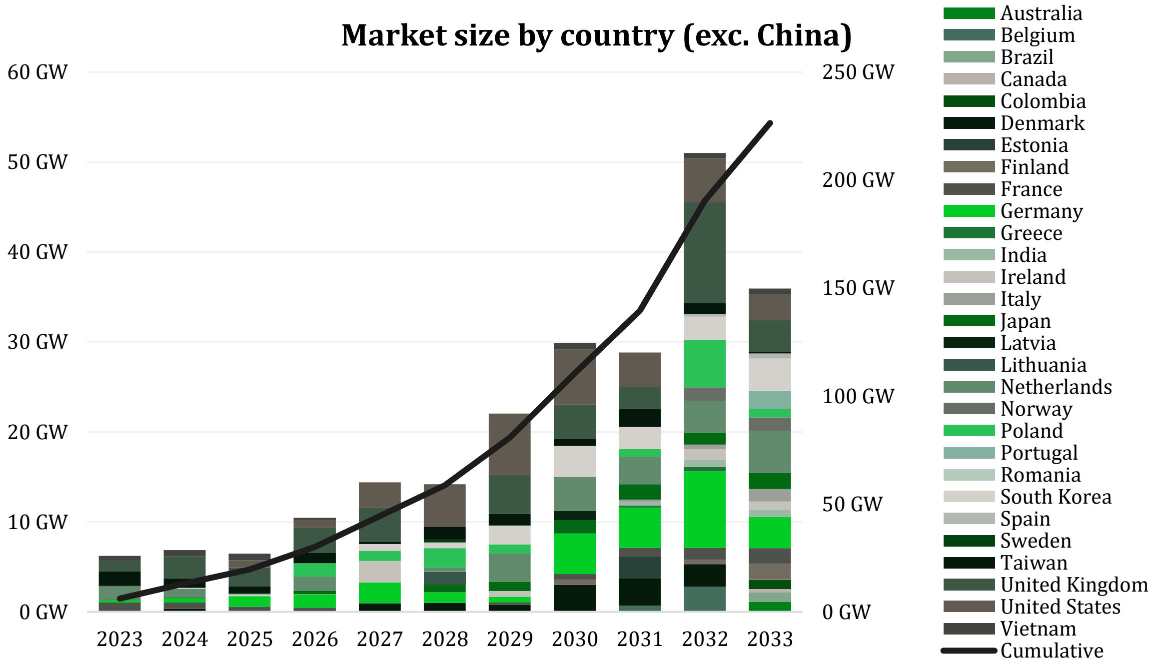
2023-2033 offshore market size is 226 GW excluding China

226 GW of additional global (excluding China) offshore wind capacity could be operational between 2023 and 2033, depending on the success of projects in development. New projects in EMEA account for circa146 GW of global installed capacity by 2033, large-scale commissioning in Europe will be led by countries with long-term leasing and development frameworks, such as the UK, Germany, NL, and Denmark.

Projects in APAC could account for over 43 GW with annual commissioning activity expected to increase from 2028 onwards as commercial-scale projects allocated from 2019 enter construction. A significant portion of commissioned capacity is in Taiwan. From 2028, build-out of offshore wind projects steps up across the region as large-scale projects come online in S. Korea and Japan (Round 1 and Round 2).

Installed capacity in the Americas regions is expected to ramp up from 2026 onwards reaching 36 GW by 2033, as developments enabled by leasing and route-to-market allocation activity from 2021 enter construction. The US is the only country in the Americas with operational capacity and projects with a firm route to market i.e., 14.8 GW awarded power contracts. However, even contract-secured projects face increasing uncertainty.

Note that these charts include all projects at any phase before commercial operations as of the time of writing the report. The charts show market size considering the project pipelines, government targets, auction timelines, and project development timelines. The forecast does not consider grid outlook and supply chain availability which we expect could reduce the forecast.



Global Offshore Wind Forecast (2/2)

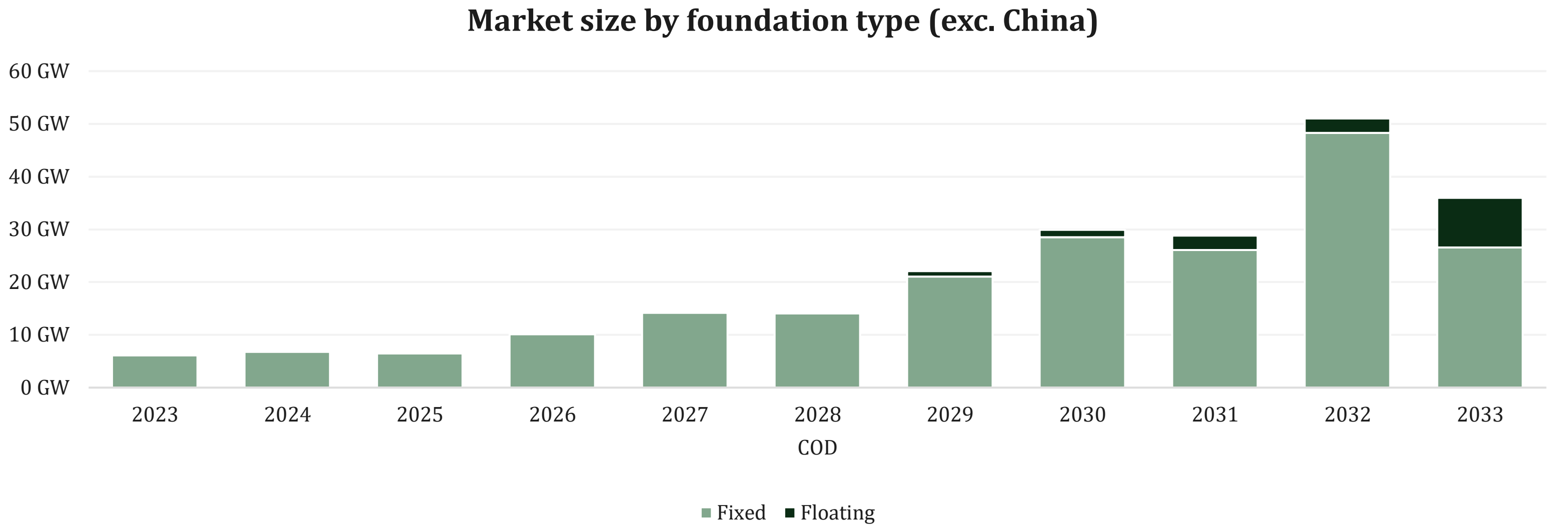
Fixed foundation wind will remain dominate over the next decade

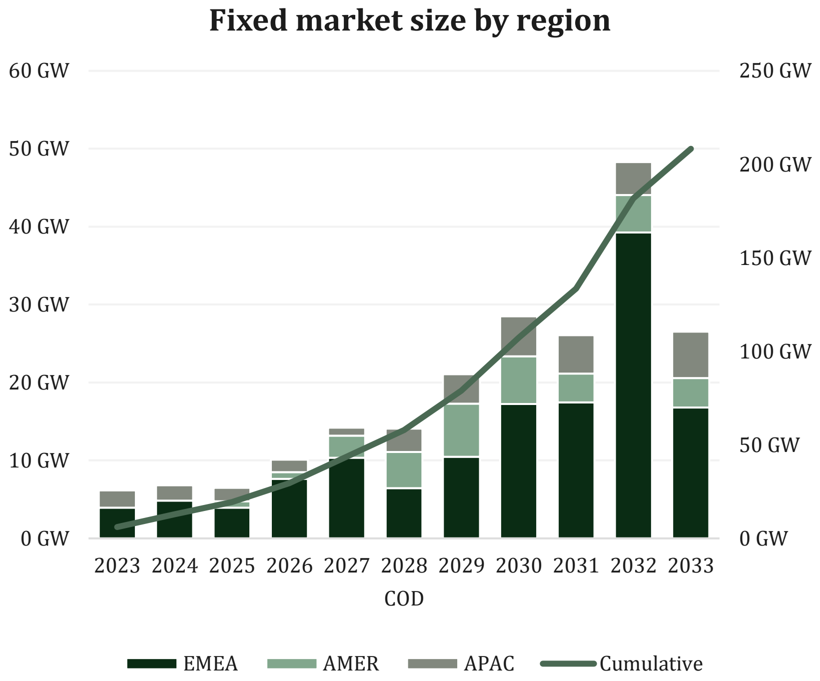
Although most the forecasted capacity is fixed-bottom offshore wind, the share of floating capacity does increase beyond 2030.

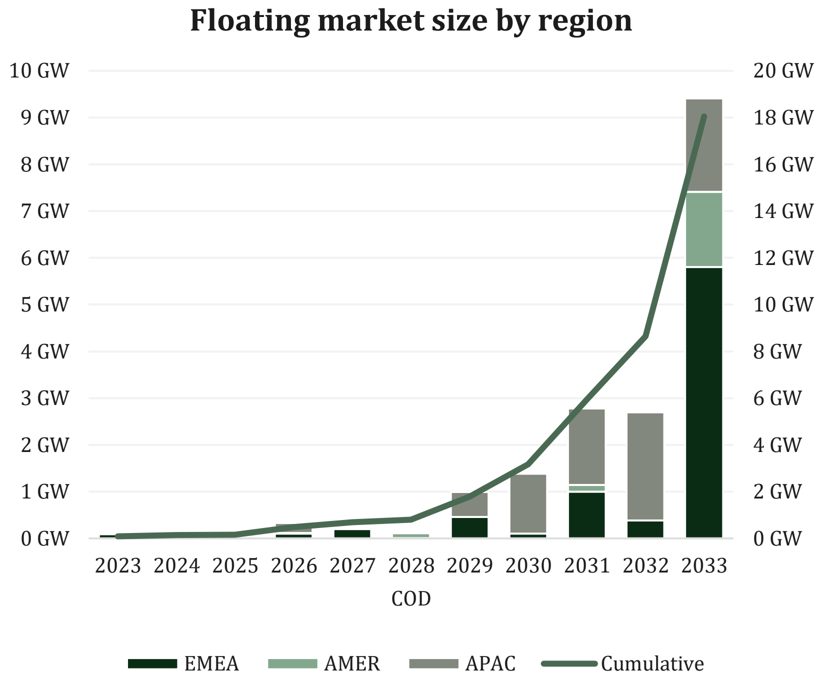
Around 210 GW of fixed bottom offshore wind is forecasted to be installed between 2023 and 2033, excluding China. EMEA is the fixed-bottom offshore wind market leader with 67%, followed by APAC with 17%, and closely followed by the Americas with 16%. Norway contributes 0.7 % of the global fixed bottom capacity with forecasted 1.5 GW by 2033.

Floating offshore wind is still maturing and there are a few roadblocks to unlock the potential. Commercial scale projects are more likely to ahead after 2030.

There are 18 GW of floating wind forecasted to reach commercial operation between 2023 and 2033.Norway is expected to deliver 8% of the global floating forecasted capacity by 2033. However, offtake visibility, regulatory uncertainty, high levelized cost of energy of floating wind, and project bankability are a few key issues that need to be addressed for floating offshore wind to accelerate.







Turbine Supply & Demand

PREPARED BY BRINCKMANN

SCOPE & FOUNDATION

Reliance

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Sources of information

In conducting this report, Brinckmann Group (Brinckmann) has relied on any written documentation provided by the Client, publicly available information, various analyst reports, industry expert interviews, Brinckmann databases and analysis.

Validation

In completing the report, Brinckmann has relied on the integrity of any data that has been provided by the Client and has been obtained through the sources of information as specified in the report.

Brinckmann has assumed that any information provided by the Client is true, accurate and not misleading; consequently, no independent verification of such information has been carried out.

Date of the Report

The Final Draft report was completed on 31.01.2024. Background data used for this report is based on information received from the Client and research and data in Brinckmann's possession as of the aforementioned completion date. Events and conditions which occur after this date may compromise the results in a material way.

Estimation

Due to data availability and the forward-looking nature of Brinckmann's analysis, some of this report's data rely on Brinckmann's estimates. Brinckmann has taken due care in producing the estimates, but Brinckmann takes no responsibility for these estimates or their accuracy.

Disclaimer

Brinckmann reserves the right to revise all findings included in this report if Brinckmann deems it necessary. Brinckmann has no responsibility to update this report for events and circumstances occurring after the completion of this report.

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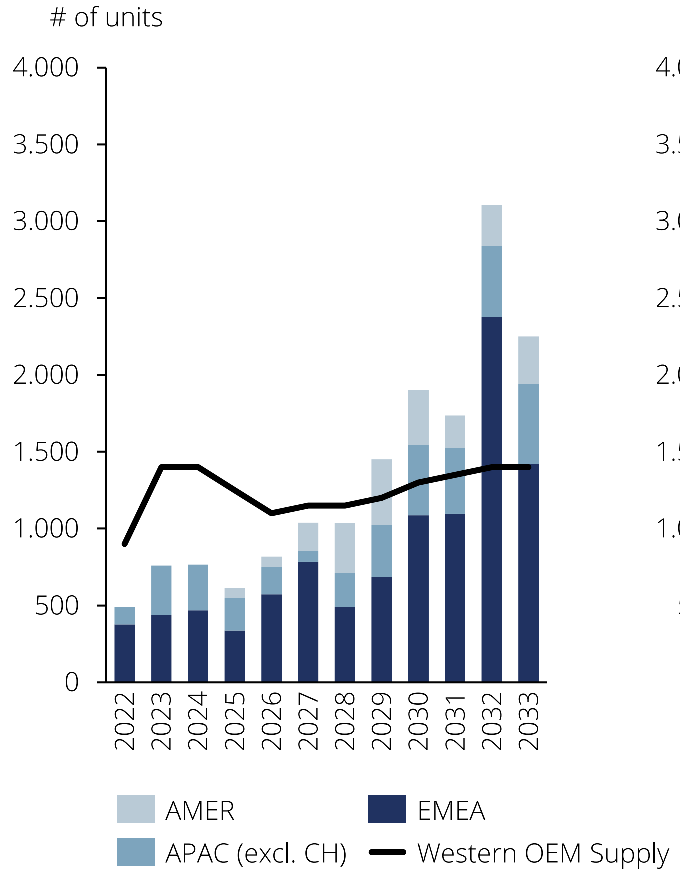
Summary

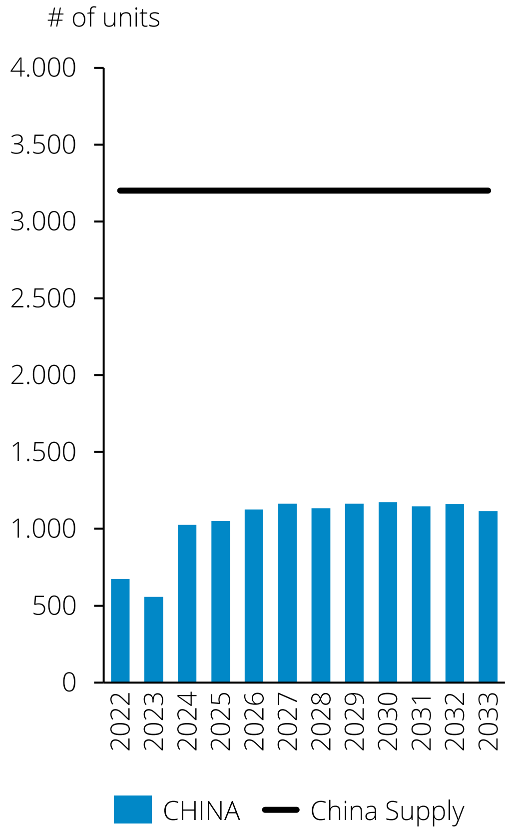
- Significant additions to global (excl. China) nacelle production capacity will be required to meet the expected surge in global offshore demand after 2028 with production capacity concentrated in north-western Europe and Asia Pacific.
- Although Chinese OEMs expanded offshore nacelle capacity during the FiT (Feed-In-tariff) rush in 2021, many players continue to expand capacity. Whereas Western OEMs are expected to expand Offshore nacelle capacity by two folds in the next five years to meet growing demand
- Western turbine manufacturers continue to dominate international markets outside of China, with an order intake growth of +106% from 2020 to 2023. Chinese players are unable to penetrate mature markets due the established position of Western suppliers, and certain policies favoring domestic players.
- Despite an increasing focus on trying to serve markets outside of China, Chinese turbine manufacturers have increased their NPIs since the phase-out of the Feed-in-Tariff (FiT). Without the subsidy scheme, Chinese developers sought larger turbine sizes to lower CAPEX, and the OEMs almost doubled their NPI output from 2021 to 2022 by focusing on increasing turbine sizes and annual energy production (AEP).
- While Western turbine OEMs target 15-20MW platforms for high runner volume in the next five years, Chinese turbines will zoom past 300m rotors and 25MW before the end of this decade.
- As Chinese OEMs are aggressively moving on from one generation to another and, at times, skipping an interim generation. There could be unforeseen product reliability challenges due to a limited track record.
- Recent macro-economic challenges have increased Western OEMs’ turbine pricing which is expected to stay elevated compared to pre-covid levels. Turbine pricing has increased by nearly 30% from pre-covid levels with the pandemic and the war in Ukraine having a significant impact on commodity prices. In certain cases, overall costs went up by nearly 40%.
- China’s strength in steel making and abundant supply chain are major cost-reduction drivers for turbine and component manufacturers. This combined with falling steel prices since the pandemic is working in favor of Chinese turbine manufacturers.

Sources: Brinckmann

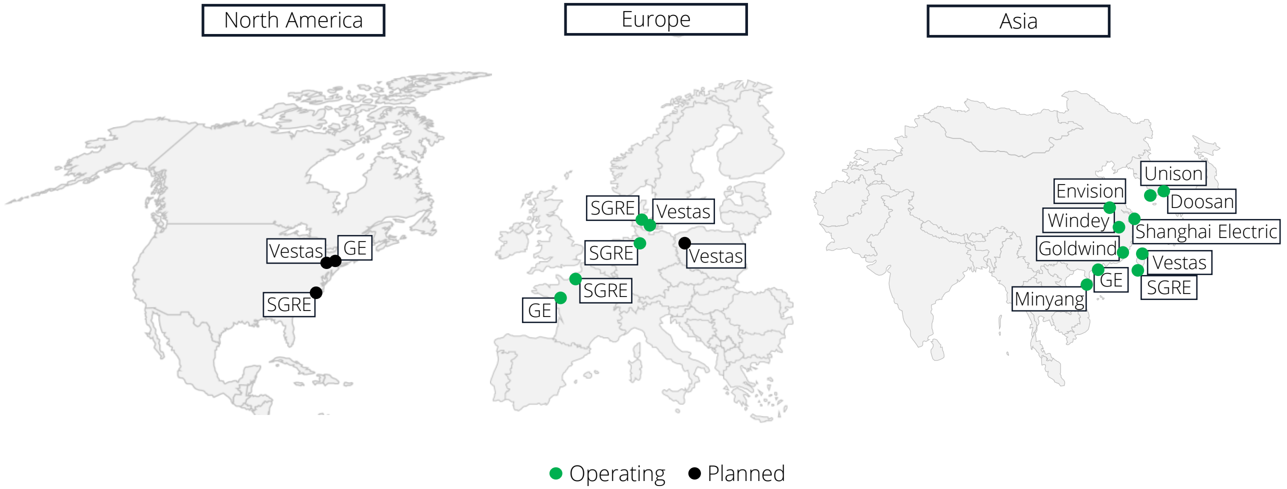
Significant additions to global (excl. China) nacelle production capacity will be required to meet the expected surge in offshore demand after 2028

Global Offshore Market Growth and Nacelle Capacity (2022 to 2033)





Nacelle Supply Chain Footprint (Current and Planned)

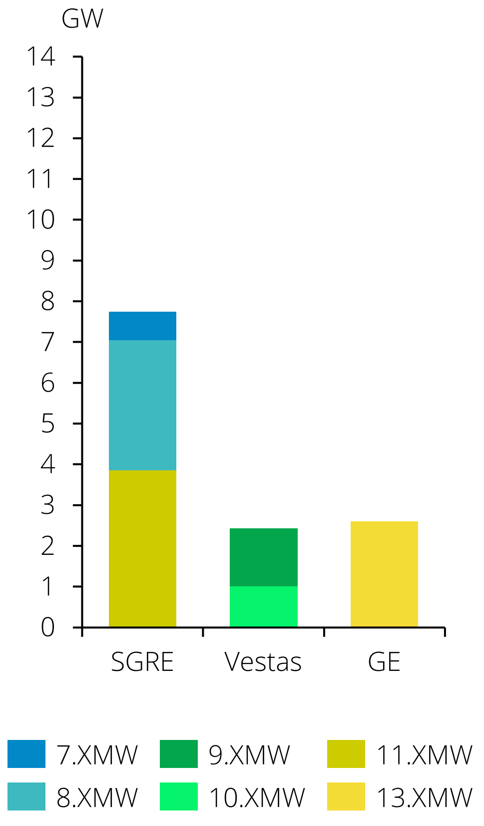


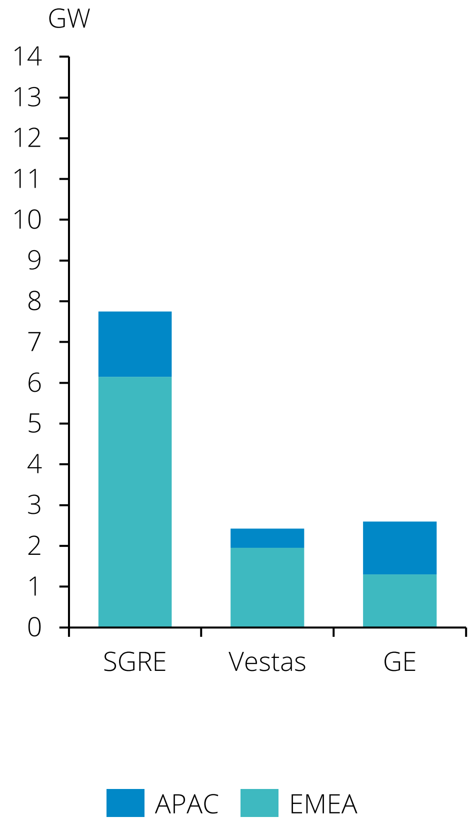
- Global capacity excluding China will be unable to cover demand post 2028. Unless further capacity additions through new facilities or expansion of existing facilities will be built, to meet growing demand, there will be a significant supply bottleneck for Western OEMs in the new decade.
- Production facilities are currently concentrated in north-western Europe and Asia, driven by regional market strengths. All leading Western OEM's are planning to establish production facilities in the USA.
- Chinese OEMs expanded offshore nacelle capacity during the FiT (Feed-In-tariff) rush in 2021, many players continue to expand capacity. The structural overcapacity will likely meet the expected increase in demand over the next decade.

Sources: Brinckmann

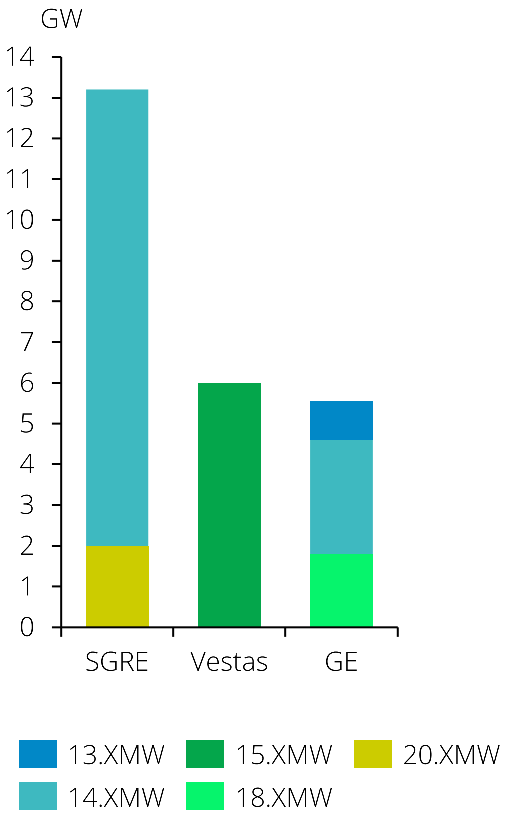
Western OEMs are expected to expand Offshore nacelle capacity by two folds in the next five years

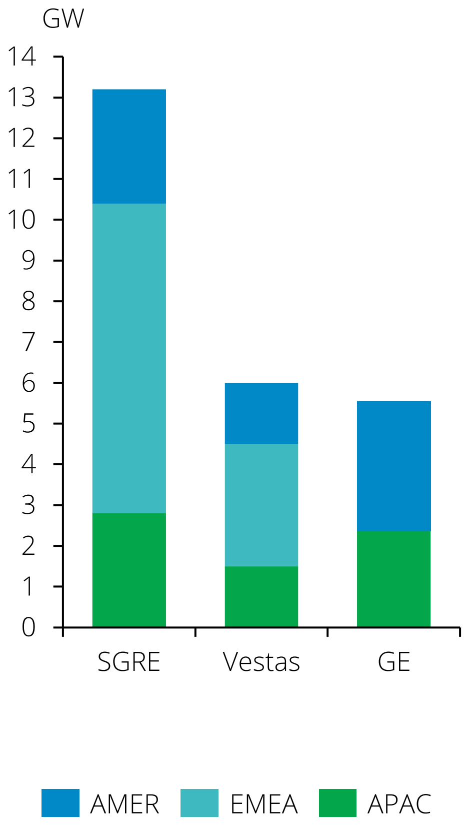
Western Turbine OEMs Current Operational Nacelle Capacity





Western Turbine OEMs Planned Nacelle Capacity

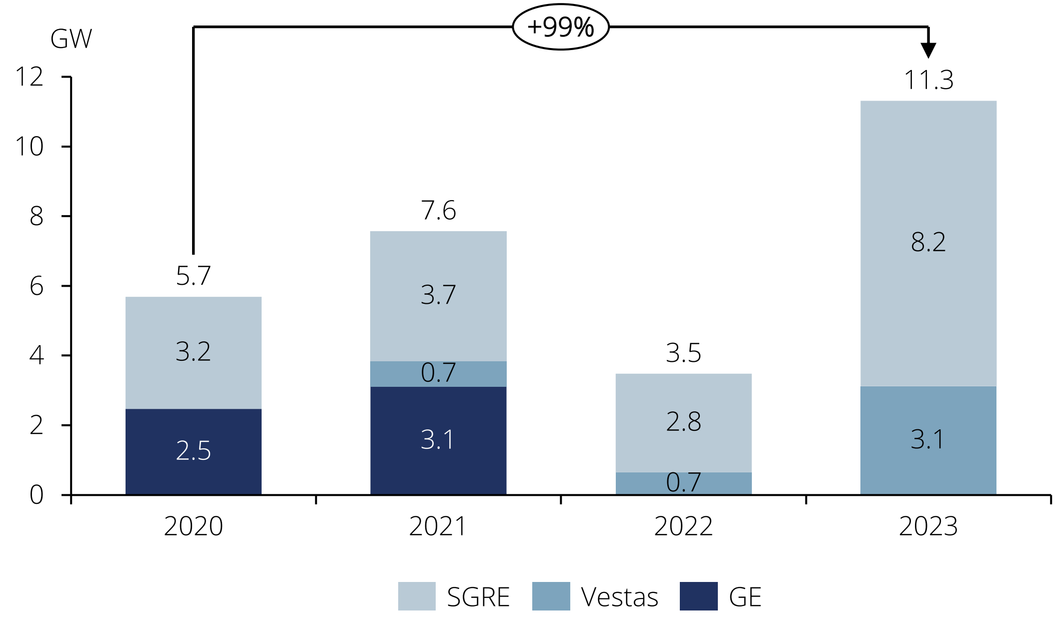




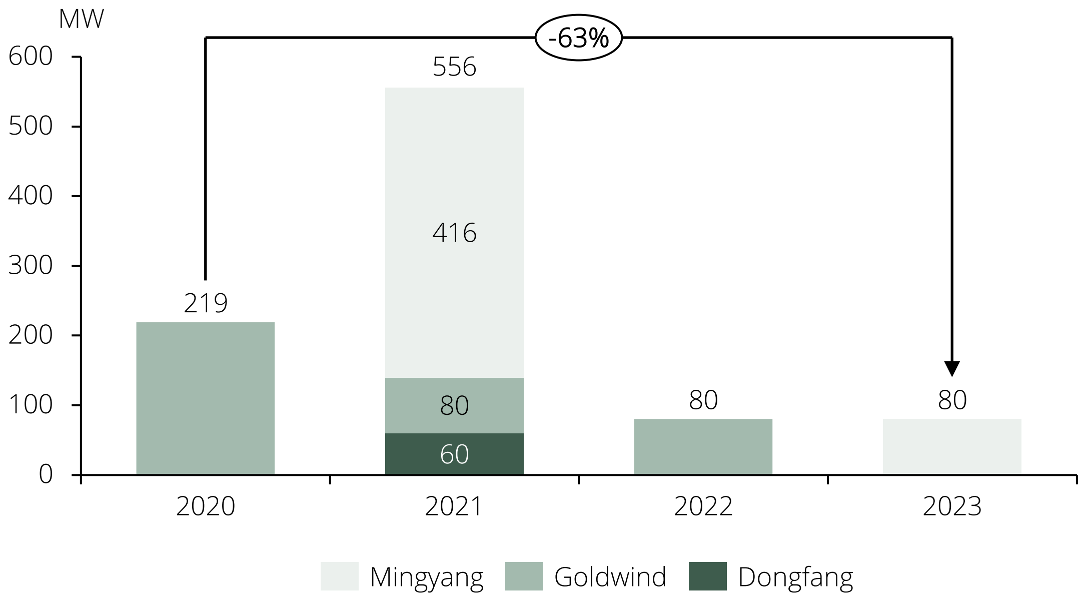
Source: Brinckmann

Western players continue to dominate global offshore orders outside China, securing 11 GW of orders in 2023

Global Offshore Order Intake By Western Turbine OEMs (2020 to 2023-Q4)



Chinese OEMs Global Excluding China Offshore Order Intake (2020 to 2023-Q4)

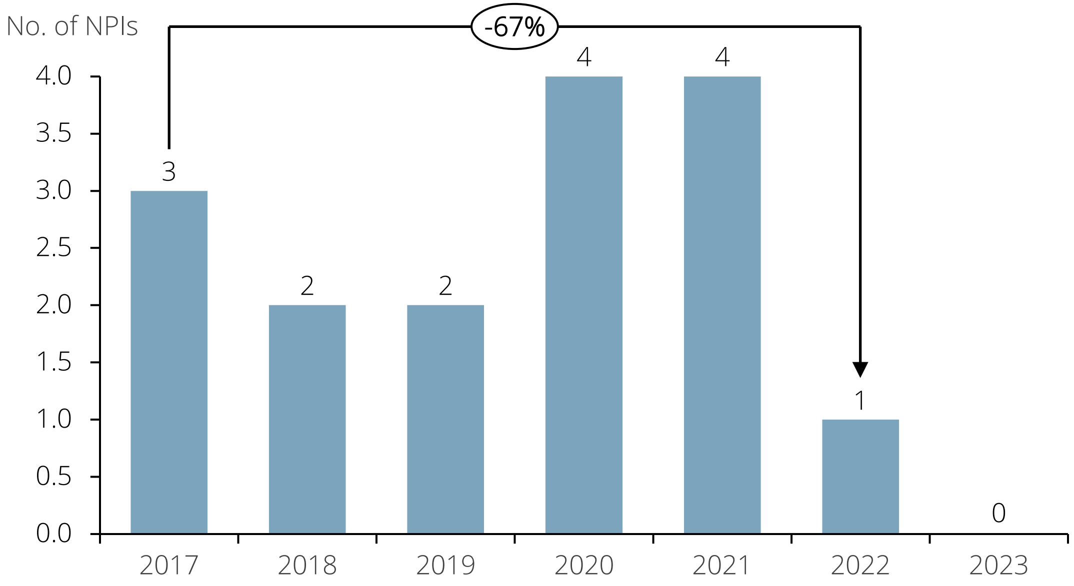


- Western turbine manufacturers continue to dominate international markets outside of China, with an order intake growth of +106% from 2020 to 2023.
- Chinese players are unable to penetrate mature markets where Western OEMs dominate, such as Europe, due to the Western players' established positions, security concerns over critical infrastructure, and policy favouring domestic suppliers.
- In the past few years, Chinese OEMs have mostly been able to win contracts for nearshore projects in Vietnam due to their highly competitive price levels, although these projects use onshore platforms. In 2023, Mingyang secured its first turbine supply deal in South Korea, and plans to deliver 13 6.5MW turbines, after securing twin-hub floating offshore wind demo in the UK in 2022.

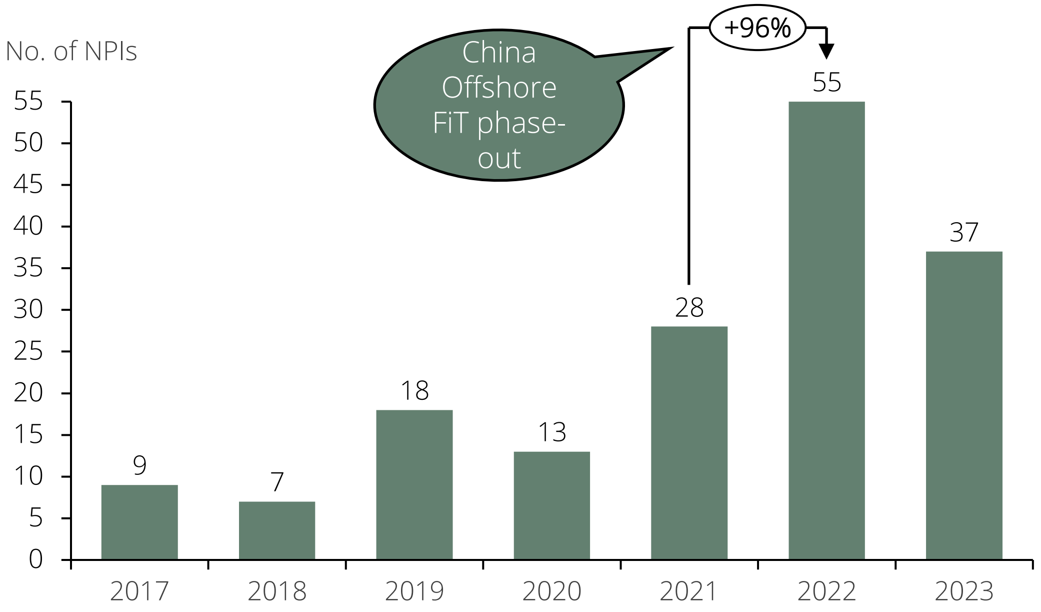
Note: Western Turbine OEMs 2023 orders for Q4 are not yet announced; Chinese international orders only include publicly announced orders.
Sources: Brinckmann

Western OEMs' new product introductions (NPIs) slowed down, while Chinese OEMs' NPIs accelerated until 2022, and declined during 2023

Western Offshore Turbine OEMs NPI Trends 2017-2023 (Q4)



Chinese Offshore Turbine OEMs NPI Trends 2017-2023 (Q4)



- Western turbine manufacturers are slowing down their NPI developments and focusing on industrialising their current platforms due to the increased supply chain and technology costs of NPIs. Cashflow constraints and the push for improvements in profit margins are limiting the capabilities of Western OEMs to compete at the same pace of NPIs when compared to the Chinese counterparts
- In contrast, Chinese turbine manufacturers have increased their NPIs since the phase-out of the Feed-in-Tariff (FiT). Without the subsidy scheme, developers sought larger turbine sizes to lower CAPEX, and the OEMs almost doubled their NPI output from 2021 to 2022 by focusing on increasing turbine sizes and annual energy production (AEP). In addition, the NPI increase was driven by the competition with Western OEMs outside of China, where commercially available turbine technology now ranges between 8 to 18MW.

Note: NPI – New Product Introduction; Western top five OEMs, Chinese top ten OEMs. NPIs include MW rating upgrades as well.

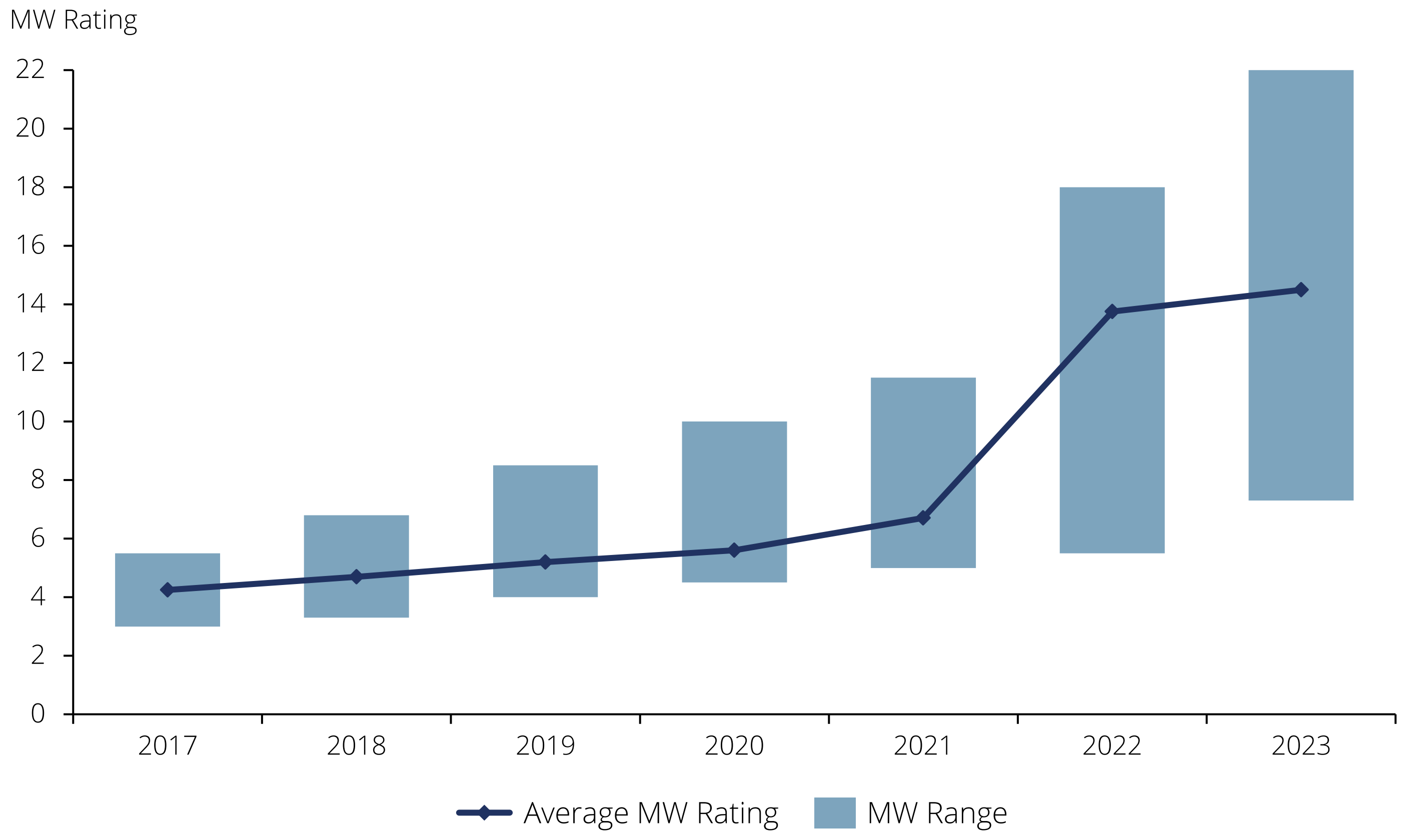
Sources: Brinckmann

Chinese OEMs offshore wind turbine sizes from NPIs doubled in the past three years, many platforms already surpassing 15+MW ratings

Key Takeaways

- In the past three years, New Product Introductions (NPI) have been frenetic in China. This rapid pace of technology iteration is driven by the phase-out of offshore wind FiT (Feed-In-Tariff) by the end of December 2021.
  - During this period, Tier II OEMs picthed 6-10MW turbine technologies, to create a product differentataion strategy against the leading turbine I player who were offering sub-6MW turbine platforms. But that has faded in 2023, as all leading players were offering larger rated turbines.
- Some of the wind turbines announced by the Chinese OEMs in the past year dwarf the Western OEMs' turbine configurations by a huge margin. By the end of 2023, nine Chinese OEMs were offering 23 platforms with ratings >=14MW; While Western OEMs only SGRE has two products and Vestas and GE each that is greter than 14MW.
- Chinese OEMs secured more than 8GW of orders for turbines larger than 10MW offshore turbines by the end of 2023. Leading Chinese OEMs produced the first nacelles of 15+MW turbines in 2023. While Mingyang producd the 18MW nacelle, the largest platform globally todate, for its MySE18-292 with 142m blades.

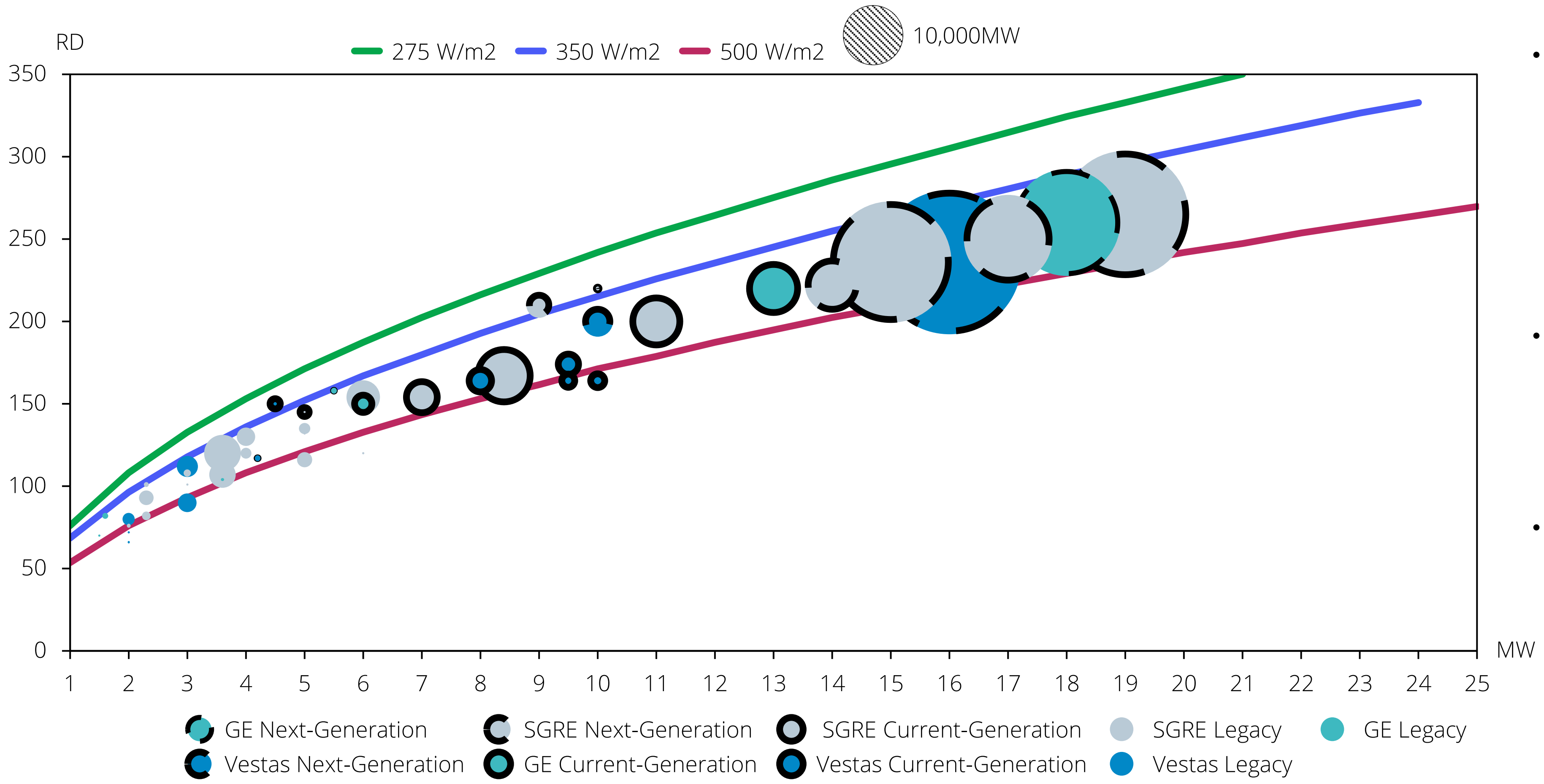
China Offshore NPI MW Rating Trends 2017 to 2023



Source: Brinckmann

Western turbine OEMs target 15-20MW platforms for high runner volume in the next five years

Global excl. China Offshore OEMs Turbine Technology Trends 2013 to 2033

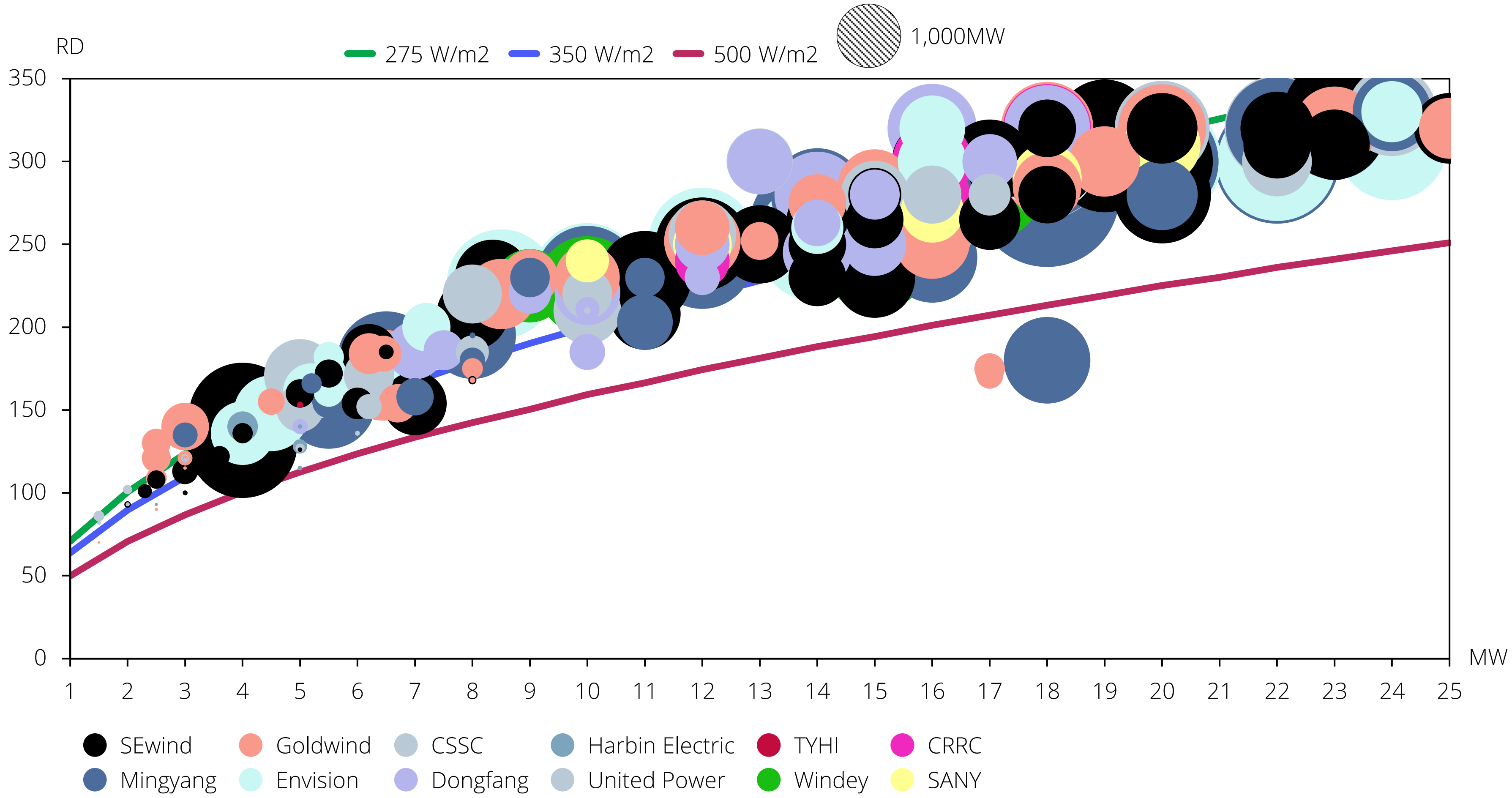


- SGRE continues to build on its solid track record of six generations of offshore technology platforms. The company is gradually scaling up its technologies to mitigate unforeseen technical risks. SGRE is planning to ramp up production of SG 14-222 DD and SG 14-236 DD turbines in 2024.
- Vestas secured their first set of orders on the V236-15MW platform in 2023, with 2.8GW across EU markets. The company also has an additional 12+GW as conditional by the end of 2023.
- GE has recently updated its Haliade-X turbine from 12MW to 14.7MW. However, the company must introduce a competitive next-generation platform soon to not lose sales prospects to its competitors SGRE and Vestas.

Note: The bubbles represent the installed capacity by various turbine models from the turbine OEMs defined in the graphic; RD – Rotor Diameter.
Sources: Brinckmann

Chinese turbines zoom past 300m rotors and 25MW before the end of this decade

China Offshore OEMs Turbine Technology Trends 2013 to 2033



- Chinese turbine manufacturers are increasing turbine ratings at an accelerated pace, with several announcements in the 10+MW segment. By the end of 2025, announcements of up to 25MW and 320m rotor diameter are expected.
- Goldwind has rolled out the first nacelle of the GW252-16MW MS GD (Medium-Speed Gear Drive) turbine, while Envision has launched the EN-252/14MW platform and installed irst commercial project usisng this technology.
- CSSC and Mingyang both have produced their first 18MW nacelles in 2023. Mingyang is planning to instal 1+GW of these turbines during 2024.
  - Mingyang has announced plans to develop an even more powerful wind turbine with a 22MW turbine and a rotor diameter of 310 metres.

Note: The bubbles represent the installed capacity by various turbine models from the turbine OEMs defined in the graphic; RD – Rotor Diameter.
Sources: Brinckmann

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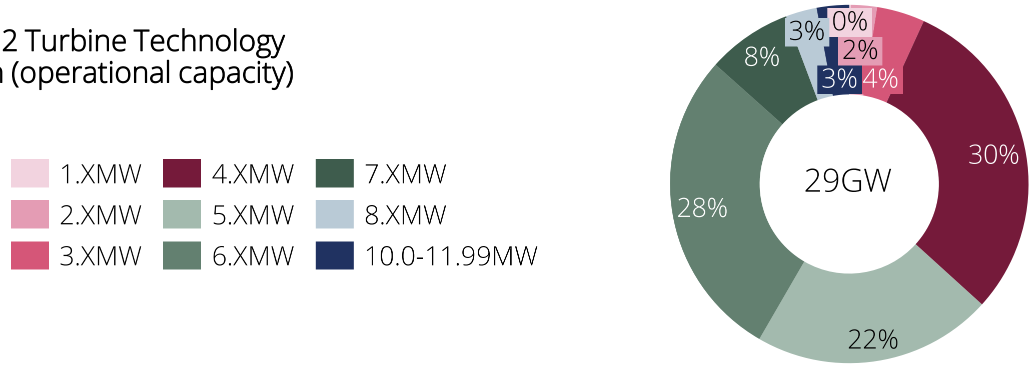
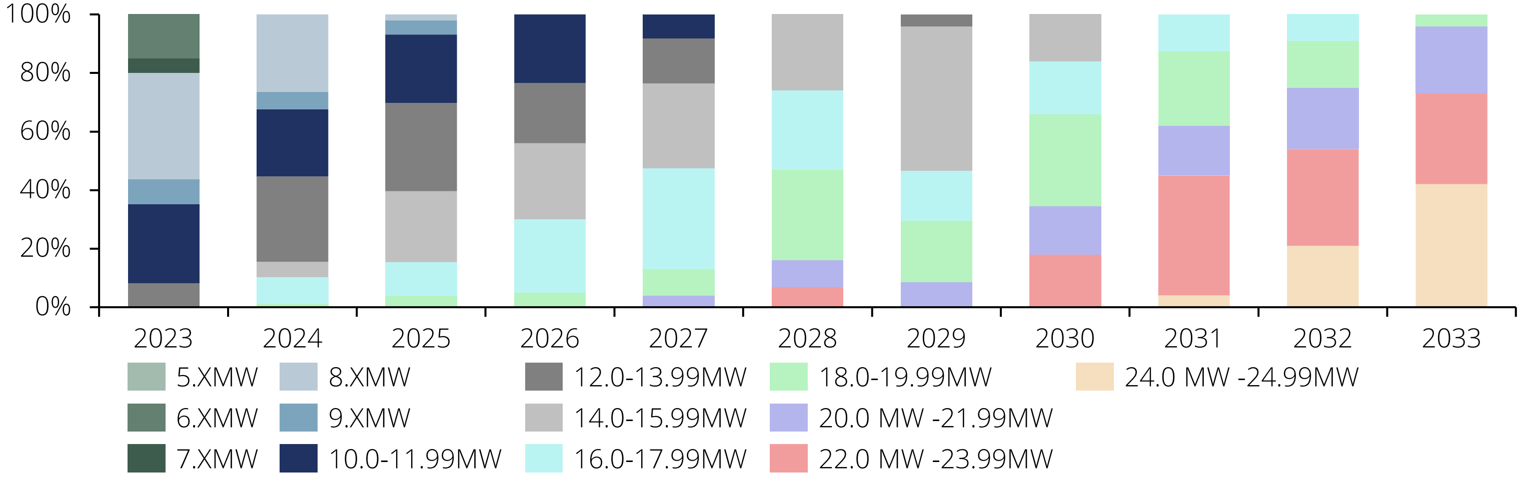
Despite a limited track record on larger rated turbines, Chinese OEMs catapult to next-generation 14-18MW platforms

Chinese Offshore Wind Turbine Technology Segmentation Trends

China YE 2022 Turbine Technology Segmentation (operational capacity)



China Turbine Technology Segmentation Forecast (new installed capacity)



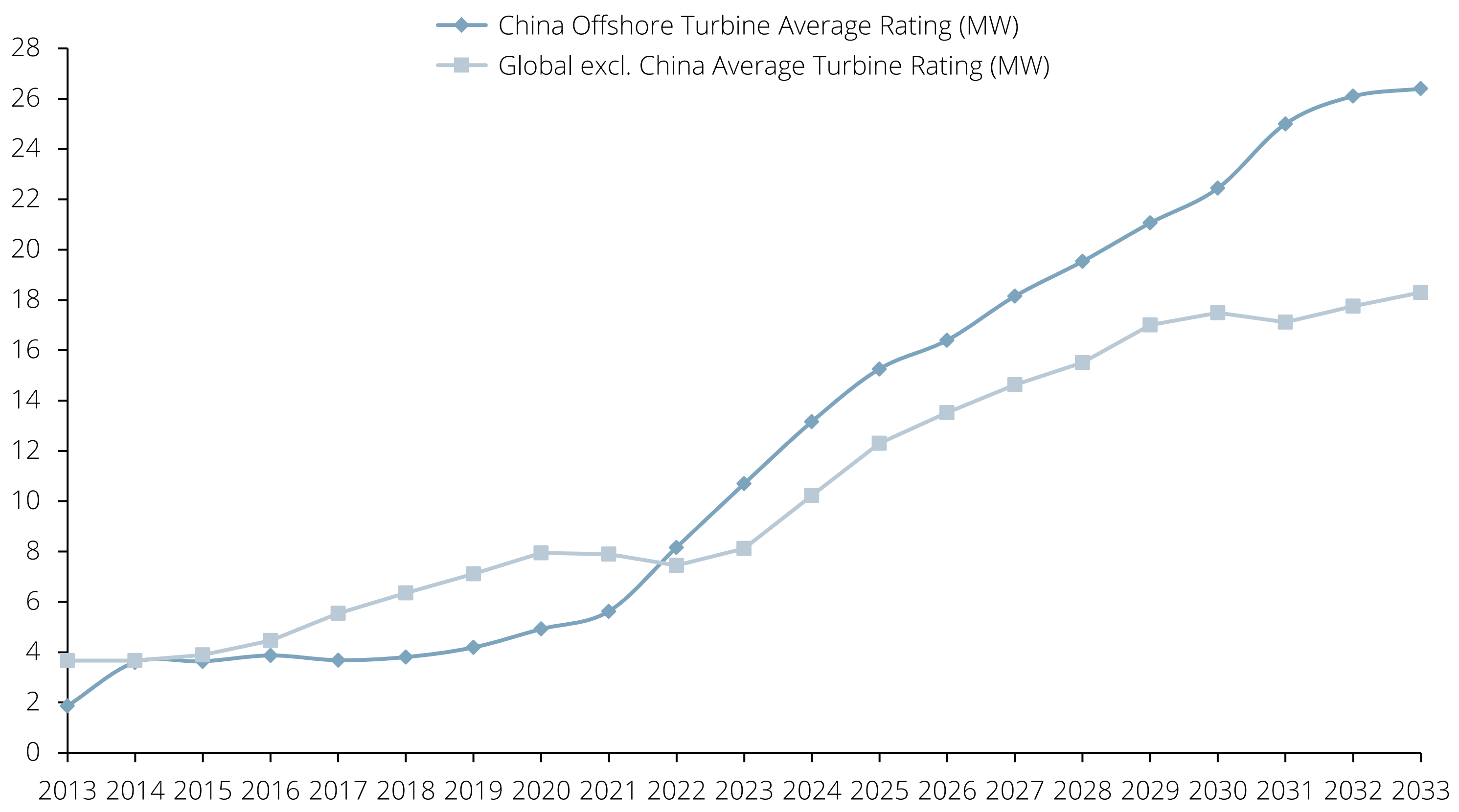
Key Takeaways

- The current operational offshore turbine fleet in China consists mainly of turbines below 10MW, typically ranging from 4 to 6MW.
- Sub-10MW technologies will be largely phased out in China in the next few years. Between 2025 and 2030, turbine installations between 10 and 20MW will dominate, before 20+MW turbines take over post 2030.
- The rapid increase in new product introductions following the FiT phase out in 2022 will accelerate the rising share of double-digit rated turbines.
- China is targeting 50GW of offshore wind capacity by 2025, 200GW by 2030 and 1000GW by 2050, ambitions that are indirectly fuelling the technology race in the country.
- As Chinese OEMs are aggressively moving on from one generation to another and, at times, skipping an interim generation. There could be unforeseen product reliability challenges due to a limited track record.

Sources: Brinckmann

Chinese offshore turbine rating developments are outpacing the rest of the world; This trend is expected to continue into the next-decade

Global Offshore Turbine MW Rating Technology Trends 2013 to 2033



Key Takeaways

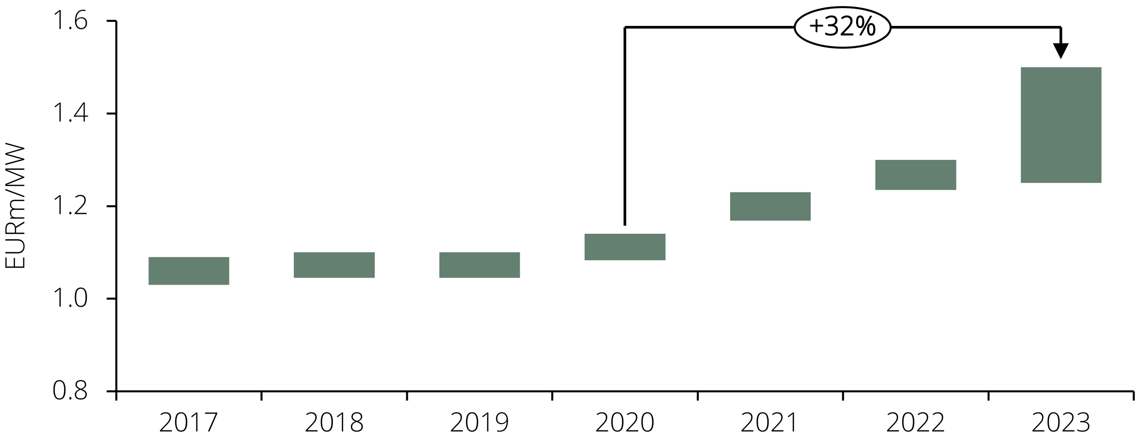
- Western OEMs are aiming to develop platforms with a capacity of 15-20MW and increase production volume in the next five years.
- To lower the costs in the low wind speed regimes, turbine OEMs historically leveraged longer rotors, but now it alone is insufficient. So the turbine OEMs, in tandem with the component suppliers, focus on the longer rotors, larger rated generators, and taller towers.
- Chinese OEMs seek a mass transition to MS GD (Medium-Speed Gear Drive) and carbon fibre blades on their next-generation offshore platforms. Leading players like Goldwind has abandoned its flagship DD technology in favour of MS GD. While Dongfang introduced both DD and MS GD architectures on its 18MW platform.
- China is expected to continue playing a leading role in global offshore wind development, and its domestic turbine manufacturers are poised to maintain their technological edge.
- With a strong government commitment, a growing domestic market, and a focus on innovation, Chinese companies are well-positioned to further advance offshore wind turbine technology and drive down costs.

Sources: Brinckmann

Recent macro-economic challenges have increased Western OEM pricing which is expected to stay elevated compared to pre-covid levels

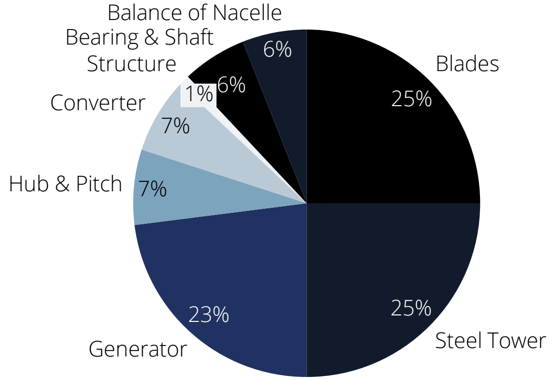
Western Offshore Pricing Trends (2017 to 2023 Q4)

Reflects pricing of commercially available 12-15MW technology for projects with FID in 2023



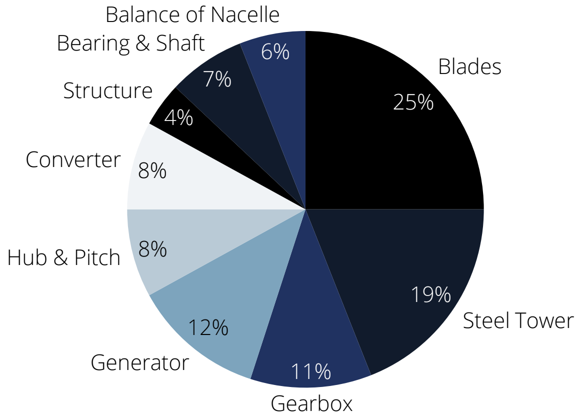
- Average Offshore wind turbine pricing has increased by nearly 30% from pre-covid levels with the pandemic and the war in Ukraine having a significant impact on commodity prices. In certain cases, overall costs went up to 40%.
- Turbine pricing is expected to remain elevated compared to pre-covid levels as certain supply bottlenecks and elevated logistics costs continue to plague the sector.
- Chinese turbine OEMs' current offshore turbine pricing including the tower in the domestic market is less than 50% of their Western peers' global pricing.

Estimated cost distribution of a Direct Drive Turbine



Note: Includes component logistics costs and indicates full turbine supply price

Estimated cost distribution of a Geared Turbine

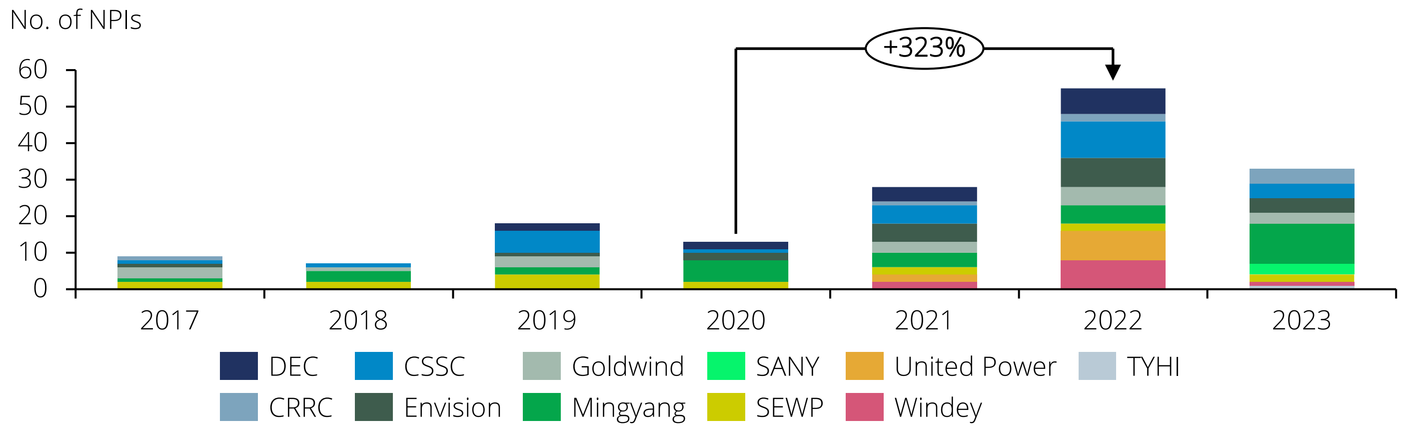


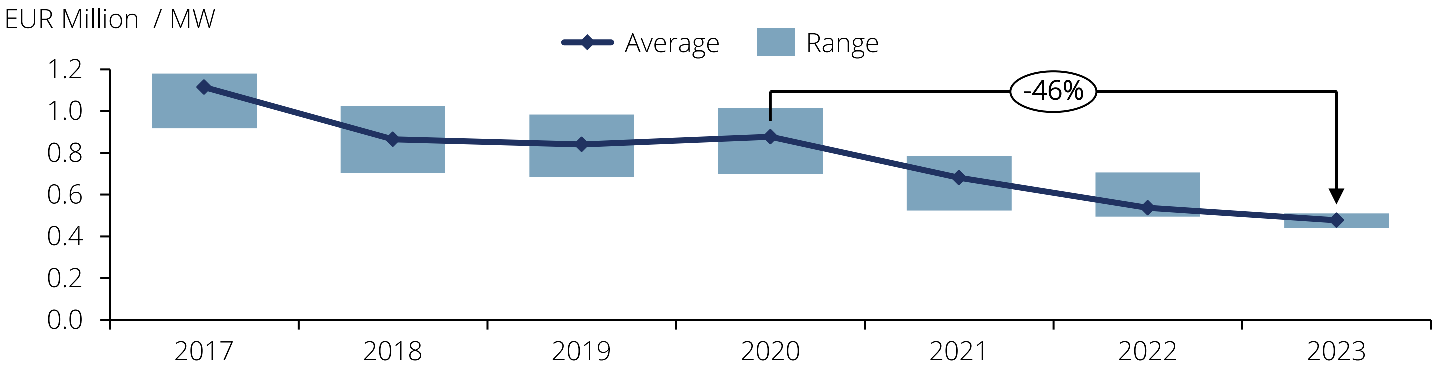
Note: Includes component logistics costs and indicates full turbine supply price

Sources: Brinckmann

Chinese OEMs capitalized on the offshore wind FiT phase-out by launching new platforms

China Offshore New Product Introduction and Turbine Pricing Trends (2017 to 2023)





Note: NPI – New Product Introduction

Source: Brinckmann

Key Takeaways

- Following the FiT phase-out, the Average Selling Price (ASP) of Chinese turbines has declined by nearly 50% from 2020-2023. This cost declines are largely attributed to increasing turbine sizes.
- Chinese offshore wind turbine pricing has experienced a significant decline over the last three years, driven by a combination of factors, including:
  - Increased competition
  - Economies of scale
  - Technology advancements
  - Evolving market dynamics
- Chinese offshore wind developers are facing increasing pressure to optimize their CAPEX to ensure the financial competitiveness of their projects. China's strength in steel making and abundant supply chain are major cost-reduction drivers for turbine and component manufacturers. This combined with falling steel prices since the pandemic is working in favor of Chinese turbine manufactures.
- Such low price levels offered by Chinese OEM create new opportunities in international markets with low wind speed regimes, where Chinese turbines fit the project profiles. However, leading Western developers have so far not sourced Chinese offshore turbines.

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Chinese OEMs compete aggressively by lowering the ASPs to secure orders in a grid parity era

Chinese Turbine OEMs 2022 Offshore Orders and ASP (Average Selling Price)

Source: Brinckmann

Key Takeaways

- Prior to the FiT phase-out, the offshore wind project received a remuneration of CNY 850/MWh (EUR 115/MWh). After this scheme ended in Dec'2021, the projects were at grid parity. No additional remuneration besides the regional coal-based power benchmark price is guaranteed.
    - To compete at those price levels, the developers must lower the CAPEX; Increasing the turbine sizes is one of the biggest levers to sustain the project IRRs (Internal Rate of Returns).
- As the offshore FiTs are phased-out, the turbine ASP in tenders has plummeted by 45% compared to two years ago. However, the prices stablised in 2023, which is partly driven by lower offshore tendered volume and turbine OEMs bidding with 12+MW offshore turbines which were relatively more expensive compared to Sub10MW turbines.
- Dongfang increased the order volume significantly in 2023 compared to 2022 due to partnership with leading developers like Datang and China Three Gorges .
- SEwind seems to have lost its share of new orders due to its switch from DD to MS GD architecture. However, the company is also gearing up with 14-18MW platform.

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Offshore represents the biggest supply chain opportunity in the mid-long term

Global Offshore Capital Components Supply Bottlenecks and Investment Potential Assessment

Component	2023 to 2026	2027 to 2030	2031 to 2033
Nacelles	🟢	🔴	🔴
Blades	🟢	🔴	🔴
Towers	🟢	🟠	🔴
Gearboxes	🟢	🟠	🔴
Converters	🟢	🔴	🔴
Generators	🟢	🔴	🔴
Main Bearings	🟠	🔴	🔴
Pitch and Yaw Bearings	🟢	🔴	🔴

🟢 No bottleneck 🟠 Potential Bottleneck 🔴 Bottleneck

Source: Brinckmann

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Current market conditions are holding back much needed investment in component manufacturing capacity to serve the post 2028 demand surge

Global Excl. China Offshore Wind Bottlenecks

Component	2023-26	2027-30	2031-33
Nacelles	No bottleneck	Bottleneck	Bottleneck
Blades	No bottleneck	Bottleneck	Bottleneck
Towers	No bottleneck	Potential Bottleneck	Bottleneck
Gearboxes	No bottleneck	Potential Bottleneck	Bottleneck
Converters	No bottleneck	Bottleneck	Bottleneck
Generators	No bottleneck	Bottleneck	Bottleneck
Main Bearings	Potential Bottleneck	Bottleneck	Bottleneck
Pitch and Yaw Bearings	No bottleneck	Bottleneck	Bottleneck

No bottleneck — Potential Bottleneck — Bottleneck

Global excl. China Offshore Wind Supply Chain Developments

Nacelles: Western OEM's are expected to expand offshore nacelle capacity by two folds in the next five years, however, global nacelle capacity will fall short of the expected market demand surge post 2028.

- In 2023, several OEM's have announced plans to build new nacelle offshore factories, incl. Vestas in Poland and New Jersey, as well as SGRE and GE in New York. Vestas is also considering building an offshore turbine factory in Scotland once orders firm up.

Blades: Offshore blade supply chain investments have been affected by the uncertain near-term offshore demand, and OEM's are refocusing manufacturing facility expansions in key markets.

- SGRE has cancelled plans to build an offshore wind blade factory in Virginia due to delays in project development in the US market, which has affected order volumes. As a result, blades for their SG14-222 Turbine will now be manufactured in Europe.
- LM Wind Power/GE has paused plans to build an offshore blade manufacturing plant in the UK. Instead, they set the focus on the US with a planned LM facility in New York.

Towers: Leading tower manufactures like CS Wind, GRI Towers and Haizea are planning capacity expansion in Europe and North America to meet the increasing demand. Nevertheless, supply will be challenged post 2028 due to a significant surge in demand.

Gearboxes:. Suppliers are expanding mainly in low cost countries like India and China to serve global demand due to increasing cost pressure. Moderate new investments in European markets are expected, while suppliers are hesitant to reopen facilities in the US market.

Converters: Western players are increasingly outsourcing their converters, demonstrated by Vestas who has sold its converters and controls business to KK Wind Solutions in 2023. As a result, independent suppliers are increasing market share, who might hold back additional capacity investments unless major component bottlenecks are closed.

Main Bearings: Due to the dedicated asset nature of offshore wind bearing production facilities, sufficient turbine demand will need to be established first for suppliers to invest in new facilities. Unless the nacelle bottleneck can be closed by sufficient capacity expansion, investments will largely be held back.

Pitch and Yaw Bearings: Similar market dynamics can be observed for pitch and yaw bearings, though Western OEMs are increasingly relying on Chinese suppliers, increasing their sourcing demographics.

Sources: Brinckmann

Despite excess structural capacity Chinese p-layers continune expansion spree across key offshore provinces

China Offshore Wind Supply Chain Developments

Component	2023-26	2027-30	2031-33
Nacelles	🟢	🟢	🟢
Blades	🟢	🟢	🟢
Towers	🟢	🟢	🟢
Gearboxes	🟢	🟢	🟢
Converters	🟢	🟢	🟢
Generators	🟢	🟢	🟢
Main Bearings	🟠	🟢	🟢
Pitch and Yaw Bearings	🟢	🟢	🟢

🟢 No bottleneck 🟠 Potential Bottleneck 🔴 Bottleneck

China Offshore Wind Supply Chain Developments

- General supply chain status: Chinese players have built capacity to meet the surge in demand in 2021 (15GW). After the FiT phase-out, the installation activity declined in 2022 (5GW) and 2023 (7GW). However, the turbine OEMs and component suppliers have expanded their manufacturing capacity across most capital components. We do not foresee any supply bottlenecks in China.
    - Due to this excess capacity and lower prices, Chinese OEMs would be well-positioned to address demand in neighbouring APAC markets like South Korea, Vietnam and Japan. Their technology offerings in the low-wind speed regimes would pave the way in these regional markets where the wind speeds are similar to those of Chinese provinces.
- Nacelles: In 2024, 11 wind turbine OEMs are active in China, of which 10 installed turbines in offshore waters. CRRC and Windey installed their first offshore turbines in 2022 and 2023, respectively. SANY has not installed any offshore turbines, but the company has already started manufacturing low-wind speed offshore turbines in Shandong. Besides the conventional markets, like Guangdong, Fujian, and Jiangsu, OEMs are now expanding capacity in new markets like Shandong, Zhejiang, and Guangxi. The nacelle supply capacity is 3x more than the current annual demand. We do not foresee any supply bottlenecks.
- Gearboxes: Many leading companies are now expanding capacity. NGC, DeLiJia, NFAIC, and Chongqing are expanding their capacity to meet the increasing demand. As the turbine sizes onshore are approaching 8-10MW, these technologies are also well suited to the offshore technologies in low-wind speed provinces where 10-12MW turbines are deployed. So, the suppliers would be in a position to meet the demand.
- Main Bearings: It's the only component in the wind turbine, where the Chinese OEMs are dependent on Western suppliers to meet a significant portion of their demand. However, in China, NPI is much faster, and Western suppliers may be constrained in building capacity to meet the demand. So, there could be potential bottlenecks for tapered roller bearings in China. Many domestic Chinese suppliers are investing in technology, R&D, and manufacturing capacity, so in the next few years, the bottlenecks will be alleviated.

Sources: Brinckmann

What can developers leverage to succeed in auction systems?

1 Pick the right battles

- A delicate balance between market share and value creation. i.e., Internal Rate of Return (IRR) of 150 to 300bps above WACC (Weighted Average Cost of Capital)
- Avoid negative bidding and competing with Oil and Gas companies. These firms usually are blessed with deep pockets; they indulge in price wars.

2 Demonstrate value over low bidding price

- Besides focusing on low bidding prices, try to engage with regulators and emphasise value-add. i.e., local job creation and boosting economic activity.
- Stronger local stakeholders' engagement, like fisheries and other relevant parties. Proactively addressing their concerns to avoid any future pitfalls.
- Local content compliance in future projects. Also, considering the start-up challenges.

3 Factoring in future cost uncertainties

- In the past eight years developers were used to significant price declines in turbines and components. But COVID, commodity inflation, and the Ukraine crisis unfolded a series of challenges for developers. Developers are on the brink of cancelling projects, because of failed negotiations with regulators.
- Factor in a cushion in the bidding prices accounting for uncertainties.

4 Sustainability and Recyclability

- Be a front runner in procuring recyclable components like blades and towers.
- Focus on future material selection with higher recyclability and energy efficiency.
- Increase supply chain transparency and information sharing.
- Increase supplier engagement and responsibility.

Sources: Brinckmann

How can developers mitigate the supply chain risks?

1

Early engagement with strategic partners

- Developers must identify the critical component shortages and closely work with the suppliers to lock in manufacturing capacity.
- Early engagement with suppliers to open up facilities in new geographies.
- These new facilities typically take three to five years to reach optimum utilisation. Become a preferred anchor customer for new plants.

2

Encourage suppliers in harvesting economies of scale

- Close partnership with turbine OEMs on next-generation turbine platforms. A cautious upgrade considering the supply chain impact on the suppliers.
- The frenetic pace of new product introduction has stressed the upstream players. So developers must carefully plan the technology choices that meet the site characteristics and also the supply chain deliverability.
- Supply chain ramp-up of new platforms and new facilities or transitions to avoid jeopardising the project schedules.

3

Close collaboration with regulators on local content policies

- As new markets open up, many countries seek local content policies.
- Close collaboration with policymakers and setting the expectations right regarding local content.
- Having a long-term vision on cost developments and choosing the best-cost manufacturing footprint vs local content markets

Sources: Brinckmann

Fixed Foundation Supply & Demand

Foundation type identification

Sustainability is our business

Fixed Foundation Selection

Foundation Overview

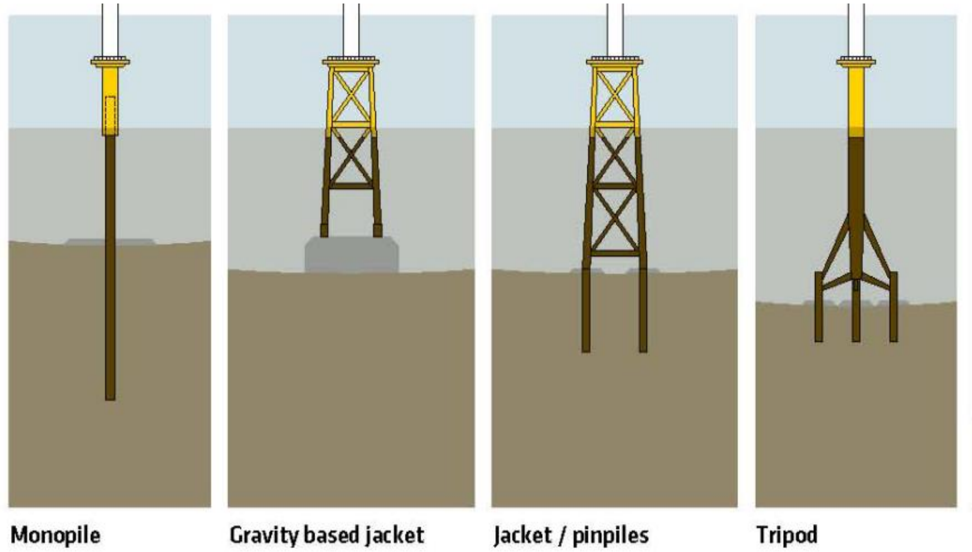
The selection of foundations utilised for an offshore wind project depends on several factors, including water depth, wind turbine size, wind and wave impact, seabed composition and ice conditions, which impact both the viability of the foundation type as well as the LCOE produced. Therefore, the suitability of foundation choice can vary from project to project. For this work package, the track record, technological readiness, cost and suitability to site characteristics of fixed projects in Norway have been analysed to determine the most suitable foundation type to be used on Norwegian fixed offshore wind development areas.

The main fixed foundation types are monopiles, jackets, gravity-based jackets and tripod foundations (see right). Though the latter two account for a negligible proportion of current installed offshore wind farm foundations, with monopiles dominating installed foundation type. Monopiles are currently the most common and cost-effective choice for offshore wind foundations. They are relatively straightforward to fabricate, inexpensive to manufacture and efficient to transport.

Jackets provide a viable alternative when suitability of monopiles reaches a limit, e.g. the technical suitability of soft soil or very hard soil, fabrication feasibility of large and long monopile for large water depths.

Fixed foundations can typically accommodate turbines in water depths up to 70m, after which point, floating foundations become a relevant solution. The boundary of the optimal depth for fixed-bottom foundations, however, is being pushed as markets and industry work to address foundation restrictions as increased demand for offshore increases the need for offshore wind in deeper waters.

<u>Top fixed foundations for offshore wind projects</u>



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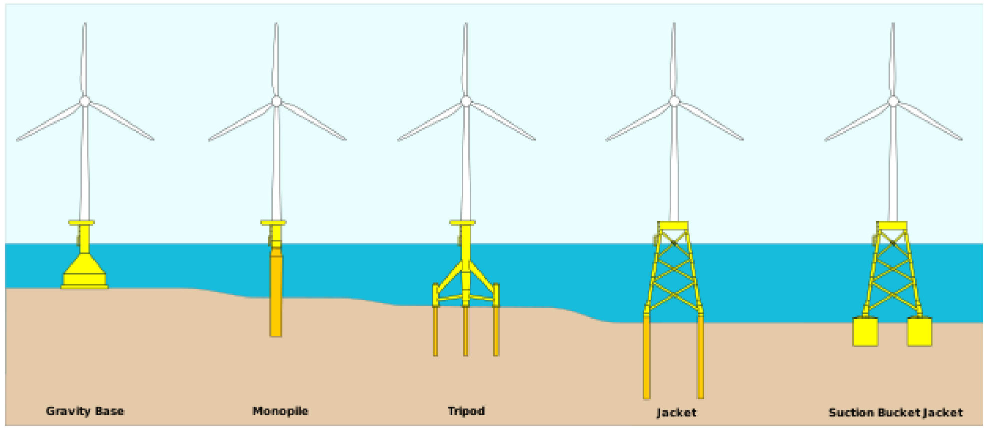


Fixed Foundation Selection

There are numerous factors that should be considered to ensure the most suitable foundation type is chosen.

There are a breadth of factors that influence foundation type chosen for offshore wind projects. ERM have carried out a high-level analysis to determine which foundation type would likely be more suitable for fixed offshore wind projects in Norway, providing a breakdown of key factors including cost, water depth, turbine size and seabed conditions. While this analysis provides the industry with information to guide foundation choice, further studies are needed to provide a complete and thorough investigation of the most suitable foundation type at the project concept design and selection phase. Where data is available, the following factors should be considered, and the importance of each factor adjusted according to the specific demands of the project.

- Cost
- Water depth
- Proposed turbines
- Seabed conditions
- Metocean conditions
- Local fabrication capabilities
- T&I strategies
- O&M strategies
- Decommissioning concerns
- Cost
- Supply chain
- Environmental impact, i.e. noise, biodiversity impacts
- Sustainability

Track record:

To date, monopiles account for 72% of installed foundations Globally. Jackets account for 15% of Global foundation installations. Monopiles account for an even larger share of installed foundations in Europe at 80%, compared to jackets (11%)*.

Cost:

Monopile foundations are popular as they are straightforward to fabricate, relatively inexpensive to manufacture, they have low transport and installation costs and a low risk profile due to their flawless track record. However, the cost gap may be reduced when alternative solutions mature.

Jacket foundations are relatively economical in terms of steel consumption; however, they can be costly in terms of extensive steel work, storage, logistics and installation and jackets utilised at water depths over 60 m are likely to incur unfeasible costs. However, when compared to monopiles, jacket foundations currently outperform monopile foundations in terms of economic benefits and structural performance in deep waters.

Fixed Foundation Selection

Water Depth

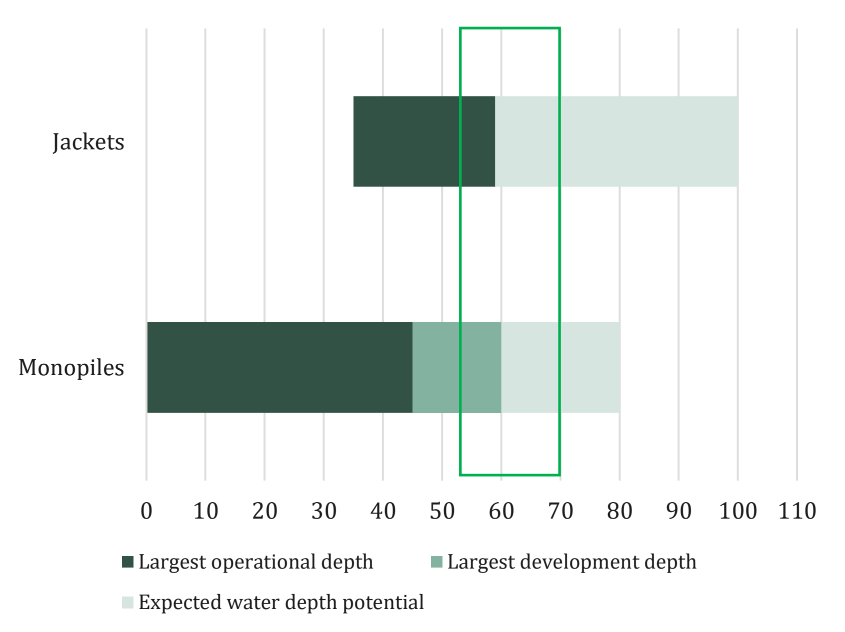
Jackets are used for deeper waters or challenging seabed conditions and are economically more feasible at increasing depths, thus they are not usually recommended for shallower waters. Jackets are a cost competitive alternative when monopiles are not suitable or less competitive for deeper waters beyond 50m. Equally, a transition depth is reached around 70m, where floating foundations are likely deemed more economical, depending on individual site characteristics.

In 2023, the World's deepest offshore wind jacket, utilising suction bucket technology, was installed at 58.6m at the Seagreen project in Scotland. Due to the research experience of offshore oil and gas industry technology, it is also argued that jacket foundations will be a superior alternative for depths of up to 80m offshore and even potentially up to 100m if the demand, cost and site conditions were to allow.

Monopiles are more economical in shallower waters than deeper water. The deepest monopile to date has been installed at 45m, at Parkwind's Arcadis Ost 1 project off the coast of Germany. The project utilised the largest monopile foundations ever installed to date, supporting a 9.5 MW turbine and weighing more than 2,000 tonnes with a diameter of up to 9.5m and a length of up to 100m. Yet even bigger monopiles are in production. Manufacturer SeAH are constructing a XXL monopile manufacturing facility at Teeside, UK. The factory will be able to produce up to 200 monopiles annually, at lengths of 120m, diameter of 15.5m and weighing 3,000 tonnes.

It is widely believed that as monopiles advance, they will be suitable for depths of up to 60 – 70m, though the timeline of when these monopiles could be built and ready for utilisation is uncertain.

**Source: ERM's GRIP database.*



Water depth ranges at which offshore wind foundations might operate
Box represents water depth range at SN2 site.
Source: ERM

Data
Monopiles: Operational – Parkwind – 45m; Development - Inch Cape – 55m; Expected – Industry views
Jacket: Operational – Seagreen – 59.6m; Development – Seagreen 1A - 59m, Expected – industry views

Fixed Foundation Selection

Turbine characteristics and seabed conditions are key factors which influence foundation choice.

WTG size:

Larger turbines will challenge the technical feasibility of the monopile foundation, especially in waters deeper than 50m. Firstly, wave action will increasingly interfere with the dynamics of the turbine structure. Secondly, the substantial weight will require lifting vessels with upgraded crane capacity and bigger hammers are needed to install the very large diameter piles. The size of the monopiles that can be installed is currently limited by the vessels lifting capacity and hammer size available in the market. It's argued that as WTG size increases to 15 – 20 MW, the water depth limit of monopiles would be restricted to 50 - 55m.

However, due to cost efficiency, it's likely that the limiting depth and maximum turbine size for monopile foundations will be pushed as far as possible. In 2023 a MOU was signed between TSC and CMIC Ocean EN-Tech Holding Co to create an improved solution for monopile installation to cope with turbines on between 15 – 20 MW. Additionally, the Inch Cape offshore wind project, which is situated in water depths of up to 55m, will utilise Vestas V236-15.0 MW turbines on XXL monopiles supplied by Dajin Offshore Heavy Industry and Guangzhou Wenchong Shipyard Heavy Industry. The monopile foundations will have a diameter of 11.5m, a length of 110m, and will weigh 2,700 tonnes.

The ability of monopiles to reach larger water depths while supporting 15+ MW at depths of up to 70m depends on how far current technological boundaries can be pushed. Meanwhile, jacket foundations which can support 15+ MW are already in existence and will become more in demand when projects are developed in areas where the current limit for feasible monopile design is met.

Seabed conditions:

Monopiles are advantageous when analysing suitability to seabed conditions as they can be used in a variety of conditions, including stone, sand, or clay where there is an underlying solid bed. Monopiles are not suitable for shallow bedrock or strata with boulders, cobbles, or coarse gravel. Monopiles are driven in to the seabed and can be installed in rocky seabed's, through pre-drilling (seen in France) or by drive-drill-drive process (seen in the UK). However, this can increase the cost of installation and in these cases, jackets could be deemed more economical and less risky.

Jackets with piles prefer seabed conditions including stiff clays and medium to dense sands. Installation is possible in softer silts and clay, and in very soft sediments overlying stiffer soils or bedrock. They are less well suited for locations with many boulders. Jackets with pin piles need to be driven into the ground, but to a lesser depth than monopiles. Jackets can tolerate some obstructions better than monopiles. Jackets with suction buckets prefer seabed conditions of medium stiff clays and fine to medium sand. They are not suitable for strata with cobbles, boulders, or coarse gravel layers or in very soft soils.

Fixed Foundation Suitability – Norway Offshore Wind Development Areas

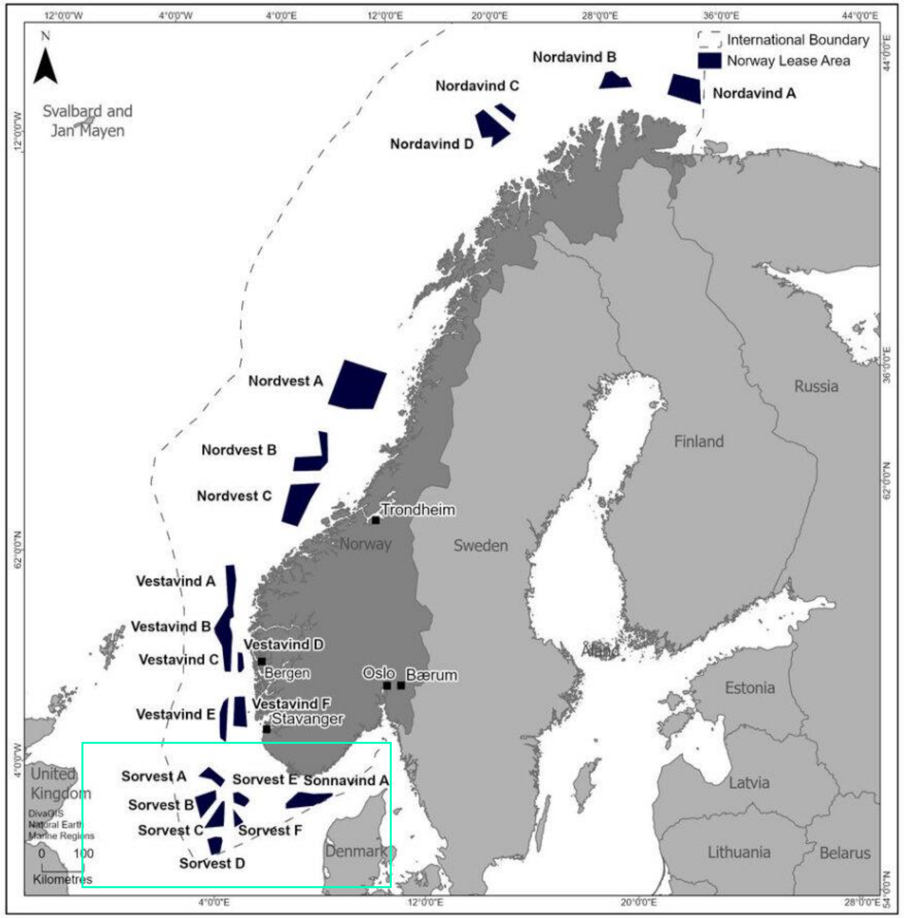
Eight fixed-bottom projects currently planned in Norway, all located off the south-west coast.

Site details

The water depths of the fixed projects announced in Norway range from 50 to 80m. Some project areas have depths in the ‘cross-over’ between the optimal depths for bottom-fixed (0 – 70 metres) and floating (100 – 300 metres) technology. The Government have declared that both fixed and floating technologies can be relevant in these areas. According to Offshore Wind Design AS, the soil in the close by oil field where soil investigations have been done previously is dominated by loose and fine sand in the upper levels and dense to very dense sand deeper down. There are also areas with silty sand, gravel and hard to very hard clay. Even if there are occasional channels with softer clay, the soil conditions are generally characterized as sandy.

Project	Technology	Minimum water depth (m)	Maximum water depth (m)	Average water depth (m)
Sørlige Nordsjø II Phase 1 and 2	**Fixed**	**53**	**70**	**60**
Sonnavind A	Fixed and floating	70	390	200
Southwest A	Fixed and floating	65	95	80
Southwest B	**Fixed**	**50**	**80**	**65**
Southwest C	**Fixed**	**55**	**75**	**60**
Southwest D	Fixed and floating	60	80	70
Southwest E	Fixed and floating	60	90	75
Southwest F	**Fixed**	**55**	**65**	**60**

Source: The Norwegian Water Resources and Energy Directorate (NVE)



Source: ERM GIS team

Summary

Based on estimated water depth and site characteristics, jackets are the most likely fixed foundation type expected to be used on Norwegian offshore wind development areas

This analysis has assessed the suitability of jackets and monopiles to be used for fixed offshore wind projects located in Norway. Water depth, turbine size and site characteristics were the key factors which fed into this analysis, as these are seen as some of the most important factors influencing the decision making of foundation type. However, there are rapid changes to existing technologies, and new technologies on the horizon, pushing the existing limitations of foundations available today.

Additionally, as mentioned previously, there are a breadth of additional factors to consider which also influence foundation type. When undertaking a thorough investigation of foundation type in the concept design and selection phase, factors including, but not limited to metocean conditions, turbine specification, local fabrication capabilities and T&I and O&M strategies should also be considered. The importance of each factor can be adjusted according to the specific demands of the project.

<u>Summary of ERM findings:</u>

	Currently suitable for water depths > 50m	Largest depth installed at	Largest installed turbine capacity*	Readiness at up to 70m	Site suitability
Jackets	✓	59m	10 MW	Expected soon	✓
Monopiles	✗	45m	9.5 MW	Uncertain timeline	✗

*at largest water depth

Norway's SN2 site is characterised by water depths of 53m – 70m. Monopiles are usually the more cost-effective option, though in the case of Norway, this would generate more expensive development due to the large water depth of planned projects. The deepest monopile installed to date is at 45m whilst supporting a 9.5 MW turbine. Monopiles have not been tested beyond 45m and it is unknown whether monopiles can be built to sustain conditions as deeper levels. Meanwhile, jackets are currently the readiest foundation for depths of 53m – 70m and have been installed at water depths of up to 59m whilst supporting a 10 MW turbine.

Even if the suitability of monopiles for larger water depths evolves quickly with the development of XXL monopiles manufactures, this may not be applicable for Sørlige Nordsjø II Phase 1 and 2 projects in the planned timeline, with an estimated COD of 2032 and 2033, respectively.

Sørlige Nordsjø II Phase 1 and 2 are generally characterised as sandy, with areas with silty sand, gravel and hard to very hard clay. Both foundation types are deemed suitable for these characteristics. However, this analysis is based on information available to date. Any additional information released on site characteristics should be further analysed to confirm that jacket foundations are suitable to use based on site-specific ground conditions.

Fixed foundation manufacturers and supply capacity

Sustainability is our business

Suppliers: Jacket Foundation

Aker Solutions – Verdal

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Aker Soltions ASA
Facility Location(s)	Verdal, Norway
Number of OSW Jackets Completed	48
Number of Projects Completed	1
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	-
Estimated Maximum Annual Capacity (tonnes/year)	13,867
Production Area (m^2)	30,000

Supplier introduction

The yard in Verdal specialises in fabricating fit-for-purpose steel substructures and jackets for offshore developments. The yard opened in 1970 and comprises 65,000m², of which 30,000m² are indoor fabrication facilities. The main product from Verdal is steel jackets for oil rigs. It was awarded the contract for 48 Jackets at Nordsee Ost in 2010.

Bladt Industries – Lindø

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Bladt Industries A/S
Facility Location(s)	Lindø, Denmark
Number of OSW Jackets Completed	112
Number of Projects Completed	3
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	-
Estimated Maximum Annual Capacity (tonnes/year)	18,489
Production Area (m^2)	40,000

Supplier introduction

Bladt Industries have operated at Odense Port (Lindø) since 2013. The company was established in 1965 and has a history in O&G but now focuses exclusively on production of foundations, transition pieces and substations for offshore wind projects. The site includes 40,000m² of roofed facilities, including workshops, paint shops, and office space. One of the four workshops is of 12,000m² and equipped with a moveable roof and back wall as well as access to a 1,200 tonnes gantry crane. The entire area has availability of around 1,000,000m² storage yards. It has completed the jacket foundations for Baltic 2, Beatrice (30/84), Wikinger at this facility.

Suppliers: Jacket Foundation

Century Bladt Foundations – Taipei Harbor

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Century Bladt Foundation
Facility Location(s)	Taipei, Taiwan
Number of OSW Jackets Completed	62
Number of Projects Completed	3
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	-
Estimated Maximum Annual Capacity (tonnes/year)	14,329
Production Area (m^2)	31,000

Supplier introduction

In 2018, the Taiwanese company Century Wind Power and the Danish Bladt Industries signed a Joint Venture (JV) Agreement. Century Wind is a steel construction fabricator, it entered the offshore industry in 2013 by fabricating the first offshore met mast in Taiwan. Bladt industries is a market leading foundation supplier. The JV is in aid of supplying the Taiwanese market with high quality foundations. It completed the jacket foundations for Changfang Phase 1 and 2 and Xidao in 2023.

Eiffage Smulders – Hoboken

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Eiffage Smulders
Facility Location(s)	Hoboken, Belgium
Number of OSW Jackets Completed	48
Number of Projects Completed	2
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	13,920
Estimated Maximum Annual Capacity (tonnes/year)	-
Production Area (m^2)	27,000

Supplier introduction

Smulders Projects started in 2001 in Hoboken with the production of transition pieces for the one of the first offshore wind farms. The site in Hoboken covers 130,000m^2 and has 2 production halls with a total surface of 27,000m^2. It completed the jacket foundation order for Thornton Bank 2 and 3 which it was awarded in 2011.

Suppliers: Jacket Foundation

Gulf Island Fabrication - Houma

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Gulf Island Fabrication Inc
Facility Location(s)	Houma, USA
Number of OSW Jackets Completed	5
Number of Projects Completed	1
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	-
Estimated Maximum Annual Capacity (tonnes/year)	18,894
Production Area (m^2)	40,877

Supplier introduction

Gulf Island Fabrication was incorporated in 1985. It has a track record in fabricating complex steel structures, modules and marine vessels. The 5 jacket foundations for the Block Island project were fabricated here. It was awarded the contract in 2015.

It is a 31,587 m^2 of covered fabrication facilities, 9,290 m^2 of warehouse facilities, and a blasting and coating facility.

Harland and Wolff – Arnish

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Harland and Wolff Heavy Industries Ltd
Facility Location(s)	Arnish, Scotland
Number of OSW Jackets Completed	28
Number of Projects Completed	2
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	-
Estimated Maximum Annual Capacity (tonnes/year)	9,707
Production Area (m^2)	21,000

Supplier introduction

In February 2021, Harland and Wolff acquired the assets of two Scottish-based yards along the east and west coasts. Now known as Harland & Wolff (Methil) and Harland & Wolff (Arnish), these facilities focus on fabrication work within the renewable, energy and defence sectors.

The facilities mainly fabricates modules and piping systems for LNG, refining and industrial facilities. The two jacket foundations for the Beatrice demonstrator and 26 of the 84 foundations for the Beatrice project were fabricated here.

Suppliers: Jacket Foundation

Harland and Wolff – Belfast

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Harland and Wolff Heavy Industries Ltd
Facility Location(s)	Belfast, Ireland
Number of OSW Jackets Completed	24
Number of Projects Completed	1
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	13,000 tonnes/year
Estimated Maximum Annual Capacity (tonnes/year)	-
Production Area (m^2)	30,000

Supplier introduction

It is a 327,800m^2 shipyard, with over 30,000m^2 covered fabrication halls with a capacity to produce 100-250t of structural steel per week capacity and 30-75t per week capacity of miscellaneous steel.

Since Harland and Wolff's establishment in 1861, over 2,000 ships, offshore vessels and various steel structures have been produced at the Belfast shipyard. The jacket foundations for East Anglia 1 were manufactured at this facility.

Harland and Wolff – Methil

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Harland and Wolff Heavy Industries Ltd
Facility Location(s)	Methil, Scotland
Number of OSW Jackets Completed	44
Number of Projects Completed	3
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	-
Estimated Maximum Annual Capacity (tonnes/year)	134,460
Production Area (m^2)	290,900

Supplier introduction

In February 2021, Harland and Wolff acquired the assets of two Scottish-based yards along the east and west coasts. Now known as Harland & Wolff (Methil) and Harland & Wolff (Arnish), these facilities focus on fabrication work within the renewable, energy and defence sectors.

The Methil site has 542,258 m^2, with 283,400m^2 of covered and open assembly areas, 7,500m^2 of covered fabrication area and 6,800m^2 of covered storage area. The jacket foundations for Ormonde, Alpha Ventus 1 and Neart na Gaoithe were completed at this facility.

Suppliers: Jacket Foundation

Hyundai Engineering & Steel Industries – Jongno-gu

HYUNDAI ENGINEERING & CONSTRUCTION

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Hyundai Engineering & Steel Industries
Facility Location(s)	Seoul, South Korea
Number of OSW Jackets Completed	28
Number of Projects Completed	2
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	60,000 tonnes/year
Estimated Maximum Annual Capacity (tonnes/year)	-
Production Area (m^2)	330,578

Supplier introduction

The company was founded in 1947. It has an exclusive manufacturing plant of 330, 578m^2. It's track record includes construction for various industrial facilities such as sluice gates, hydraulic iron pipes, airplane hangars, and jackets. It completed some of the jackets for Greater Changhua 1 and 2a.

Lamprell – Jebel Ali

Lamprell

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Lamprell
Facility Location(s)	Dubai, UAE
Number of OSW Jackets Completed	36
Number of Projects Completed	1
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	15,000 MT/annum
Estimated Maximum Annual Capacity (tonnes/year)	-
Production Area (m^2)	51,350

Supplier introduction

The Jebel Ali facility was purpose-built and inaugurated in mid-2002. Located in the Jebel Ali Free Zone, it occupies an area of a 161,000m^2. It includes more than 16,000m^2 of covered workspace with internal overhead cranes suitable for structural pre-fabrication and assembly activities under cover. In addition to the covered fabrication areas, the Jebel Ali facility has five module fabrication pad totalling 35,350m^2.

From 2016 to 2018, 36 of the Jacket foundations for the East Anglia 1 project were manufactured at this facility. The facility has capabilities to produce 15,000 MT of steelwork annually.

Suppliers: Jacket Foundation

Lamprell – Hamryiah

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Lamprell
Facility Location(s)	Sharjah, UAE
Number of OSW Jackets Completed	45
Number of Projects Completed	1
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	40,000 MT / annum
Estimated Maximum Annual Capacity	-
Production Area (m^2)	70,000

Supplier introduction

Lamprell's Hamriyah Phase 1 facility has been operational since early 2010. The facility has a 20,000m^2 covered fabrication shop and nearly 50,000 m^2 of fabrication pads. The Phase 1 facility can produce 40,000 MT of steelwork annually. In 2022, Lamprell invested in a state-of-the-art automated production line that is being used for the serial fabrication of offshore wind substructures. The production line, which was commissioned in 2023, has the ability to construct transition pieces, monopiles, jackets and floating wind components for renewables projects.

From 2019 to 2020, Lamprell manufactured 45 jackets for the Moray East project at the Hamryiah facility.

Navantia-Windar - Brest

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Navantia-Windar
Facility Location(s)	Brest, France
Number of OSW Jackets Completed	62
Number of Projects Completed	1
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	50 jackets / annum
Estimated Maximum Annual Capacity	-
Production Area (m^2)	-

Supplier introduction

In 2020, WINDAR FRANCE was created to carry out construction work in the Port of Brest. Across its Brest and Fene facilities, Navantia-Windar can produce 100 jackets annually.

Navantia-Windar manufactured 62 jackets for the Saint Brieuc farm utilising its facility in Brest.

Suppliers: Jacket Foundation

Navantia-Windar - Fene

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Navantia-Windar
Facility Location(s)	A Coruña, Spain
Number of OSW Jackets Completed	71
Number of Projects Completed	2
Number of OSW Jackets Contracted	62
Number of Projects Contracted	1
Annual Capacity (Stated by Supplier)	50 jackets / annum
Estimated Maximum Annual Capacity	-
Production Area (m^2)	-

Supplier introduction

Across its Brest and Fene facilities, Navantia-Windar can produce 100 jackets annually.

Navantia-Windar manufactured 29 jackets for the Wikinger project and 42 jackets for the East Anglia 1 project utilising its facility in Fene. The Navantia-Windar JV has also signed a contract to manufacture 62 jackets for the Dieppe-Le Treport offshore wind farm in France, due to enter operations around 2027.

Saipem - Karimun

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Saipem
Facility Location(s)	Karimun, Indonesia
Number of OSW Jackets Completed	78
Number of Projects Completed	2
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	35,000 t/year
Estimated Maximum Annual Capacity	-
Production Area (m^2)	819,419

Supplier introduction

Saipem Karimun Yard is located on Karimun Island, Indonesia, 30 km away from Singapore Island. Built in 2011, Karimun yard is Saipem's largest yard, used for the fabrication of jackets, topsides, modules for oil and gas, renewables and infrastructure projects.

Saipem completed EPC contracts for 32 jackets for Haineng (Formosa 2) and 46 jackets for Neart na Goaithe at their Karimun Yard.

Suppliers: Jacket Foundation

Sembcorp Marine – Tuas Boulevard Yard

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	Sembcorp Marine
Facility Location(s)	Tuas, Singapore
Number of OSW Jackets Completed	15
Number of Projects Completed	1
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	144,000 t / annum
Estimated Maximum Annual Capacity	-
Production Area (m^2)	120,000

Supplier introduction

Sembcorp Marine is a Singapore-based marine and offshore engineering group. They have three yards in Singapore. The Tuas Boulevard Yard has a 120m^2 steel structure fabrication workshop with a yearly production capacity of 144,000 tonnes of steel components.

Sembcorp Marine completed 15 jackets for the Haineng (Formosa 2) offshore wind farm at the Tuas Boulevard Yard facility in Singapore.

Sing Da Marine Structure Corporation (SDMS) – Sing Da Harbour

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	SDMS
Facility Location(s)	Kaohsiung, Taiwan
Number of OSW Jackets Completed	87
Number of Projects Completed	3
Number of OSW Jackets Contracted	-
Number of Projects Contracted	-
Annual Capacity (Stated by Supplier)	50 jackets / annum
Estimated Maximum Annual Capacity	-
Production Area (m^2)	19,000

Supplier introduction

Sing Da Marine Structure Corporation (SDMS) is the first company in Taiwan to break ground on the jacket foundation factory. Sing Da Harbour was opened in 2019 as a manufacturing plant for offshore wind turbine jacket foundations. The facility has a 12,000 m^2 outdoor assembly plant and a 7,000m^2 indoor assembly plant. The facility has an average annual output of up to 50 jackets.

At Sing Da Harbour, SDMS manufactured 56 jackets for Greater Changhua 1 and 2a and 31 jackets for Zhongneng offshore wind farm.

Suppliers: Jacket Foundation

SK oceanplant - Samkang Shipyard

Key information and stated capability

Parameter	Parameter(s) Description
Facility Owner(s)	SK oceanplant
Facility Location(s)	Samkang, South Korea
Number of OSW Jackets Completed	48
Number of Projects Completed	3
Number of OSW Jackets Contracted	52
Number of Projects Contracted	1
Annual Capacity (Stated by Supplier)	-
Estimated Maximum Annual Capacity	32 jackets/ annum
Production Area (m^2)	-

Supplier introduction

SK oceanplant, previously known as Samkang M&T, provide substructures for offshore wind turbines and are also looking to expand its operation into floating offshore wind and offshore substations.

SK have manufactured 27 jackets for the Greater Changhua 1 and 2a projects and 21 jackets for Taipower Phase 1. The company also won the contract to supply 52 jackets for the Hai Long offshore wind farm. The company cut the first steel for the project in January 2023.

Due to lack of availability of supplier and yard data, the maximum annual capacity for SK oceanplant is estimated based off the completion times for the manufacturing of foundations for the aforementioned projects.

Jacket Foundation Weight Estimation Methodology

Multiple regression is used to estimate average jacket weight to be used in the future projects.

Foundation weight	Water depth	Turbine Size
2000	42.56	14
2000	42.56	14
2000	33.99	14
2000	52.21	10
2000	50.56	10
1000	47.41	9.5
1200	35.03	9.5
1200	33	9.5
1200	32.35	9.5
1240	26.48	8.8
1100	39.56	8.4
950	28	8.3
1695	40.33	8
1175	35.86	8
1035	44.99	7
845	42.12	7
480	5	7
550	23.7	6.15
573	19.07	6.15
573	16.94	6.15
900	32	6
1500	25.41	6
1100	21.12	5.2
805	42.65	5
650	39.15	5
520	28.37	5
450	19.51	5
900	28	4
550	28.57	3.6
450	17.5	3.45

Source: GRIP

To estimate the number of units each supplier capable of fabricating, we either used the stated tones/year capacity by the supplier or calculated the estimated capacity using the yard area. A multiplier for (tonnes/year) per m^2 was calculated based on suppliers which listed data for both yard areas and annual capacity in tonnes. The multiplier was calculated to be 0.462 (tonnes/year) per m^2.

The ton/year capacity is divided into the average jacket weight for 15MW (average turbine size between 2023-2033) turbine at 60m water depth.

To estimate the average jacket weight for 15MW turbine at 60m water depth we used the historic data from 30 projects globally (exc. China). ERM tracks foundation details of the offshore wind project through its market intelligence tool, GRIP.

The foundation design is a complex process and there will be project specific variables and financial variables. For the purposes of this study, it is estimated that jacket weight will be depending on water depth and the turbine size. Multiple regression model is used to understand the relationship between the foundation weight, water depth and turbine size. Multiple regression is a statistical technique is used to analyse the relationship between a single dependent variable and several independent variables.

The following relationship is identified:

*Jacket weight=9.33*water depth+ 106*turbine size*

However, the R2 of the model is 0.94 that means relatively good regression model performance, therefore it is a sufficient indicator to estimate jacket weights.

The model results 2100t/jacket that is used to calculate number of units per foundation.

An Estimated 440 Units / Year is Available for Jacket Foundations

Supplier	Facility Location	Current Capacity (units)
Aker Soltions ASA	Verdal	7
Bladt Industries A/S	Lindø	9
Century Wind Power Co. Ltd and Century Bladt Foundation	Taipei Harbor	7
Eiffage Smulders	Hoboken	7
Gulf Island Fabrication Inc	Houma	9
Harland and Wolff Heavy Industries Ltd	Arnish	5
	Belfast	6
	Methil	64
Hyundai Engineering & Steel Industries	Jongno-gu, Seoul	29

Supplier	Facility Location	Current Capacity (units)
Lamprell	Jebel Ali	8
	Hamryiah	21
Navantia-Windar	Brest	50
	Fene (A Coruña)	50
Saipem	Karimun	17
Sembcorp Marine	Sembcorp Marine Tuas Boulevard Yard	69
Sing Da Marine Stucture Corporation (SDMS)	Sing Da Harbour	50
SK oceanplant	Samkang shipyard	32
	Total	**440**

Fixed foundation demand to 2033

Sustainability is our business

Foundation demand

Over 200 GW of fixed capacity is forecasted to be deployed between 2023-2033.

Findings

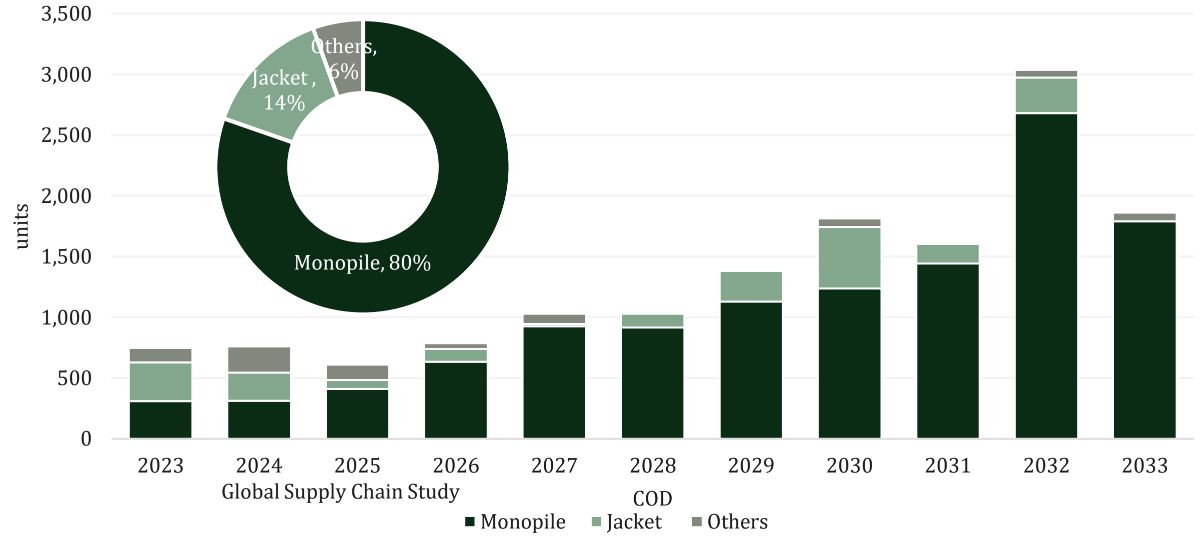
Globally, fixed offshore wind capacity is expected to reach up to 340 GW by 2033. Commissioning activity is expected to peak in 2032 when near 50 GW of capacity is expected to reach COD.

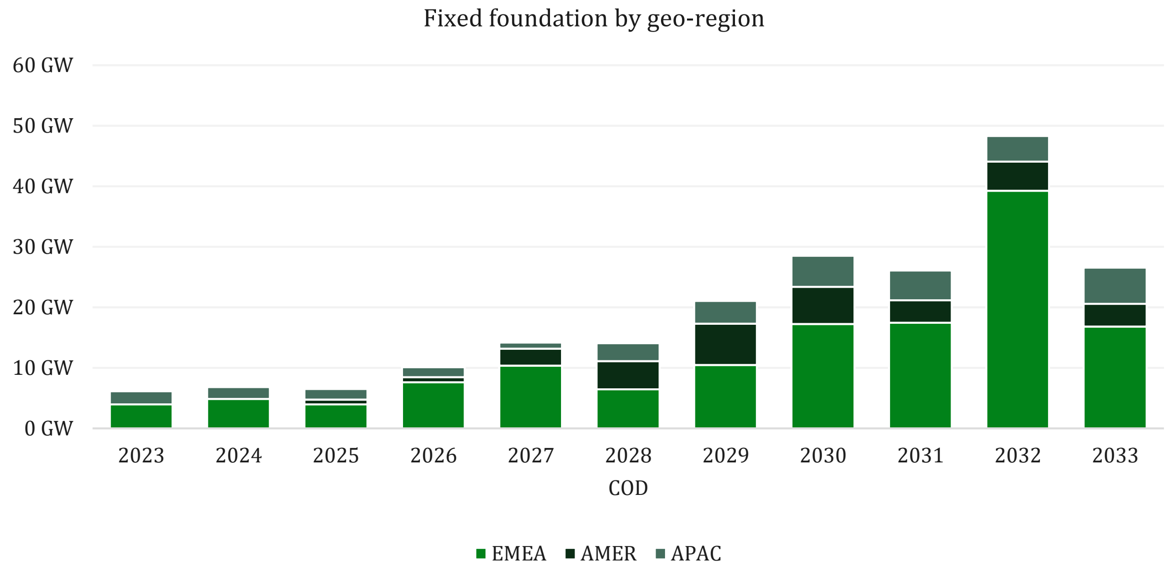
EMEA accounts for the largest proportion of capacity forecast to be commissioned up until 2033, followed by AMER and then APAC. ERM estimated the demand for fixed foundations, around 14,700 fixed foundations need to be fabricated to meet demand of projects reaching COD by 2033. Monopiles represent 80% of this demand, while jackets represent 14%.

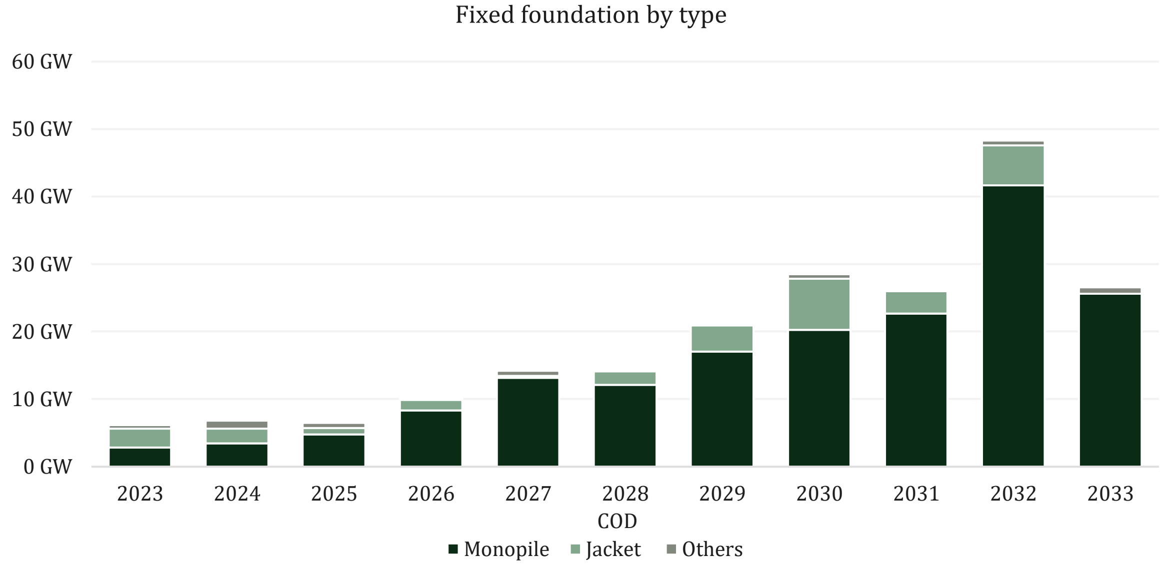
Assumptions

-Demand is based on the forecasted demand presented in the “Market Sizing” report.

-For the fixed bottom projects that the foundation type is not selected yet, jacket is estimated for the water depths greater than 60m with exception of countries that is known jackets are preferred due to local content advantage (i.e. Taiwan).







Potential Supply / Demand Bottlenecks

Sustainability is our business

Supply vs. Demand

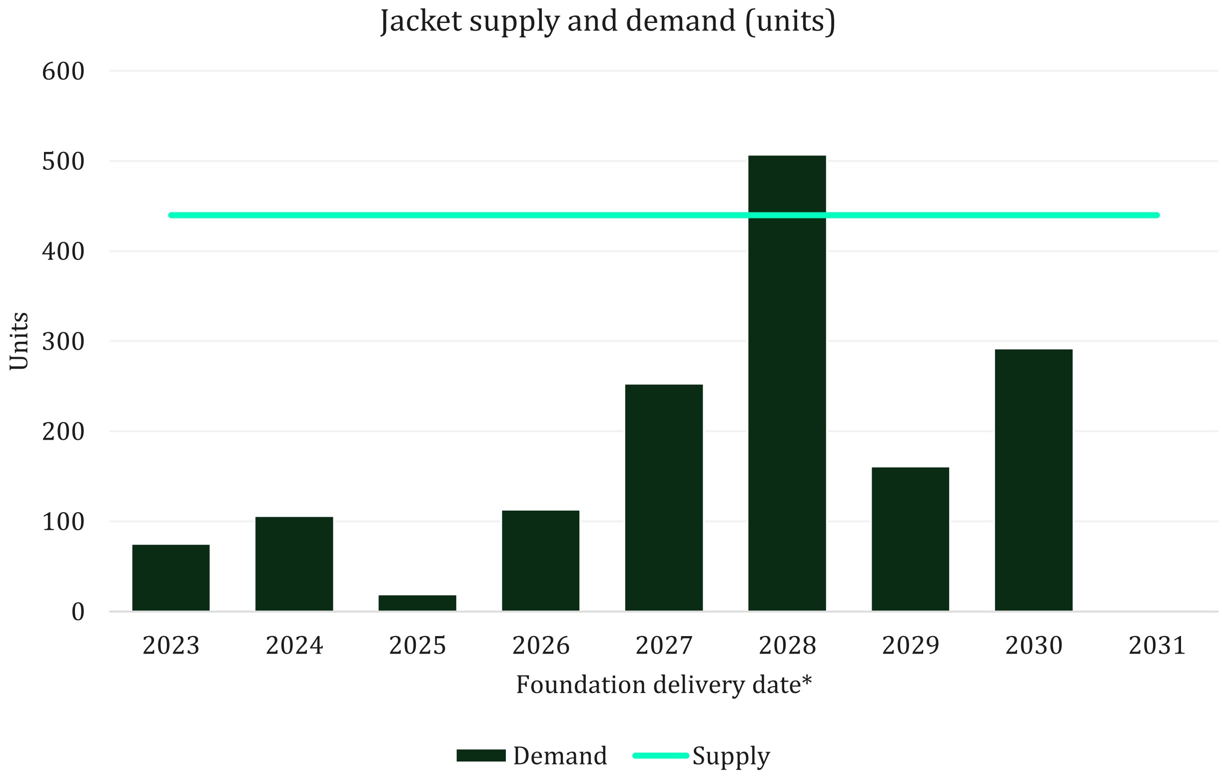
ERM analysis forecasts there to be 440 units of jackets in supply annually, at a global scale.

Of the 17 facilities identified and researched, its estimated that global supply of jackets is around 440 units per year. Based on ERM's global offshore wind commissioning forecast, it is estimated there is sufficient capacity for existing suppliers to meet the current global demand for jacket foundations for offshore wind projects up until 2031.

Supply is estimated to be much higher than demand for most years in the forecasted period. The lowest demand is seen in 2025, where currently, only 19 jacket foundations are estimated to be required. Jacket demand is lower than 200 units for six of the nine years. Based on current project announcements, there are no jackets in demand for 2031. However, demand is expected to outweigh supply in 2028, where over 500 units are estimated to be required.

With the global expansion of the offshore wind industry, there's a need to build competent regional logistical hubs with global partners and local experts. Jacket structures are easier to be fabricated in-country to increase local knowledge and local content. We saw examples in Taiwan. Therefore, it is expected that majority of the jacket demand are for projects located in APAC (i.e. Taiwan).

Its only later in the decade, from 2027 onwards, where demand for jackets is seen more significantly in the EMEA and AMER regions. In 2029 and 2030, the EMEA region accounts for the highest proportion of jacket demand. As no facilities have announced plans to increase their capabilities, the supply of jacket foundations is expected to remain the same over the forecasted period. However, this could change going forwards if existing suppliers expand or reduce their capabilities to produce jackets, or new jacket suppliers emerge into the supply chain.



*The foundation delivery date is calculated to be two years before the project commissioning date.

Floating Foundation Supply & Demand

Summary

Floating foundation supply *could* meet the expected demand; however, incentives are currently lacking.

Floating offshore wind (FOW) currently has no dedicated supply chain for the serial manufacture of floating foundations. Fabrication yards with relevant capabilities in adjacent offshore industries include oil and gas (O&G), fixed-bottom offshore wind monopile (MP), tower, and offshore substation (OSS) manufacturers, and ports / shipyards (see breakdown in Figure 3). There is an opportunity for yards with expertise in large steel structures to capitalise on this gap; however, this would need to be supported with a healthy, financially viable FOW project pipeline, which is not expected until the end of this decade.

The adjacent figures show the breakdown of the 46 yards that were included in this analysis, spanning the North Sea, Southern Europe, and South Korea. If sufficient initiatives and investments are provided for FOW, the global supply capacity could support circa 15 GW/year, based on data gathered from 46 yards and the assumptions listed in Appendix 1. North Sea yards could support 5 GW/year of floating capacity, Southern Europe could support 2.5 GW/year, and South Korea just under 7 GW/year. The baseline capacity scenario will be dependent on a viable business case (i.e. sufficient confirmed FOW project pipeline) to pivot to floating foundations. Only 30 of the 46 yards assessed have expressed interest in supporting FOW construction activities, equating to an estimated potential FOW supply ambition of over 14 GW/year.

This analysis is not exhaustive, as it only includes suppliers in the regions listed above and uses high level supply capacity estimates which are primarily driven by yard areas. There is significant uncertainty around the rate of FOW deployment/scale up in coming years, meaning that more accurate data on floating foundation supply and demand will become available as the industry matures.

Figure 1. Estimated Supply Capacity by Region[1]

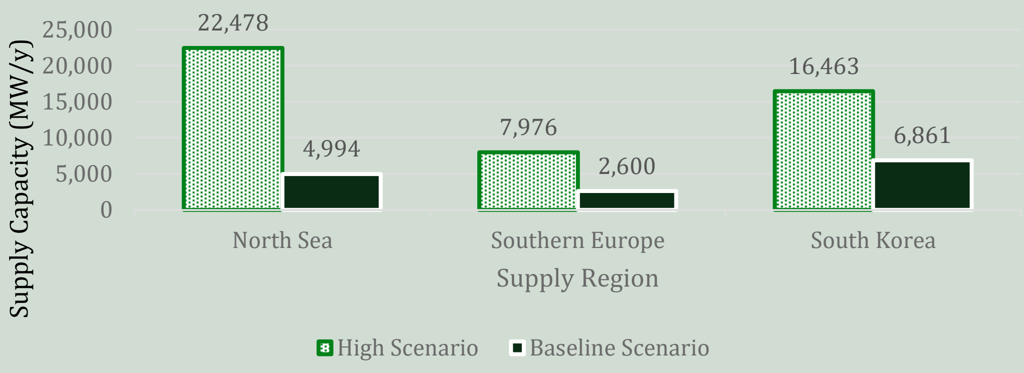


Figure 2. Breakdown of Supplier FOW Experience[1]

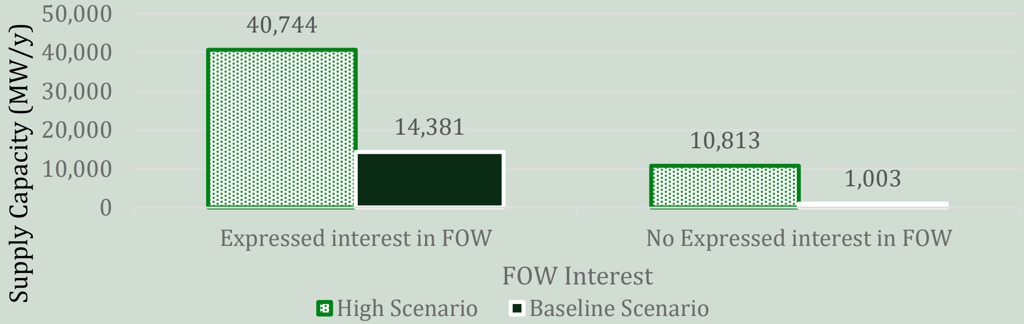
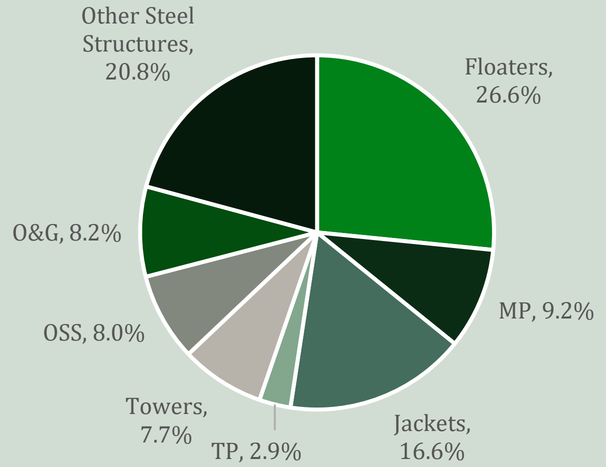


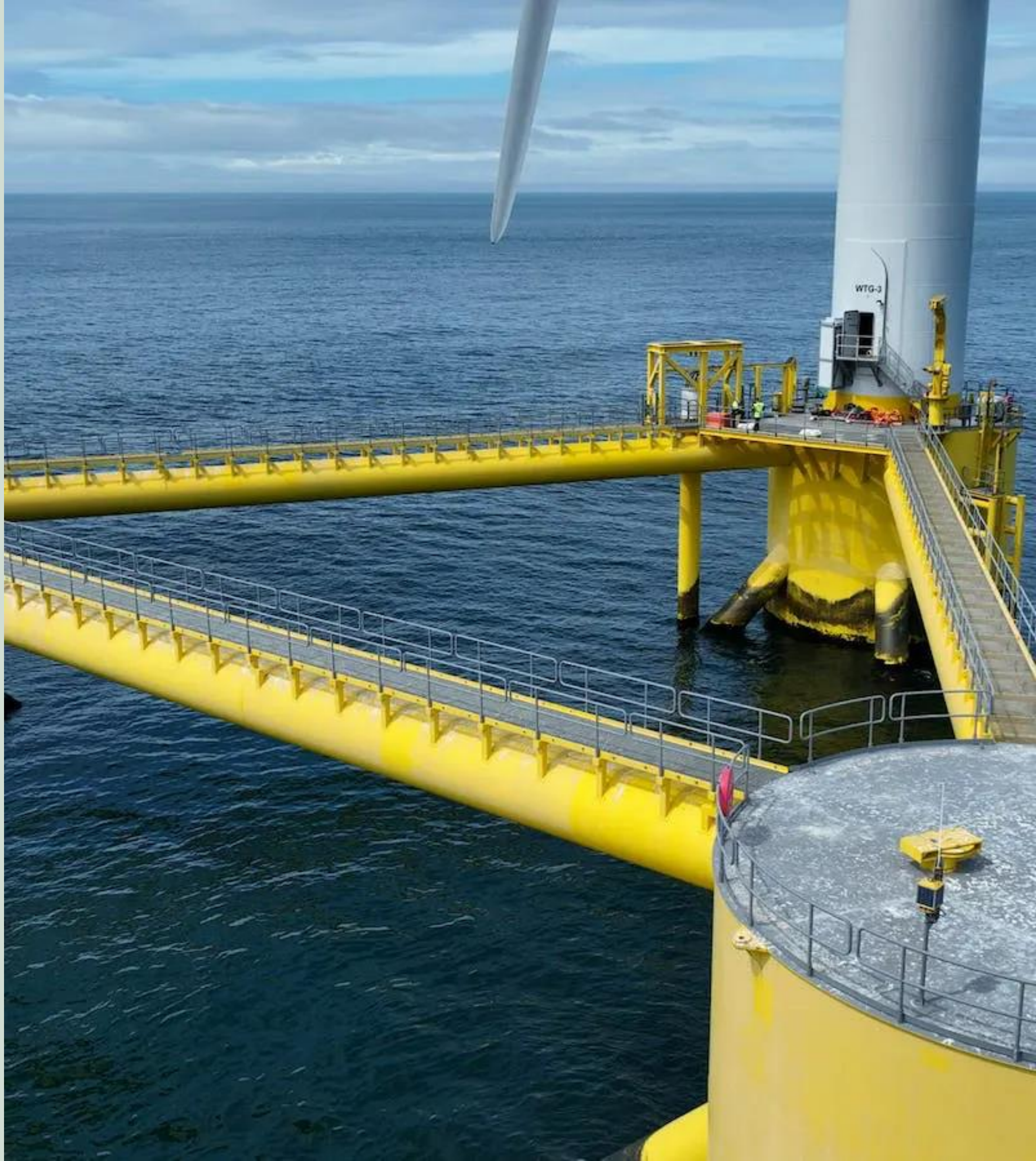
Figure 3. Breakdown of Supplier Focus Areas[1]



[1] See Appendix 1 for underlying assumptions.

Floating Foundation Background

Sustainability is our business



Relevant Supplier Categories and Market Breakdown

FOW lacks a **dedicated supply chain** due to the early-stage status of the market, and uncertainty around the rate at which projects will scale up from pre-commercial scale to GW-scale. Alongside announced FOW-specific fabrication yards, this analysis includes suppliers with relevant fabrication capabilities in the following adjacent industries:

- Oil and gas (O&G);
- Fixed-bottom offshore wind (FBOW), including monopile (MP), offshore substation (OSS) and tower manufacturers with plans to support FOW; and,
- Ports / shipyards.

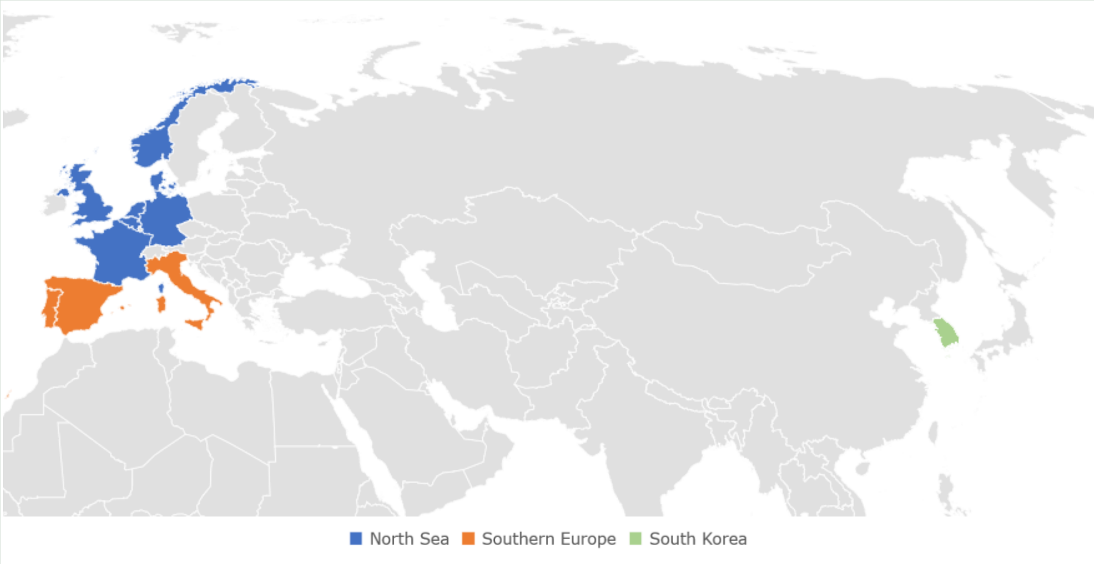
The primary markets selected are the North Sea, Southern Europe, and South Korea. Countries with relevant fabrication capabilities are identified in the adjacent figure.

The supplier selection included in this report is not fully comprehensive, as future developments are uncertain due to the open-ended nature of the FOW market at this early stage. Smaller suppliers were screened out if deemed unsuitable for serial manufacture.

For further assumptions detailed please refer to Appendix 1.

Market Breakdown by Country

Country	Region
United Kingdom	North Sea
Denmark	North Sea
Norway	North Sea
Germany	North Sea
Netherlands	North Sea
Belgium	North Sea
France	North Sea
Spain	Southern Europe
Portugal	Southern Europe
Italy	Southern Europe
South Korea	Asia



Source: ERM GRIP

Foundation Selection

Why Floating?

- Many markets have no seabed in the fixed-bottom depth range (<c.70m)
- Better wind resource –> higher capacity factor
- More scalable (less constrained by impacts on coastal activities / ecosystems)

Barriers

- Higher €/MWh than fixed-bottom
- Relatively unproven – only c.200 MW operational in 2023
- Currently no dedicated supply chain

Dominant floating offshore wind (FOW) foundation (FOU) categories

Barge

Free-surface stabilized structure with large water plane area and relatively small draught. Barges have relatively similar characteristics to semi-subs.

Spar

Weight-buoyancy stabilized structure with a relatively large draught compared to barges, semisubmersibles and TLPs. Concept feasibility has been proven by the high TRL of Equinor's Hywind design, enhancing bankability. The monospar concept benefits from simpler manufacturing / supply chains than other foundation types, however deployment will be significantly limited by water depths (with >100m draft required for >15 MW unit capacity). Spar designs are therefore only suitable to certain geographies (i.e. Norway due to deepwater ports).

TLP

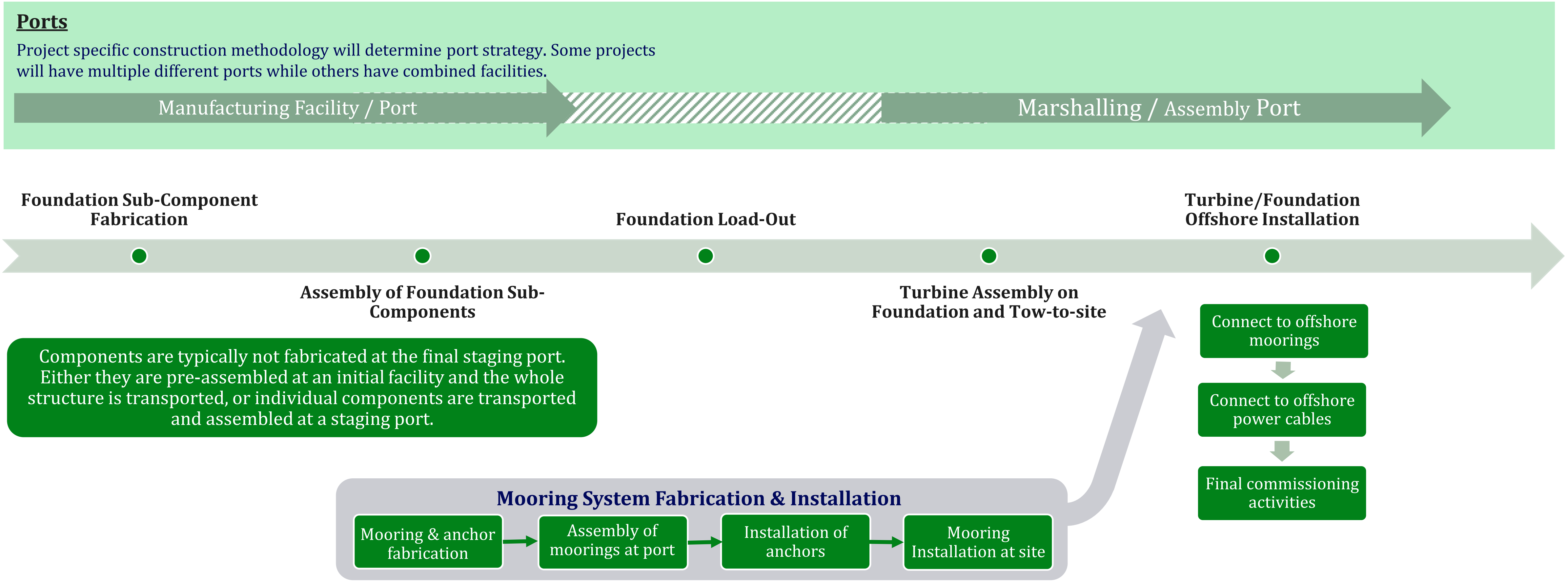
Vertically moored floating structure whose station keeping system consists of tethers or tendons anchored at the seabed. TLPs are operationally stable and have a very low heave (vertical) motions. TLP installation is more complex due to the mooring integration difficulty (to achieve the required tension in the mooring lines) and higher buoyancy, which means increased weather sensitivity. TLP designs must account for transit, which required additional material, negating the potential material savings in designs purely accounting for the operational state.

Semi-Sub

Large columns are linked to each other by bracings. The columns provide the ballast and flotation stability (column-stabilized). The most versatile designs, generally more resilient and easier to install than TLPs. Concept feasibility has been proven by the high TRL of PPI's Windfloat concept, enhancing bankability. Sem-subs are expected to dominate market share globally.

Overview of Floating Foundation Construction Process

The construction process for floating offshore wind is complex and the specifics are dependent on local manufacturing, infrastructure, and port capabilities.



Tower / Monopile Fabricators

Fabricator availability lookahead

Monopile Fabricators

- Looking ahead to 2030, the majority of monopile fabrication facilities are likely to be operating at near full capacity, particularly those that are set up to support with the production of next generation foundations with diameters of 10m or greater.
- Fabricators in Europe are not only experiencing significant demand from the European market, but also from the developing US market. The US supply chain for foundations is a long way off being able to fulfil local market demand, thus many projects are sourcing foundations from established fabricators within Europe. Although the US local supply chain will develop over time, sustained US demand for European fabricators is anticipated to continue for some time.
- Limited European monopile fabrication capacity has seen several European projects look to fabricators in the Far East to supply monopiles, further highlighting the shortage of local market capacity – this is before adding potential demand from floating foundation components.

Tower Fabricators

- Looking ahead to 2030, similarly to the monopile fabricators, tower manufactures are likely to be operating close to full capacity due to the forecast number of turbines to be installed.
- That said, tower manufactures operate independent from the main turbine component manufactures, meaning that facilities without long-term exclusivity agreements already in place, could be attracted towards producing floating foundation components upon receipt of a large-scale agreement.

As discussed, due to the lack of existing dedicated FOW supply chain, MP and tower suppliers are included in this report, however it should be noted that there is uncertainty around the future availability of these suppliers.

Floating Foundation Supply

Sustainability is our business

Suppliers: North Sea

Aker Solutions

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Floaters, O&G, hydrogen, CCUS, hydropower
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Aker ASA / TRG Holding AS
Headquarter location	Fornebu, Norway
Facility location	Egersund, Sandnessjøen, Stord, Verdal
Number of employees	22,500
Yard area (m^2)	250,000; 85,000; 318,000; 650,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	Schlumberger, Subsea 7, Ocean Yield, SalMar, Saudi Aramco

Supplier Introduction:

Aker Solutions delivers integrated solutions, products, and services to the global energy industry (including O&G and renewables solutions). Aker Solutions has over 40 years of expertise in designing, delivering, and servicing semi-submersible drilling and production platforms and offers versatile foundation solutions for offshore wind projects, including steel jacket substructures, concrete or steel gravity-based structures (GBS), floating substructures, and converter platforms.

FOW Track record*:

Parameter	
Number of projects performed	1
Projects performed	Hywind Tampen
Project pipeline	-

Wergeland Base AS

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	O&G, shipping, floaters
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Wergelend Group
Headquarter location	Gulen, Norway
Facility location	Gulen Industrial Harbour
Number of employees	40
Yard area (m^2)	1,430,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	N/A

Supplier Introduction:

Wergeland Base in Gulen Port has been identified as a 'Nordic port and super site'. Wergeland Base has developed and expanded Gulen Industrial Harbour during the last decade. Over the last six decades, the port has developed from concrete production to a shipping and O&G service provider. Wergeland have announced a Letter of Intent for the purchase of a 2600 t Huismann Skyhook crane and announced an ambition to be the primary assembly site for offshore wind in Norway.

FOW Track record*:

Parameter	
Number of projects performed	1
Projects performed	Hywind Tampen
Project pipeline	Utsira Nord

*The track record covers projects that have entered construction since 2018 where the supplier information is publicly available.

Suppliers: North Sea

Welcon A/S

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Floaters, towers
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Unknown
Headquarter location	Give, Denmark
Facility location	Esbjerg
Number of employees	190
Yard area (m^2)	106,000
Annual Capacity (kton/year)	200
Co-operation/JVs	Marmen, Smulders,

Supplier Introduction:

Welcon is a steel manufacturer with almost 60 years of experience in steel construction, which specialises in plate preparation, plate rolling, welding, surface treatment, assembly, and loading & transport. It has a significant track record in the wind industry, having produced over 6,000 tower sections since 2010 (with a 1,100/year capacity).

FOW Track record*:

Parameter	
Number of projects performed	1
Projects performed	TetraSpar Demonstrator
Project pipeline	-

Sif Offshore Foundations

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	MPs, TPs
Direct FOW experience?	No
Expressed interest in FOW?	Yes
Owner(s)	-
Headquarter location	Roermond, Netherlands
Facility location	Rotterdam
Number of employees	600
Yard area (m^2)	620,000
Annual Capacity (kton/year)	300
Co-operation/JVs	Ecowende, Smulders

Supplier Introduction:

Sif has almost 75 years of experience in rolling and welding, and specialises in the welding of high-quality, super-strong steel alloys for severe and cold conditions. Sif has a proprietary welding machine design, and a 5,000 tonnes rolling machine. Sif's stated capabilities are MPs with diameter of 11m, weight of 1,800t, length of 105m, and production rate of 4-5/week.

*The track record covers projects that have entered construction since 2018 where the supplier information is publicly available.

Suppliers: North Sea

EEW Group

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Steel pipes, FBOW
Direct FOW experience?	No
Expressed interest in FOW?	Yes
Owner(s)	-
Headquarter location	Erndtebrück, Germany
Facility location	Rostock
Number of employees	2,000
Yard area (m^2)	32,000
Annual Capacity (kton/year)	250
Co-operation/JVs	Bladt Industries

Supplier Introduction:

EEW Group is a leading manufacturer of large-diameter steel pipes with more than 85 years of experience. Capabilities include forming steel plates, welding, pipe sizing/calibrating, and coating. Alongside straight steel pipes for monopiles, transition pieces, pipes for jacket constructions and piles, EEW offers additional services, such as coating or the fitting of secondary steel components.

Steelwind Nordenham

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Monopiles, Transition pieces
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	Dillinger Group
Headquarter location	Nordenham, Germany
Facility location	Nordenham
Number of employees	275
Yard area (m^2)	180,000
Annual Capacity (kton/year)	288
Co-operation/JVs	N/A

Supplier Introduction:

Since 2014, Steelwind has been manufacturing offshore wind foundations at their Nordenham facility, which is strategically located with convenient access to the North Sea. Steelwind provides a specialized fabrication system based on the integral production of Monopiles and Transition Pieces, including all necessary onshore works and services, like coating and installation of secondary steel or electrical installations.

Suppliers: North Sea

Smulders

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	MPs, TPs, jackets, tripods, OSS, floaters, O&G
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Eiffage Métal
Headquarter location	Hoge Mauw, Belgium
Facility location	Hoboken, Vlissingen, Newcastle
Number of employees	1,400
Yard area (m^2)	130,000; 29,208; 320,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	HSM Offshore Energy, Iv-Offshore, Sif, EFAB

Supplier Introduction:

Smulders is an international steel construction company with more than 50 years' experience in the engineering, construction, supply and assembly of steel constructions. Smulders offers a full range of services from engineering and fabrication to the complete turnkey solutions of substations and foundations. Smulders has a track record of over 2,000 transition pieces, 160 jackets and 35 OSSs.

Hollandia

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	O&G, OSS, other steel structures
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	-
Headquarter location	Rotterdam, Netherlands
Facility location	Rotterdam
Number of employees	400
Yard area (m^2)	130,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	Strukton Systems, Standard Investment

Supplier Introduction:

Hollandia has been contributing towards the evolution of European steel since 1928, with steel construction experience spanning infrastructure, energy systems, and industrial structures. Hollandia's offshore wind experience to date has been limited to OSS manufacture.

Suppliers: North Sea

Haizea Wind Group

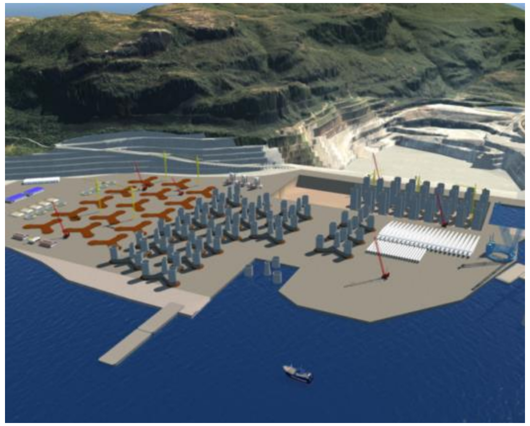
Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Towers, MPs, TPs
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	-
Headquarter location	Bilbao, Spain
Facility location	Brest
Number of employees	1,100
Yard area (m^2)	40,000
Annual Capacity (kton/year)	60
Co-operation/JVs	SICA Metalúrgica

Supplier Introduction:

Haizea Wind Group is dedicated to the construction and assembly of large metal structures for offshore WTGs, such as towers, monopiles, or primary steel for transition pieces. The Group has large facilities in Spain (Port of Bilbao, Agurain, Itziar and Aranda de Duero), Argentina and France (Port of Brest)- the latter of which is included in the 'North Sea' market.

Windworks Jelsa



Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Floaters
Direct FOW experience?	N/A
Expressed interest in FOW?	Yes
Owner(s)	NorSea
Headquarter location	Jelsa, Norway
Facility location	Jelsa
Number of employees	Unknown
Yard area (m^2)	800,000
Annual Capacity (kton/year)	267
Co-operation/JVs	N/A

Supplier Introduction:

If this port is developed as planned, it will be ideally suited to fabrication and assemble of Norwegian floating offshore wind projects in Norway's Southwest region. The port will have large areas with high bearing capacity and major drydock solution and deep-water access in sheltered waters with low tidal variations, enabling the assembly of complete wind turbines and foundations, ready for tow-out to installation sites. The potential to use local aggregates and supply of cement means that WindWorksJelsa will be particularly suited to concrete FOU fabrication.

Suppliers: North Sea

Aibel

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	O&G, OSS
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Ferd, Ratos, Sixt AP Fund
Headquarter location	Stavanger, Norway
Facility location	Stavanger, Haugesund
Number of employees	5,300
Yard area (m^2)	234,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	Hitachi ABB, Aker BP

Supplier Introduction:

Aibel builds and builds and maintains platforms and other infrastructure for the energy industry, with a focus on European offshore wind and the electrification of offshore O&G installations and onshore processing plants. Aibel owns modern yards in Norway and Thailand with significant prefabrication and construction capacity.

FOW Track record*:

Parameter	
Number of projects performed	1
Projects performed	Hywind Scotland
Project pipeline	-

HSM Offshore Energy

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	OSS, jackets, offshore hydrogen
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	Gilde Investment
Headquarter location	Schiedam, Netherlands
Facility location	Schiedam, Stormpolder
Number of employees	170
Yard area (m^2)	105,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	Smulders, Iv-Offshore

Supplier Introduction:

HSM Offshore Energy is an integrated solution provider in Engineering, Procurement, Construction, Installation and Commissioning (EPCIC) of multi-disciplinary offshore projects. Projects include integrated platforms, modules and jackets for the offshore upstream energy sector, with a focus on high-voltage substations, green hydrogen platforms, gas production and processing modules, carbon capture and storage infrastructures and steel jacket foundations.

*The track record covers projects that have entered construction since 2018 where the supplier information is publicly available.

Suppliers: North Sea

EFAB (ENGIE Fabricom)

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	OSS, piping systems, steelwork, modules
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	EQUANS
Headquarter location	Middlesborough, UK
Facility location	Immingham and Middlesbrough
Number of employees	250
Yard area (m^2)	56,656
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	Smulders

Supplier Introduction:

EFAB provides construction and engineering capabilities for the Power, Utilities, Chemical and Renewables sectors from their Immingham and Middlesbrough site locations. EFAB has a Manufacturing and Development Centre with dock access is well equipped to handle Modular Construction requirements. The Immingham facility is dedicated to the manufacture and assembly of piping systems, steelwork, EC&I and modules.

Babcock

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Defence (warships, nuclear submarines, land vehicles, aircraft)
Direct FOW experience?	No
Expressed interest in FOW?	Yes
Owner(s)	Doosan Babcock
Headquarter location	London, UK
Facility location	Devonport and Rosyth
Number of employees	29,000
Yard area (m^2)	Rosyth: 56,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	N/A

Supplier Introduction:

Babcock is an international defence company operating in the UK, Australasia, Canada, France and South Africa. Babcock's services include technical and engineering support, and the design and manufacture of a range of defence and civil specialist equipment, from naval ship and weapons handling systems to liquid gas handling systems. Babcock Rosyth is home to one of the largest waterside manufacturing and repair facilities in the UK.

Suppliers: North Sea

Titan Wind Energy

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Towers
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	BP Wind Energy
Headquarter location	Suzhou, China
Facility location	Cuxhaven, Esbjerg
Number of employees	2,483
Yard area (m^2)	600,000; 320,000
Annual Capacity (kton/year)	Unknown; 45
Co-operation/JVs	N/A

Supplier Introduction:

Titan Wind Energy has been producing wind turbine towers primarily for the European market. The company is capable of delivering operational support globally, including service, repair, consultancy and inspection.

Bladt Industries

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	MPs, jackets, OSS
Direct FOW experience?	No
Expressed interest in FOW?	Yes
Owner(s)	CS Wind
Headquarter location	Aalborg, Denmark
Facility location	Aalborg, Esbjerg, Odense
Number of employees	1,000
Yard area (m^2)	550,000; unkown; 1,000,000
Annual Capacity (kton/year)	200; unkown; unkown
Co-operation/JVs	Semco Maritime, Century Wind Power, EEW Group

Supplier Introduction:

Bladt Industries specialise in manufacturing complex large-scale steel structures, including foundations and substations, to the offshore wind industry globally. The company's purpose is to support a green future, with a vision to be the market leader within offshore foundations and substations.

Suppliers: North Sea

Eiffage Métal

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Floaters, jackets, OSS, structures,
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Eiffage Métal
Headquarter location	Unknown
Facility location	Fos-sur-Mer
Number of employees	2,300
Yard area (m^2)	118,321
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	Smulders, HSM Offshore Energy, Iv-Offshore, Sif, EFAB

Supplier Introduction:

Eiffage Métal is a turnkey steel construction provider, with expertise including substations, foundations, met masts and offshore wind turbine parts, buildings, and engineering, nuclear and industrial structures. Smulders is a subsidiary company of Eiffage Métal.

Archimed

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Floaters
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Matière, Ponticelli
Headquarter location	Port-la-Nouvelle
Facility location	Port-la-Nouvelle
Number of employees	170
Yard area (m^2)	Unknown
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	N/A

Supplier Introduction:

Archimed has put in place an ambitious plan for the industrialization of offshore wind by integrating the entire value chain. This project, entitled the MPA plant, aims to establish an industrial facility in France dedicated to the construction and assembly of steel wind floats, in line with France's target of 40 GW of offshore wind installed by 2050, which equates to an estimated 30 to 40 floats per year.

Suppliers: North Sea / Eastern Europe

Chantier de Atlantique

Key information and stated capability:

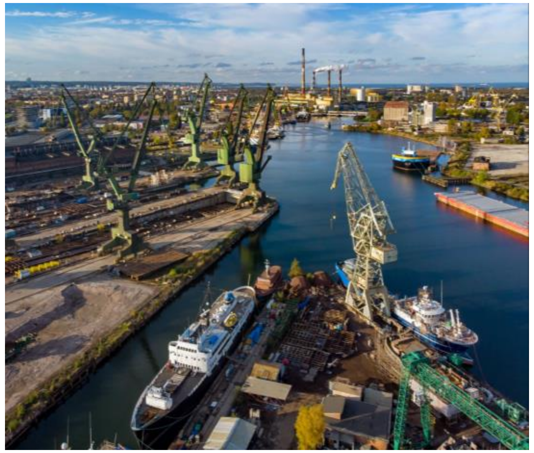
Parameter	Parameter(s) Description
Supplier Type	OSS, floaters, ships
Direct FOW experience?	No
Expressed interest in FOW?	Yes
Owner(s)	French government
Headquarter location	Saint-Nazaire
Facility location	Saint-Nazaire
Number of employees	3,500
Yard area (m^2)	249,340
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	N/A

Supplier Introduction:

Chantier de l'Atlantique is one of the world's largest shipyards which has historically produced military vessels, cruise boats and offshore substations.

As part of their diversification strategy, they have started producing OSS with success (on going contracts with RTE and Orsted). This has included OSS foundations, and future capabilities will include floating OSS and foundations.

Stocznia Gdańska



Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Ships, offshore structures, wind towers, O&G
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	Industrial Union of Donbas, Polish Government
Headquarter location	Gdansk
Facility location	Gdansk
Number of employees	2,200
Yard area (m^2)	629,426
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	N/A

Supplier Introduction:

Gdansk Shipyard is a large facility in Poland, spanning wind towers (current production capacity is 18-20 towers per month), offshore O&G devices and constructions, and shipbuilding. Gdańsk Shipyard exists since 1844, while the Gdańsk Shipyard as a company was established in 1947.

Suppliers: North Sea / Eastern Europe

Damen Shipyards Mangalia

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Ships, OSS
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	Romanian Government
Headquarter location	Mangalia
Facility location	Mangalia
Number of employees	1,500
Yard area (m^2)	980,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	N/A

Supplier Introduction:

Mangalia Shipyard was established in 1997 and in 2018, Damen Group acquired a majority stake in the shipyard (with the Romanian Government retaining the rest). Damen developed the shipyard's capabilities, and it is now one of the top shipyards in Europe for offshore industry capabilities. However, the Romanian government recently passed a new corporate governance law (Law 187/2023) which nullified the agreement between the two parties as the new law forcefully removes Damen from the management role at Mangalia.

Suppliers: Southern Europe

Navantia-Windar JV

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	MPs, jackets, floaters
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Navantia - Windar JV
Headquarter location	
Facility location(s)	Fene, Brest
Number of employees	Unknown
Yard area (m^2)	682,667
Annual Capacity	20 platforms/year
Co-operation/JVs	Iberdrola

Supplier Introduction:

Joint Venture between Navantia and Windar to build offshore wind substructures. The construction takes place in Navantia's shipyard in Fene, Galicia, Spain.

FOW Track record*:

Parameter	
Number of projects performed	3
Projects performed	WindFloat Atlantic, Hywind Scotland, Kincardine
Project pipeline	-

Navantia

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	OSS, jackets, MPs, floaters
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Sociedad Estatal de Participaciones Industriales (SEPI)
Headquarter location	Madrid
Facility location(s)	Ferrol, Cádiz (future).
Number of employees	+ 4,000
Yard area (m^2)	682,500
Annual Capacity	20 platforms/year
Co-operation/JVs	N/A

Supplier Introduction:

Navantia is a Spanish state-owned company that traditionally focused on the design and construction of high technology vessels. In 2022, the company launched its Navantia Seanergies brand to promote its activity related to green energies, focused on offshore wind energy and hydrogen. Its aspiration is to become a global supplier of structures for offshore wind energy.

FOW Track record*:

Parameter	
Number of projects performed	-
Projects performed	-
Project pipeline	Ocean Winds signed an agreement with Navantia for the supply of OSW components from 2027 to 2031, with an expected supply of 8-12 floaters annually.

*The track record covers projects that have entered construction since 2018 where the supplier information is publicly available.

Suppliers: Southern Europe

Windar

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	TPs, towers
Direct FOW experience?	No
Expressed interest in FOW?	Yes
Owner(s)	Bridgepoint
Headquarter location	Avilés, Spain
Facility location(s)	Avilés, Spain.
Number of employees	+ 1,500
Yard area (m^2)	190,000
Annual Capacity (kton/year)	60 kton/year
Co-operation/JVs	N/A

Supplier Introduction:

Windar Renovables was founded in 2007 with the aim of becoming a global leader in the field of the manufacture of wind turbine towers. The company's business model also includes the manufacture of substructures for the offshore wind industry.

Haizea Bilbao

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Towers, MPs, TPs
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	Haizea Group
Headquarter location	Bilbao, Spain
Facility location(s)	Bilbao, Spain
Number of employees	1,100
Yard area (m^2)	210,701
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	SICA Metalúrgica

Supplier Introduction:

Founded in 2018 in Port of Bilbao, Haizea Bilbao is a company dedicated to the construction and assembly of large metal structures for offshore WTGs, such as towers, monopiles, or primary steel for transition pieces.

Suppliers: Southern Europe

Dragados Offshore

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	MPs, tripods, jackets, OSS
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	Vinci
Headquarter location	Cádiz, Spain
Facility location(s)	Cádiz, Spain
Number of employees	Unknown
Yard area (m^2)	510,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	Siemens Energy, Wood

Supplier Introduction:

Dragados Offshore was founded in 1972 as an EPC contractor for oil and gas, and other energy-related industries. The company provides comprehensive solutions from concept to delivery, including detailed design, construction engineering, procurement, construction, transportation, commissioning, offshore installation, and hook-up of offshore floating platforms.

GRI Renewable Industries

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Towers
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	Gestamp
Headquarter location	Madrid, Spain
Facility location(s)	Seville, Spain
Number of employees	5000
Yard area (m^2)	Unknown
Annual Capacity (kton/year)	210 kton/year
Co-operation/JVs	ARP Baltic Towers, Mitsui

Supplier Introduction:

GRI Renewable Industries was founded in 2008 to manufacture towers and flanges for the wind sector, both onshore and offshore. Its facility in Spain is located in the Guadalquivir river, which is the only navigable river in Spain.

Suppliers: Southern Europe

CS Wind (former ASM Industries)

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Towers
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	-
Headquarter location	Seoul, South Korea
Facility location(s)	Port of Aveiro, Portugal
Number of employees	Unknown
Yard area (m²)	250,000
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	Vestas

Supplier Introduction:

CS Wind is headquartered in Korea and is the leading wind turbine tower manufacturer globally. It established its first production facility in Vietnam in 2003. In 2022, CS Wind took full ownership of ASM Industries, a Portuguese wind tower producer. ASM Industries was the primary supplier of two semi-submersible platforms for the WindFloat Atlantic.

FOW Track record*:

Parameter	
Number of projects performed	1
Projects performed	WindFloat Atlantic (2 semi-submersibles)
Project pipeline	-

Saipem

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Jackets, O&G, floaters
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Eni
Headquarter location	Milan, Italy
Facility location(s)	Arbatax, Italy
Number of employees	30000
Yard area (m²)	194,476
Annual Capacity (kton/year)	12 kton/year
Co-operation/JVs	Seaway7, Boskalis, HitecVision, Daewoo E&C Co., Chiyoda Corporation

Supplier Introduction:

Saipem is a major global player in engineering services for the design, construction and operation of complex infrastructures and plants in the energy sector, both offshore and onshore.

FOW Track record*:

Parameter	
Number of projects performed	1
Projects performed	Hywind Scotland
Project pipeline	-

*The track record covers projects that have entered construction since 2018 where the supplier information is publicly available.

Suppliers: Southern Europe

Rosetti-Marino

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	O&G, OSS, jackets
Direct FOW experience?	No
Expressed interest in FOW?	Yes
Owner(s)	/
Headquarter location	Ravenna, Italy
Facility location	Piomboni Yard
Number of employees	700
Yard area (m^2)	104,000
Annual Capacity (kton/year)	300
Co-operation/JVs	Global Energy Group

Supplier Introduction:

Rosetti-Marino is an Italian manufacture with a focus on the construction of heavy offshore steel structures, spanning O&G and offshore wind. These structures include integrated topsides, jackets, compression & utility modules, subsea templates & manifolds.

Nervión

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Ships, jackets, floaters
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	Grupo Amper
Headquarter location	Madrid, Spain
Facility location(s)	Ferrol
Number of employees	500
Yard area (m^2)	74,000 (Ferrol) +105,000 (As Somozas)
Annual Capacity (kton/year)	/
Co-operation/JVs	BAR Technologies

Supplier Introduction:

Nervión Naval-Offshore has over 60 years of experience in the shipbuilding industry and, as part of Grupo Amper, now manufactures fixed and floating foundations for offshore wind farms.

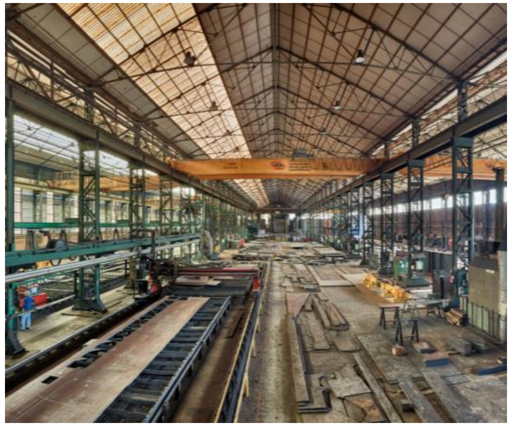
FOW Track record*:

Parameter	
Number of projects performed	1
Projects performed	Kincardine
Project pipeline	-

*The track record covers projects that have entered construction since 2018 where the supplier information is publicly available.

Suppliers: South Korea

Navacel



Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	O&G, TPs, anchors, towers, floaters
Direct FOW experience?	Yes
Expressed interest in FOW?	Yes
Owner(s)	/
Headquarter location	Bilbao, Spain
Facility location(s)	Bilbao, Spain
Number of employees	50
Yard area (m^2)	30,000
Annual Capacity (kton/year)	/
Co-operation/JVs	/

Supplier Introduction:

NAVACEL's experience covers specialized design, fabrication, handling, and transport of large-scale offshore components and platforms.

FOW Track record*:

Parameter	
Number of projects performed	1
Projects performed	Hywind
Project pipeline	-

*The track record covers projects that have entered construction since 2018 where the supplier information is publicly available.

Suppliers: South Korea

Hyundai Engineering & Steel Industries

Key information and stated capability:

Parameter	Parameter(s) Description
Supplier Type	Offshore steel structures
Direct FOW experience?	No
Expressed interest in FOW?	No
Owner(s)	Korea Shipbuilding & Offshore Engineering (KSOE)
Headquarter location	Seoul, South Korea
Facility location(s)	Yulchon, South Korea
Number of employees	Unknown
Yard area (m^2)	330,580
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	RWE, GE

Supplier Introduction:

Hyundai Engineering and Steel Industries will take care of all steel related projects such as offshore and plant steel structures, all different types of steel bridges and high-rise building steel structures.

Hyundai Heavy Industries

Key information and stated capability:

Parameter-	Parameter(s) Description
Supplier Type	Floaters, fixed platforms
Direct FOW experience?	No
Expressed interest in FOW?	Yes
Owner(s)	Korea Shipbuilding & Offshore Engineering (KSOE)
Headquarter location	Ulsan, South Korea
Facility location(s)	Ulsan, South Korea
Number of employees	14,000
Yard area (m^2)	1,180,757
Annual Capacity (kton/year)	Unknown
Co-operation/JVs	-

Supplier Introduction:

Hyundai Heavy Industries was founded in 1972 focused on the business of shipbuilding. Currently, the company's business also includes Naval & Special Ship, Engine & Machinery, and Offshore & Engineering. Within its services, HHI can supply TLPs, spars, and semi-submersibles.

Foundation Supply Cost Impacts

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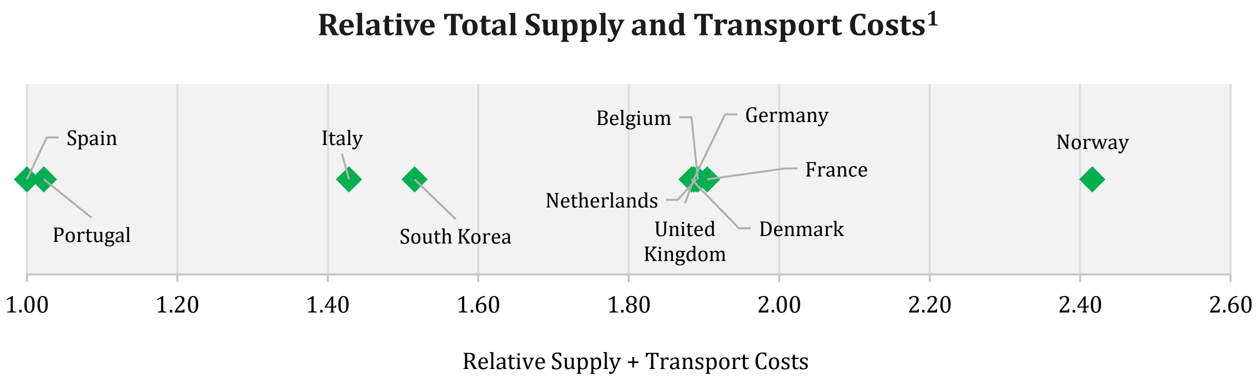
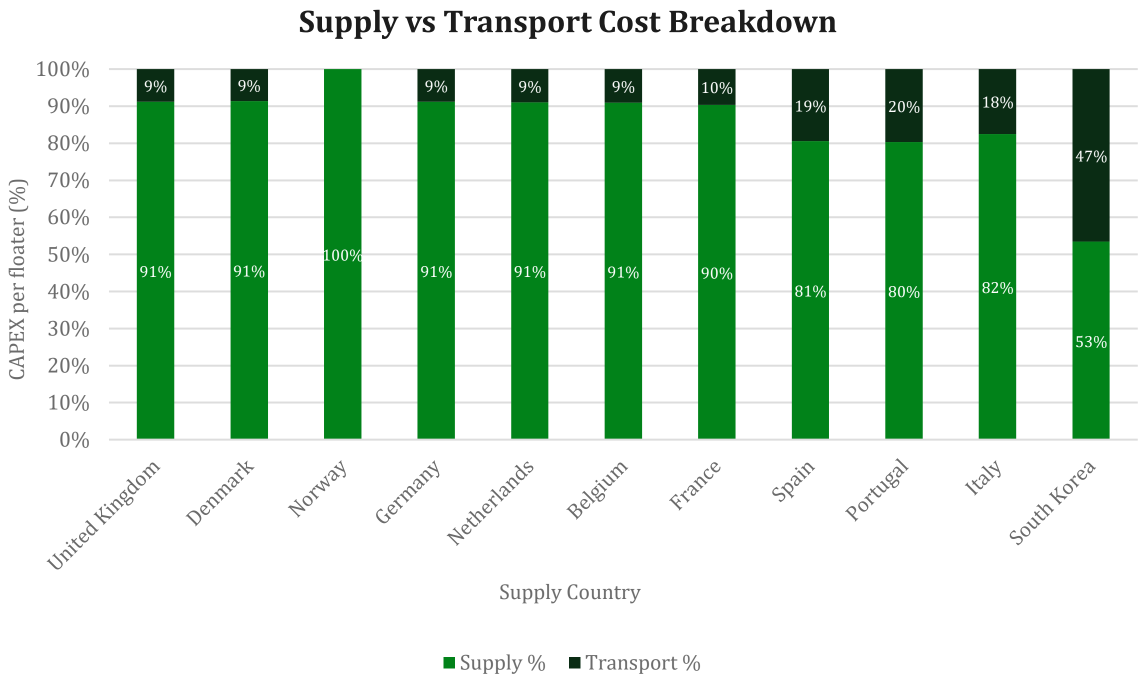
Supply and Transportation Costs - Outputs

Including supply costs indexed by region and estimated transportation costs.

- This analysis is for comparative purposes for supply from the selected countries to Norway (Stavanger was selected as a representative destination port). Detailed foundation costing would require additional design/engineering analysis.
- The indicative results in the adjacent figures show that Spain and Portugal are likely to have the optimal supply and transport capital expenditure (CAPEX) breakdown.
- Norway is expected to have very high supply costs, due to its high labour rate (as per the labour rate index outlined on the previous slide).
- The countries in Northern and Western Europe are characterised by low transportation costs (covering transit across the North Sea to Norway) with relatively high supply costs.
- South Korea is expected to have one of the lowest supply costs, with the highest transportation cost resulting from the extremely long navigation distance to Norway. This also entails logistical risk, due to the complexity around transporting high volumes of large floater components across this distance, and the need for extended access to scarce heavy lift vessels.





[1] Normalised to baseline of lowest cost country = 1

Foundation Demand to 2033

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Floating foundation demand

18 GW of floating capacity is forecasted to be deployed between 2023-2033

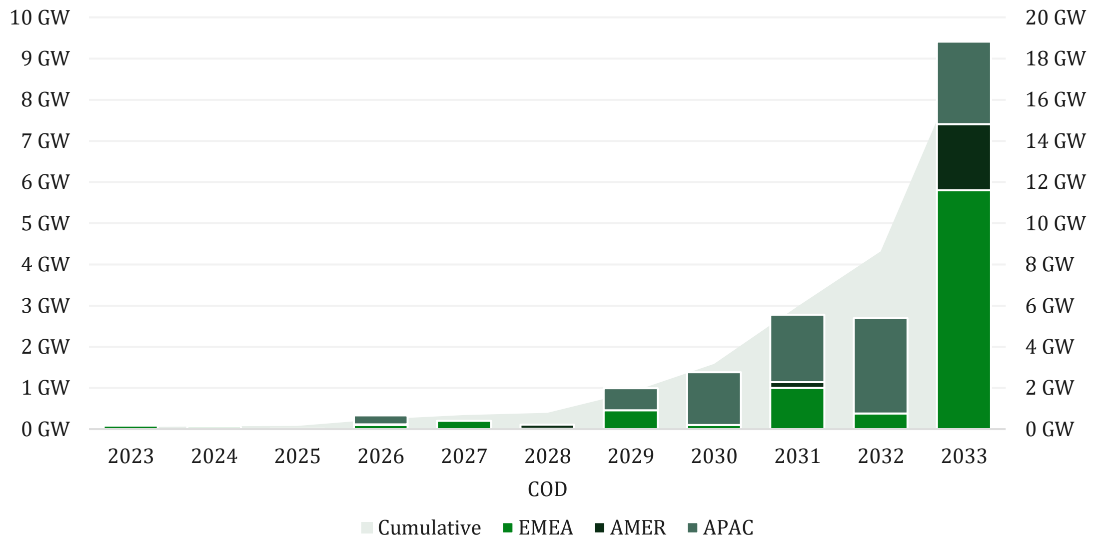
By leveraging its offshore wind market intelligence tool, global renewable infrastructure projects database (GRIP), ERM has extracted the planned project pipeline to build a floating forecast to 2033. ERM uses a combination of bottom-up and top-down forecasting (when bottom-up forecasting is not practical). We can use bottom-up forecasting when projects have secured seabed exclusivity. However, a top-down method is more appropriate for dates further in the future to ensure that we take into account government OSW targets, OSW policies, and ongoing or planned auctions when considering the most likely built-outs.

Globally, a total of 218MW capacity of floating wind energy is currently operational. 18 GW of floating wind energy is expected to reach commercial operation by 2033. Of the forecasted 18 GW by 2033, about 80% of the pipeline of floating wind energy will be realized after 2030 with a peak demand in 2033.

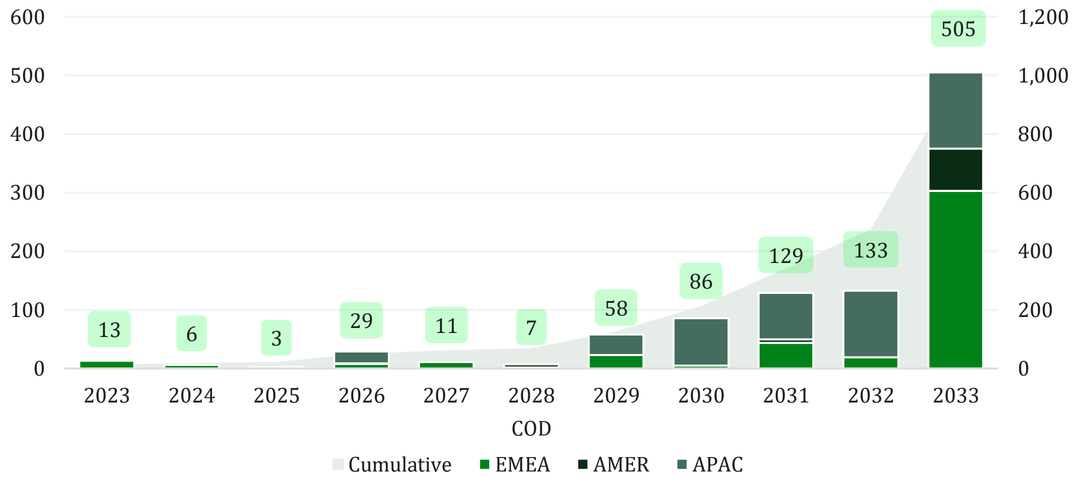
Around 46% of the installed capacity is expected to be in the EMEA, followed by APAC by around 44%. ERM estimated the floater demand in the number of units and around 980 floaters need to be fabricated to meet the demand of projects reaching commercial operations by 2033.

There are a few key issues to solve for the floating industry to unlock the forecasted potential. The majority of the floating markets are newly set up and have no route to market mechanisms or regulatory certainty. This imposes a great risk to the project development pipeline and project finance. Most of the announced projects still need to secure seabed exclusivity.

Floating foundation demand by COD (MW)



Floating foundation demand by COD (units)



ERM

Potential Supply / Demand Bottlenecks

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Floating foundation supply vs demand

Findings

Several yards are capable of fabricating floating structures but as yet, existing yards are carrying out serial substructure fabrication or assembly, therefore there is no large scale dedicated floating substructure supply capacity. There is an opportunity for yards with expertise in large steel structure to capitalise on this gap, however this would need to be supported with healthy, financially viable FOW project pipeline. The demand for floating structures is almost negligible prior to 2027 and after 2027, the first commercial scale projects are expected to reach COD, with a significant ramp up starting in 2031. Therefore, there may not be a business case for yards to switch from other focus areas (i.e. O&G structures, ship building, fixed bottom offshore wind) to supporting FOW at scale until projects targeting COD after 2030 begin procurement activities.

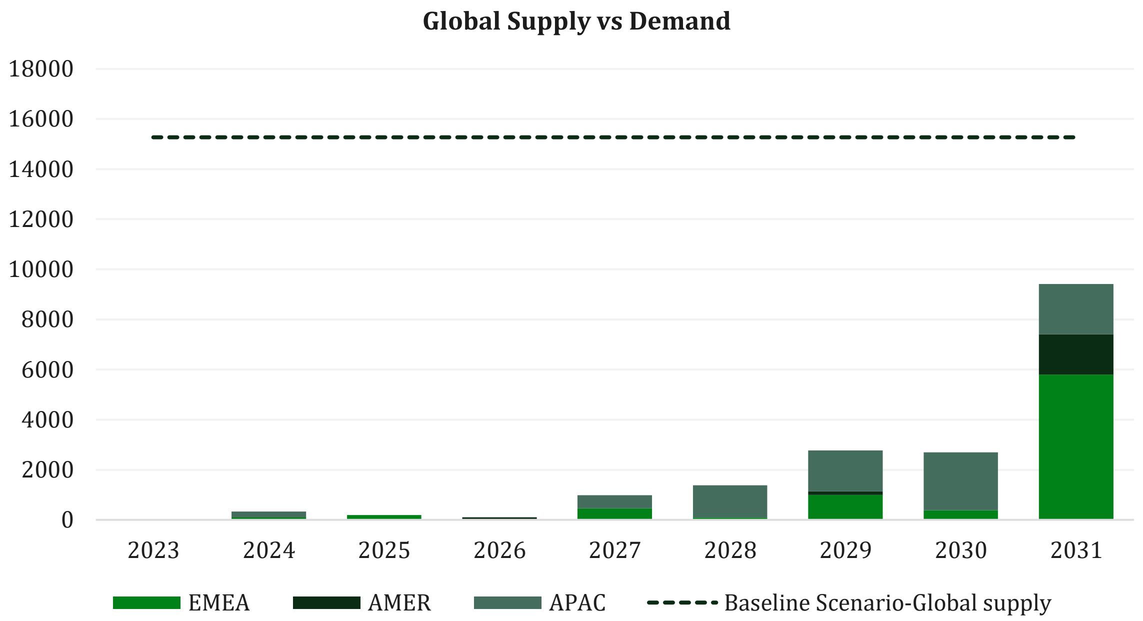
If sufficient initiatives and investments are provided for FOW, the global supply capacity could support around 15 GW/year, based on data gathered from 46 yards and the assumptions below. North Sea yards could support 5 GW/year and Southern Europe could support around 2.6 GW/year of floating capacity. The baseline capacity scenario will still be dependent on a viable business case (i.e. sufficient confirmed FOW project pipeline) to pivot to floating foundations.

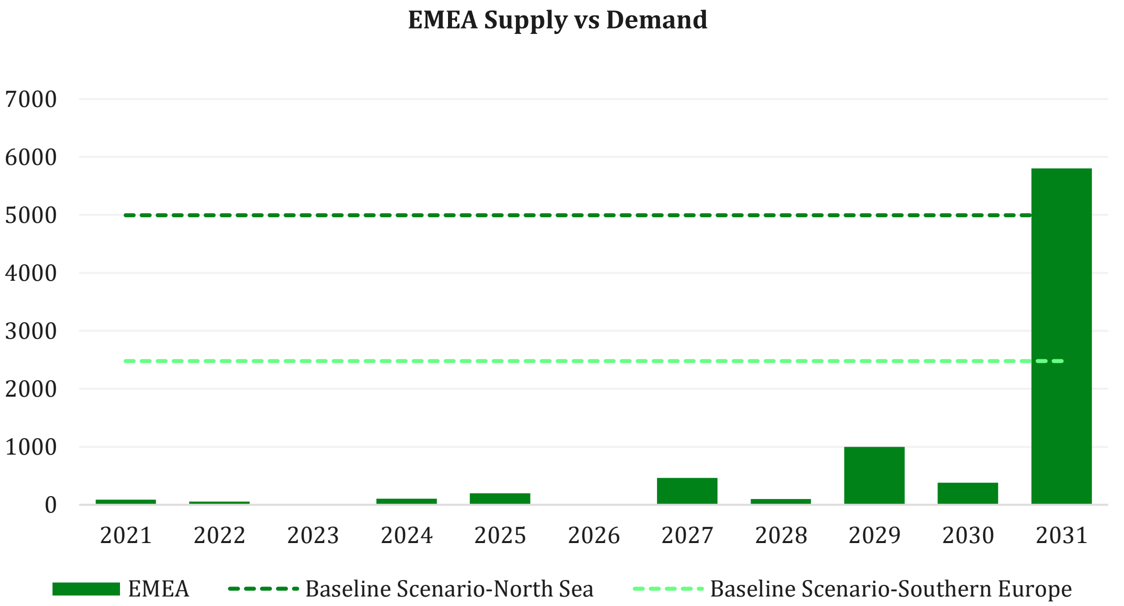
Assumptions

- Data collected from 46 yards located in 11 different countries presented in Slide 8.

- Capacity fraction allocated to FOW estimated for each yard to estimate the baseline scenarios (see Appendix-Slide 39).

- These supply capacity estimates are primarily driven by yard areas. Capacity estimates derived from steel supply/fabrication would require further analysis.





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Appendix 1 - Yard Capacity Assumptions

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General Assumptions

- The supplier selection included in this report is not fully comprehensive, as future developments are uncertain due to the open-ended nature of the FOW market at this early stage.
- Yard capacity estimation was carried out using the extrapolations in the subsequent slides. The lower bound was used for yards with data availability for both yard area and steel fabrication capacity.
- Assuming only steel semi-submersible foundations in this analysis as this archetype is expected to dominate the FOW market.
- Smaller suppliers were screened out if deemed unsuitable for serial manufacture.
- The 'high scenario' assumes 100% availability of all yards for FOW, providing an upper bound for the capacity.
- For the 'low scenario' yards which are not dedicated to FOW, an estimated yard allocation to FOW was assumed based on the following categories:

Yard Status	Assumed Yard Fraction Allocated to FOW
Minimal orders for applications competing with FOW	75%
FBOW+FOW order book expected	50%
Large FBOW order book but some availability expected	20%
Overbooked for FBOW and O&G, no expressed interest in FOW	0%

Floater Mass Extrapolation

- This extrapolation enables unit/year estimates for yards with publicly available steel structure production capacities, by equating the floater mass to the production capacity.
- It should be noted that the t/MW ratio is likely to decrease slightly as unit capacities increase as floater mass will not scale linearly (due to economies of scale and balance of plant scaling).

Floater Mass Data[1,2,3]

Item	Mass (t)	Unit Capacity (MW)	Mass:Capacity Ratio (t/MW)	Source
Steel floater	3500	17	205.9	2
	4000	20	200.0	1,2
	3500	15	233.3	3
	Average	/	**213.1**	**1,2,3**

Floater Mass Extrapolation

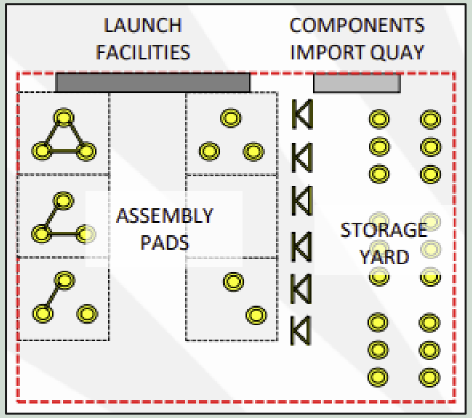
WTG Unit Capacity (MW)	Floater Mass (t)
10	2,130
11	2,340
12	2,560
13	2,770
14	2,980
15	3,200
16	3,410
17	3,620
18	3,840
19	4,050
20	4,260
21	4,470
22	4,690

[1] FOW-PR19-Strategic-Infrastructure-Dev-Summary-May-22-AW3.pdf (catapult.org.uk)
[2] Renewable UK FOW Taskforce Roadmap
[3] Construction port (guidetofloatingoffshorewind.com)

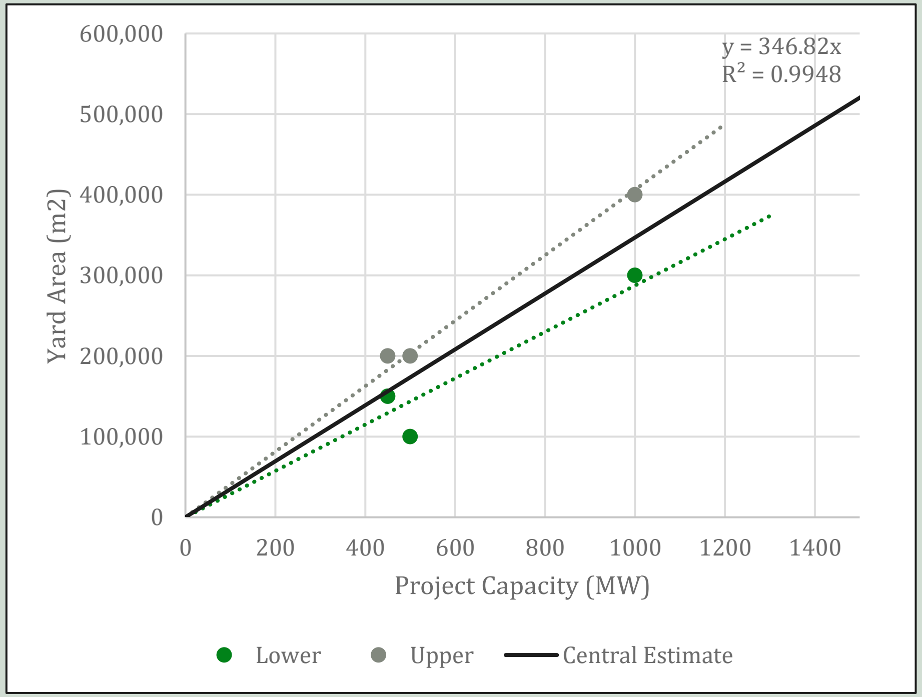
Assembly Footprint

- This extrapolation enables unit/year estimates for yards with known yard areas but no publicly available steel structure production capacities, by equating the yard area requirements to the production capacity.
- Publicly available data for yard areas were used where available, and the applicable yard area was measured for those with no published data.

Example Steel Floater Yard Layout[2]



Assembly Footprint Extrapolation[1,2,3]



Project Capacity = Yard Area / 346.82

[1] FOW-PR19-Strategic-Infrastructure-Dev-Summary-May-22-AW3.pdf (catapult.org.uk)
[2] Renewable UK FOW Taskforce Roadmap
[3] Construction port (guidetofloatingoffshorewind.com)

Subsea Cable Supply & Demand

Main Export Cable Suppliers

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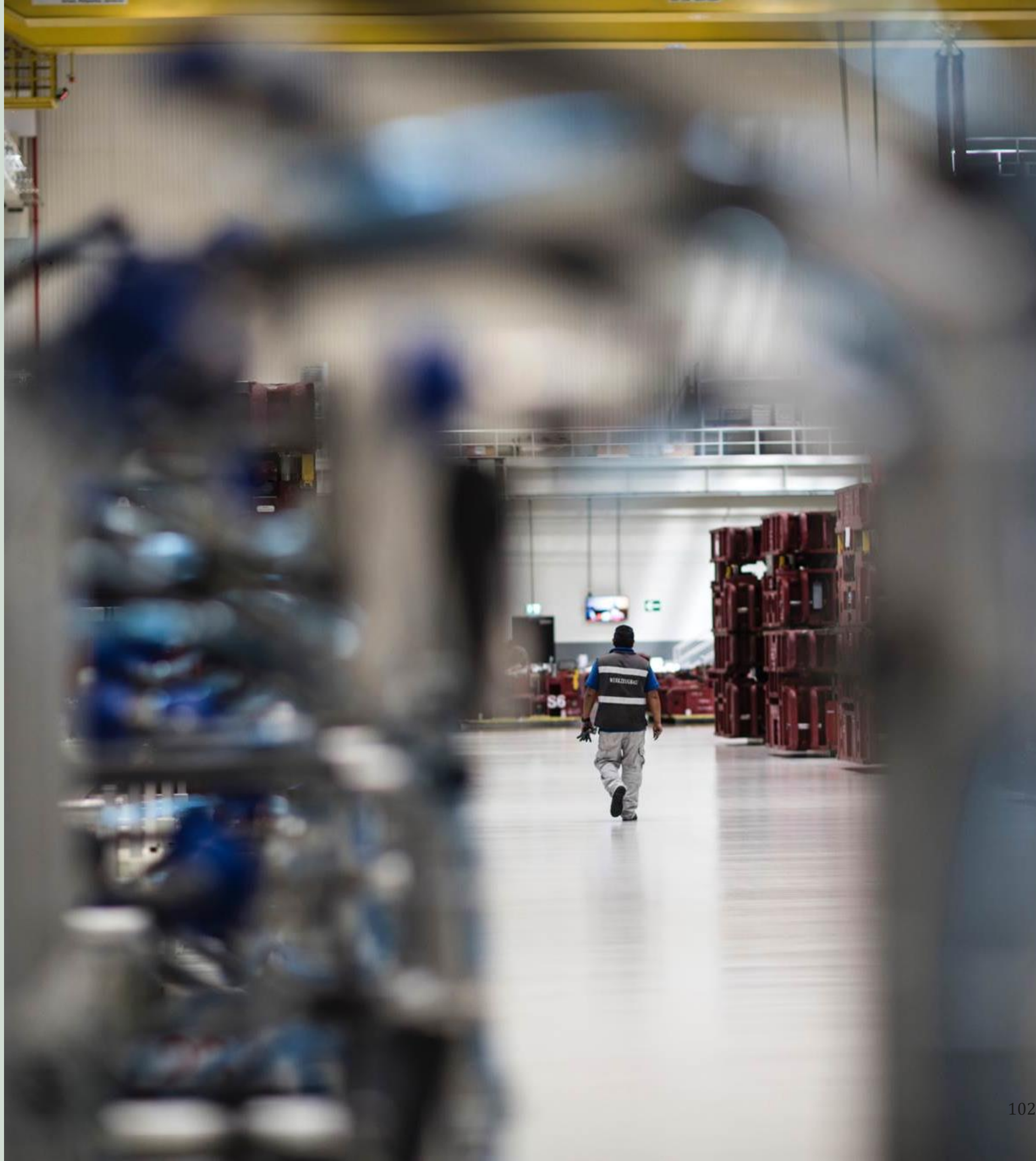


Approach to Identifying Suppliers and Estimating their Capacity

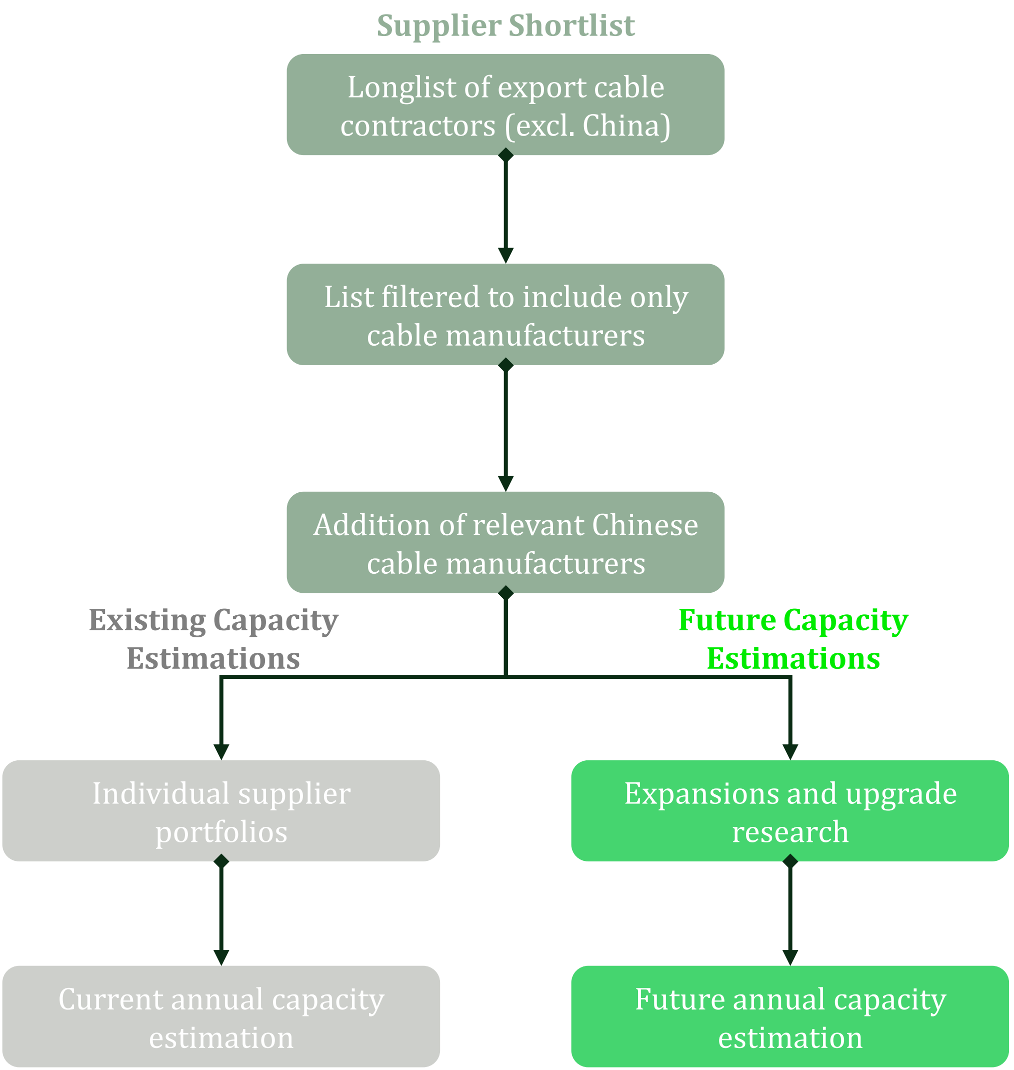
A longlist of export cable suppliers was created by first downloading from GRIP every cable contractor on record for past and future offshore wind projects. Next, we filtered for companies manufacturing capabilities, noting length of cable supplied to each offshore wind project on record.

Availability of Chinese offshore wind project data is limited, however, there are Chinese cable manufacturers that have shown interest in international markets and are relevant to this study. To identify applicable Chinese companies, we interviewed internal ERM cable experts and studied public announcements to build out the list of Chinese cable manufacturers and understand the lengths of cables supplied to offshore wind projects. The export cable shortlist included both cable manufacturers tracked in GRIP as well as the Chinese cable manufacturers.

Supplier capacities were then estimated by assuming the entire cable length per project would be installed in a single year (the export cable installation year) and combined to aggregate capacity per year per supplier. The suppliers' current capacities were taken as the maximum cable length delivered in a single year before 2024.

The shortlist of cable manufacturers was further studied to identify existing facilities as well as announced expansion plans for existing and new facilities. Where expansion plans included details on annual capacities, these were included directly as stated in the supplier capacity forecast. Where a supplier announced a new cable manufacturing plant or upgrade, but did not provide capacity details, it was assumed that the new plant would be roughly in line with the average capacity of that supplier's existing plants. For example, if a supplier has a total estimated capacity of 300 km/year, two existing cable plants, and plans to build a new plant to enter operation in 2026, then the average existing plant capacity of 150 km/year would be allocated to the new plant, resulting in a forecasted capacity of 450 km / year from 2026.

Overview of Approach



Supplier Profiles – Hellenic Cables and LS Cable

Hellenic Cables

Key information and stated capability:

Parameter	Description
Owner	Cenergy Holdings
Headquarter location	Athens, Greece
Facility location(s)	Corinth, Greece
Number of employees	c. 2,100
Capacity	100 km/year
Co-operation/JVs	*No known collaborations*

Supplier Introduction:

Hellenic Cables provides a complete range of services and turnkey solutions in the onshore and offshore cable sectors. In early 2023, investment in the Corinth plant was announced to double submarine cable production capacity. The plant is supported by the Thiva, Greece and Bucharest, Romania land power and telecom cable plants. In 2022, Hellenic Cables had a revenue of 0.6 bn EUR.

Track record:

Parameter	
Number of projects performed	10
Projects performed	Rentel; Borkum West 2.2; Borkum Riffgrund 2; Modular Offshore Grid (MOG); Seamade Seastar & Mermaid; Hollandse Kust (zuid) & Beta; Vesterhav Nord & Syd
Project pipeline	Baltica 2; Baltyk 2 & 3; Gennaker (western substation); N-3.7; N-3.8

Sources: Hellenic Cables website, reNEWS.biz, ERM GRIP database

LS Cable

Key information and stated capability:

Parameter	Description
Owner	LS Group
Headquarter location	Seoul, South Korea
Facility location	Donghae, South Korea
Number of employees	c. 6,100
Capacity	200 km/year
Co-operation/JVs	PTSC; DNV; Northland Power Korea

Supplier Introduction:

In addition to the recent completion of its Donghae HVDC subsea cable factory, the LS Cable has plans to build subsea cable production plants in the US, UK and Vietnam in order to provide more competitive prices in its key markets. In 2022, LS Cable had a revenue of 3.0 bn EUR.

Track record:

Parameter	
Number of projects performed	11
Projects performed	Westermost Rough; Luchterduinen; Rampion; Block Island; Norther; Yunlin; Greater Changhua 1 & 2; Haineng (Formosa 2); Hollandse Kust (west) Alpha; Hollandse Kust (noord) Alpha
Project pipeline	Hailong 2 & 3; Norfolk Boreas; Norfolk Vanguard East & West

Sources: LS Cable website, Business Korea, Yonhap News Agency, The Korea Times, DNV website, offshoreWIND.biz, ERM GRIP database

Supplier Profiles – Nexans and NKT

Nexans

Key information and stated capability:

Parameter	Description
Owner	Nexans
Headquarter location	Paris, France
Facility locations	Halden, Norway; Hannover, Germany; Charleroi, Belgium; Charleston, USA
Number of employees	c. 28,000
Capacity	400 km/year
Co-operation/JVs	*No known collaborations*

Supplier Introduction:

Nexans provides solutions and services along the entire value chain of offshore wind farms. In 2022, Nexans began the expansion of its Halden factory, including capability to 525 kV HVDC and 400 kV HVAC. This will increase the supplier's capacity, with completion originally planned for 2023. The Charleston facility was also recently expanded. In 2022, Nexans had a revenue of 8.3 bn EUR.

Track record:

Parameter	
Number of projects performed	24
Projects performed	Blyth Offshore Wind Test Site 1; Hornsea 2; East Anglia 1; Beatrice; London Array; Arklow Bank
Project pipeline	Moray West; Empire Wind; Empire Wind Phase 2; Ocean Wind; Dieppe-Le Treport

Sources: Nexans website, Offshore Energy, AFRY website, ERM GRIP database

NKT

Key information and stated capability:

Parameter	Description
Owner	NKT Group
Headquarter location	Brondby, Denmark
Facility locations	Cologne, Germany; Karlskrona, Sweden
Number of employees	c. 4,500
Capacity	500 km/year
Co-operation/JVs	*No known collaborations*

Supplier Introduction:

NKT's solutions bring power to interconnections, hydro-electric and nuclear power plants, as well as onshore and offshore wind farms, oil and gas platforms and solar energy. NKT has HV submarine cable production facilities in Cologne and Karlskrona. The firm also owns the NKT Victoria cable laying vessel. In 2022, NKT had a revenue of 1.4 bn EUR.

Track record:

Parameter	
Number of projects performed	23
Projects performed	Rentel; Borselle Alpha and Beta; Walney Extension East; Moray East; Triton Knoll; Horns Rev 3; Kriegers Flak
Project pipeline	Baltic Eagle; Dogger Bank A, B & C; East Anglia 3; BorWin5; Arcadis Ostwind 2

Sources: NKT website, ERM GRIP database

Supplier Profiles – Orient Cable and Prysmian

Orient Cable (NBO)

Key information and stated capability:

Parameter	Description
Owner(s)	Ningbo Orient Group
Headquarter location	Ningbo, China
Facility location	Zhejiang Province, China
Number of employees	c. 1,300
Capacity	100 km/year*
Co-operation/JVs	*No known collaborations**

Supplier Introduction:

Orient Cables claims to have over 98% market share of the China HV submarine cable market, supplying array, export HVAC/HVDC and dynamic cables to offshore projects. Despite only having supplied export cables in China, the company is also active in the European market, having been chosen to supply the Baltica 2 array cables. In 2022, Orient Cable had a revenue of 0.9 bn EUR.

Track record:

Parameter	
Number of projects performed	9*
Projects performed	Zhejiang Zhoushan Putuo No. 6 Zone 2 OWP; Guangdong Yangjiang Qingzhou 1 & 2; Yangjiang Qingzhou III; Putian Pinghai III; Yangjiang Shapa Phases 1-5
Project pipeline	Unknown*

Sources: Orient Cable website, offshoreWIND.biz, Offshore Energy, Financial Times, ERM GRIP database

Prysmian

Key information and stated capability:

Parameter	Description
Owner	Prysmian Group
Headquarter location	Milan, Italy
Facility location(s)	Pikkala, Finland; Arco Felice, Italy
Number of employees	c. 30,000
Capacity	500 km/year
Co-operation/JVs	Transelectrica

Supplier Introduction:

Prysmian has worked on supply-only and turnkey projects, including for fixed and floating offshore wind farms, and can produce cables up to 275 kV HVAC. As part of the Commonwealth Wind project, Prysmian intends to build a state-of-the-art manufacturing facility for submarine transmission cables in Massachusetts, USA. In 2022, Prysmian had a revenue of 16 bn EUR.

Track record:

Parameter	
Number of projects performed	36
Projects performed	Saint-Nazaire; Deutsche Bucht; Vineyard; Neart Na Gaoithe; Nordsee Ost; Walney 1 & 2; Meerwind; Thanet
Project pipeline	Dolwin 4 & 5; Calvados; Sofia; Commonwealth Wind; Yeu-Noirmoutier; Coastal Virginia Offshore Wind; Park City Wind; Borwin 4; IJmuiden Ver Alpha; Nederwiek 1; BalWin 1 & 2; Provence Grand Large; Gruissan

*Limited publicly available information.

Sources: Prysmian website, reNEWS.biz, IENE, ERM GRIP database

Supplier Profiles – Sumitomo Electric and ZTT Cable

Sumitomo Electric

Key information and stated capability:

Parameter	Description
Owner(s)	Sumitomo Electric Group
Headquarter location	Osaka, Japan
Facility location(s)	Hitachi, Japan (J-Power Systems); Tanajib, Saudi Arabia (J-Power Systems); Pune, India (J-Power Systems)
Number of employees	c. 280,000
Capacity	50 km /year*
Co-operation/JVs	Seaway 7

Supplier Introduction:

Sumitomo Electric manufactures power and fibre optic cables for automotive, info-communications, energy, environment and industrial materials industries. Subsidiary J-Power Systems recently supplied the NEMO interconnector (400 kV HVDC). In 2022, Sumitomo had net sales of 25 bn EUR. Sumitomo Electric received approval for plans to establish a power cable factory in Scotland.

Track record:

Parameter	
Number of projects performed	5*
Projects performed	Southwest Sea Phase 1 Demonstration Project; Noshiro Port Offshore Wind Power Generation Project; Akita Port Offshore Wind Power Generation Project; Gwynt y Môr
Project pipeline	*Unknown**

Sources: Sumitomo Electric website, Inverness Courier, Seaway 7 website, ERM GRIP database

ZTT Cable

Key information and stated capability:

Parameter	Description
Owner(s)	ZTT Group
Headquarter location	Jiangsu Province, China
Facility location(s)	Alagoas, Brazil; Shanghai, China
Number of employees	c. 16,000
Capacity	100 km/year*
Co-operation/JVs	*No known collaborations**

Supplier Introduction:

ZTT Cable is a major supplier of HVDC and HVAC subsea cables in China and has numerous locations around the world. The company has supplied cables for various industries including offshore wind export cables. In 2022, ZTT Cable had a revenue of 7.2 bn EUR.

Track record:

Parameter	
Number of projects performed	7*
Projects performed	Jiangsu Binhai South H3 OWP; Hohe See; Gode Wind 3; Kaskasi; Yangjiang Nanpeng Island; Kaskasi II; Jiangsu Rudong 6
Project pipeline	Baltica 2; Gennaker (eastern substation); CGN Huizhou Port II

*Limited publicly available information.

Sources: ZTT Cable website, offshoreWIND.biz, ERM GRIP database

Base Estimate 1,750 km / year Capacity for Offshore Wind

This base estimate could increase by 2,700 km / year for a total 4,450 km / year if we also add factory expansion plans. Further increases could come from China's Orient Cable and ZTT bringing existing capacity to 1,950 km / year and future post-expansion capacity to 4,850 km / year.

Supplier	Location of Current Facilities	Upgrades Underway or Planned	Current and Future Capacity
Hellenic Cables	• Corinth, Greece	• Corinth, Greece expansion (operational: 2025)	• Current: 100 km/year • 2025: 200 km/year
LS Cable	• Donghae, South Korea	• Donghae, South Korea expansion (operational: 2025) • USA plant in planning (quoted as starting at 50% of Donghae capacity) • Company looking to construct subsea cable plants in UK, Vietnam and Taiwan	• Current: 200 km/year • 2025: 400* km/year • Future: 1100* km/year
Nexans	• Halden, Norway • Hannover, Germany • Charleroi, Belgium • Charleston, USA	• Halden, Norway expansion (operational: 2024)	• Current: 400 km/year • Later in 2024: 500* km/year
NKT	• Cologne, Germany • Karlskrona, Sweden	• Karlskrona, Sweden expansion (operational: 2027)	• Current: 500 km/year • 2027: 750* km/year
Orient Cable	• Zhejiang Province, China	• Yangijng, China (unknown operational date, plant in construction phase- 2025 is estimated for the operational date)	• Current: 100 km/year • Near future (2025 estimated): 200* km/year
Prysmian	• Pikkala, Finland • Arco Felice, Italy	• Massachusetts, USA (2027**)	• Current: 500 km/year • 2027: 750* km/year
Sumitomo	• Hitachi, Japan (J-Power Systems) • Tanajib, Saudi Arabia (J-Power Systems) • Pune, India (J-Power Systems)	• Scotland plant in planning, The Highland Council's north planning applications committee approved the planning permission in 2024. The capacity is estimated to come online around 2028.	• Current: 50 km/year • Future (2028 estimated): 100* km/year
ZTT Cable	• Alagoas, Brazil • Shanghai, China	• No known expansion plans	• Current: 100 km/year

*Assuming facility/expansion capacities will be consistent with current facility capacities.
**Commonwealth Wind project export cable installation scheduled for 2027; new plant to support, and operational date inferred. Facilities consider AC and DC plants with capacities exceeding 132 kV.
Source: supplier public websites, GRIP and ERM analyses.

Capacity (excl China)	Capacity (inc China)	Description
1,750 km / year	1,950 km / year	Base estimate
4,450 km / year	4,850 km / year	Base plus expansion plans

Export Cable Demand to 2033

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Forecasted Export Cable Installation

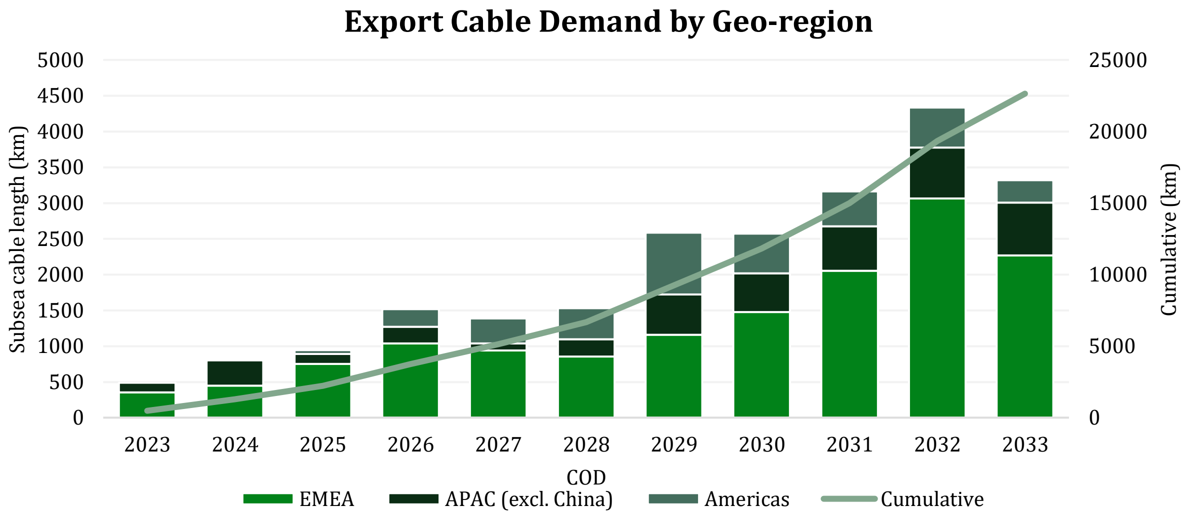
Methodology - Expected subsea cable installation was derived from COD forecasts. Cable length required per project was sourced from public data sources and where this wasn't available, we used the GRIP model which follows the equation below.

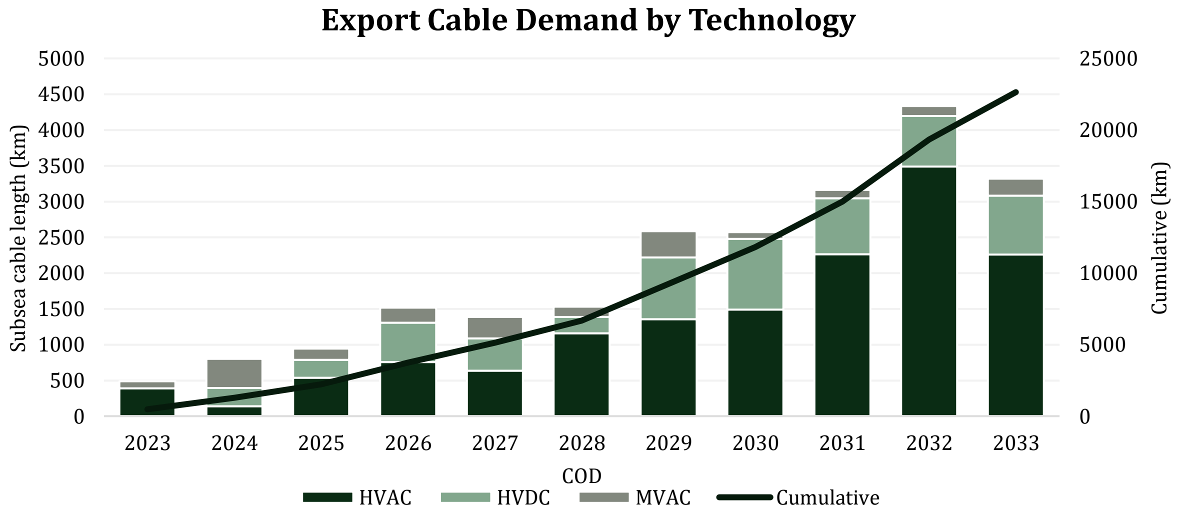
Total cable length (km) = no cables * (median distance to shore*1.1832 + 5.9033)

Insights - Subsea cable demand, as expected increases in line with the project build out forecast period. There is a ramp up in demand from 2029. This heightened demand is linked to the concerted efforts of nations working to achieve offshore wind targets by 2030. The market is predicted to experience a peak in cable demand for projects reaching COD in 2032. The EMEA market consistently dominates the landscape across the entire forecast duration. The APAC region experiences a growth in demand in 2029 but this plateaus for the remaining forecast period.

HVAC cables have been the industry standard technology for export cables and continue to be within the forecast period. With longer transmission distances HVAC cables become increasingly inefficient therefore the industry have begun to implement HVDC cables. HVDC systems exhibit lower transmission losses over long submarine cable lengths. The higher cost of HVDC systems; however, will prevent it from becoming the industry norm in the short term. The demand for HVDC cables remains relatively steady throughout the forecast period.

Around 22,000 km (excluding China) of export cable is forecasted to be installed between 2023 and 2033. Considering the protracted timeline involved in offshore wind project development, it is unlikely that subsea cable demand will markedly surpass the forecasted levels within this period.





ERM

Potential Supply / Demand Bottlenecks

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Export Cable Demand vs Supply

Conclusions

Nexans, NKT, Prysmian, Hellenic Cables, Sumitomo and LS Cables will be the main export cables suppliers (excluding China). Subsea cable demand, as expected, increases throughout the forecast period, with a ramp up in demand from 2027. The current offshore wind export cable supply capacity is estimated to be 1750 km/year[1], excluding Chinese cable manufacturers. A shortage of supply is expected with the current capacities, driving almost every supplier to propose expansion plans. The future capacity could increase by 2,700 km / year[1] (to a total 4,450 km / year[1]) to meet the increased demand forecast in 2027 and the peak demand in 2030. If the current expansions go forward, or Chinese manufacturers enter the international markets, there may not be an immediate export cable shortage.

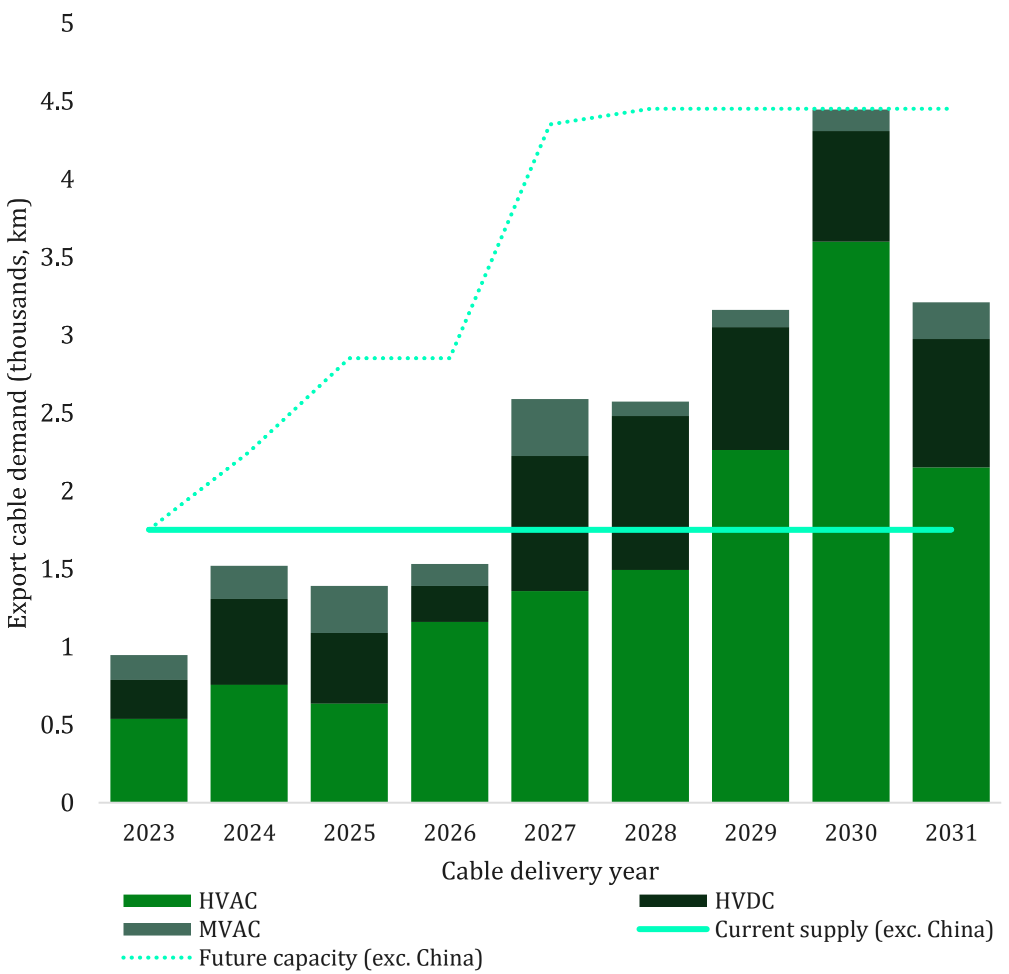
Although interconnectors are outside the scope of this study, industry expects a shortage of HVDC cables starting 2025, due to the booming interconnector industry after the energy security concerns in Europe.

Assumptions

- Cable demand is estimated to be 2 years prior to COD, based on the historical project trends. Cable demand is measured in km of cables.
- Plants manufacturing HVDC cables can be easily converted to HVAC cable manufacturing so, the supply and demand curves are applicable to the total HVDC and HVAC markets.
- Export cable suppliers are often the same companies that supply interconnectors. Although growth in demand for interconnectors will impact capacity it is expected that this will be compensated with the conservatism of using historical data.
- Chinese suppliers' primary market will be China with some expected sales abroad.

1) Existing capacity of 1,750 km / year , additional capacity of 2,700 km / year and future capacity of 4,450 / year is based on suppliers current and planned capacities (excluding China) as detailed on slide 12

Subsea Cable Demand vs Supply, by Technology



Vessel Supply & Demand

Foundation Installation Vessel Supply

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Heavy-Lift Foundation Installation Vessel Supply

The table shows the current fleet of 20 heavy-lift vessels active in offshore wind foundation installation, broken down by foundation type.

Supply of heavy-lift vessels active in foundation installation[1]

Vessel	Operator	Flag	Status	Jackets	Monopiles	XXL Monopiles
Les Alizés	Jan de Nul	LU	Active	✓	✓	✓
Svanen	Van Oord	BS	Upgrade	✓	✓	✓
Alfa Lift	Seaway 7	NO	Active	✓	✓	✓
Strashnov	Seaway 7	CY	Active	✓	✓	✓
Bokalift 2	Boskalis	CY	Active	✓	✓	
Orion	DEME	BE	Active	✓	✓	
Saipem 3000	Saipem	BS	Active	✓	✓	
Sapura 3500	Sapura Energy	PA	Active	✓	✓	
Seaway Yudin	Seaway 7	CY	Active	✓	✓	
Matador 3	Bonn & Mees	NL	Active	✓		
Asian Hercules III	Boskalis	SG	Active	✓		
Bokalift 1	Boskalis	CY	Active	✓		
Green Jade	CDWE	TW	Active	✓		
Aegir	Heerema	PA	Active	✓		
Balder	Heerema	PA	Active	✓		
Sleipnir	Heerema	PA	Active	✓		
Thialf	Heerema	PA	Active	✓		
Saipem 7000	Saipem	BS	Active	✓		
Gulliver	Scaldis	LU	Active	✓		
Rambiz	Scaldis	BE	Active	✓		
Total				**20**	**9**	**4**

Source: GRIP vessels database, ERM analysis.
[1] Data excludes Chinese suppliers

Supply of heavy-lift vessels active in foundation installation

- There are no new build heavy-lift vessels set to enter the market as operators are focusing on increasing their fleet of jack-ups.
- Svanen is the only heavy-lift vessel scheduled to have a crane upgrade which will increase the lifting capacity from 3000t to 4500t. The upgrade includes an extension of the gantry crane and upgrades to the lifting hooks, gripper, and structure of the vessel to accommodate the latest hammer size. The upgraded vessel will be operational from Q3 2024.
- There are more vessels capable of installing jackets than monopiles so it likely that operators will schedule upgrades to widen the fleet of monopile installation vessels.
- Most of the fleet is European and works primarily in the EMEA market. Vessels focused on the APAC and AMER markets are in short supply.
- Some jack-ups have the capability of installing both foundations and turbines so are active in both markets. These vessels have been outlined on the next slide.

Jack-up Foundation Installation Vessel Supply

Although predominantly served by heavy-lift vessels, there are 12 jack-up vessels able to install foundations (in addition to their more common use of turbine installation) resulting in a total of 32 vessels with jacket foundation installation capabilities.

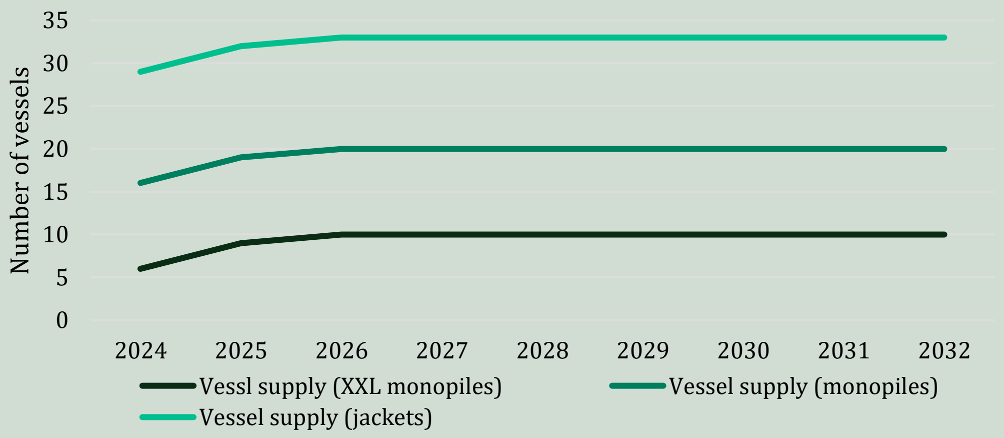
Supply of jack-up vessels active in foundation and turbine installation[1]

Vessel	Operator	Flag	Status	Jackets	Monopiles	XXL Monopiles	Turbines
Wind Ally	Cadeler		Construction	✓	✓	✓	✓ >20 MW
Wind Ace	Cadeler		Construction	✓	✓	✓	✓ >20 MW
NG20000X 1	Havfram		Construction	✓	✓	✓	✓ >20 MW
NG20000X 2	Havfram		Construction	✓	✓	✓	✓ >20 MW
Boreas	Van Oord	NL	Construction	✓	✓	✓	✓ >20 MW
Ventus	Seaway 7	NO	Active	✓	✓	✓	✓ 15 MW
Wind Scylla	Cadeler	PA	Active	✓	✓		✓ 14 MW
Innovation	DEME	DE	Active	✓	✓		✓ 10 MW
Blue Wind	Shimizu Corp	JP	Active	✓	✓		✓ 15 MW
Aeolus	Van Oord NV	NL	Active	✓	✓		✓ 15 MW
Wind Lift 1	Harren & Partner	DE	Active	✓			✓ <10 MW
CP-16001	Penta-Ocean	JP	Active	✓			✓ 14 MW
Total				**12**	**10**	**6**	**12**

Source: GRIP vessels database
[1] Data excludes Chinese suppliers

Supply of vessels active in foundation and turbine installation

- The table shows the current fleet of jack-up vessels able to install foundations in addition to their typical turbine installation.
- Vessel operators are building new jack-ups with the capability of installing both monopiles and turbines to maximise the vessel utilisation. This also allows for long-term contracts to be made between vessel operators and developers.
- The chart below shows the total supply of foundation installation vessels (12 jack ups plus 20 heavy lift).



Heavy-Lift (Foundation) Vessel Specifications (1/4)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Outreach	Upcoming contracts
 BONN & MEES	**Name:** Matador 3 **Type:** Floating sheerleg **Dim:** 70m x 32m **Deck:** - **Max load:** 1169t	• Foundation Installation (jackets)	2002	1800t	Max height (above deck): 75 m	
 Boskalis	**Name:** Asian Hercules III **Type:** Floating sheerleg **Dim:** 106.42m x 52m **Deck:** - **Max load:** -	• Foundation Installation (jackets)	2015	5000t	Max height (above deck): 120 m	
 Boskalis	**Name:** Bokalift 1 **Type:** Heavy lift vessel **Dim:** 216m x 43m **Deck:** 6300m^2 **Max load:** 15000t	• Foundation Installation (jackets)	2012	3000t @ 28m	Boom length: 100m Max height (above deck): 110m	2025: **Inch Cape** monopiles, substation and cables
 Boskalis	**Name:** Bokalift 2 **Type:** DP2 Crane Vessel **Dim:** 231m x 49m **Deck:** 7500m^2 **Max load:** -	• Foundation Installation (jackets and monopiles)	2000 (converted in 2021)	4000t @ 28m	Boom length: 100m Max height (above deck): 103m	Current: **South Fork** monopiles 2024: **Revolution Wind** monopiles
 CDWE	**Name:** Green Jade **Type:** DP3 installation vessel **Dim:** 216.5m x 49m **Deck:** 8232 m^2 **Max load:** 23,000t	• Foundation Installation (jackets) • Wind turbine installation	2023	4000t @ 42m	Max height (above deck): 125 m	2024: **Hai Long** jackets and turbines

Heavy-Lift (Foundation) Vessel Specifications (2/4)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Outreach	Upcoming contracts
	**Name:** Orion **Type:** DP3 installation vessel **Dim:** 216.5m x 49m **Deck:** 8000 m^2 **Max load:** 30,000t	• Foundation Installation (jackets and monopiles)	2019	5000t @ 30m	Boom length: 160m Max height (above deck): 180m	Current: **Moray West** monopiles 2024: **CVOW Commercial** substations
	**Name:** Aegir **Type:** Heavy lift vessel **Dim:** 211m x 46m **Deck:** - **Max load:** 4500t	• Foundation Installation (jackets)	2013	5000t @ 33m	Boom length: 125m Max height (above deck): 96 m	
	**Name:** Balder **Type:** Semi-submersible crane vessel **Dim:** 154m x 106m **Deck:** - **Max load:** 8000t	• Foundation Installation (jackets)	1978	3628t @ 52m (6,300t in tandem)	Max height (above deck): 98m	
	**Name:** Sleipnir **Type:** Semi-submersible crane vessel **Dim:** 220m x 102m **Deck:** 1200m^2 **Max load:** 20,000t	• Foundation Installation (jackets)	2019	10,000t @ 48m	Boom length: 144m Max height (above deck): 129m	2024: **Sofia** HVDC converter
	**Name:** Thialf **Type:** Semi-submersible crane vessel **Dim:** 201.6m x 88.4m **Deck:** - **Max load:** 12,000t	• Foundation Installation (jackets) • Wind turbine installation	1985	7100t @ 31.2m (14,200t in tandem)	Max height (above deck): 95 m	2024: **Empire Wind 1 and 2** foundations and substation 2026: **Beacon Wind 1 and 2** foundations and substation

Heavy-Lift (Foundation) Vessel Specifications (3/4)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Outreach	Upcoming contracts
	**Name:** Les Alizés **Type:** DP2 installation vessel **Dim:** 236.8m x 52m **Deck:** 9300 m^2 **Max load:** 61,000t	• Foundation Installation (jackets and monopiles)	2023	5000t @ 36m	Max height (above deck): 125m	Current: **Borkum Riffgrund 3** monopiles 2025: **Thor** foundations
	**Name:** Saipem 3000 **Type:** DP heavy lift vessel **Dim:** 162m x 38m **Deck:** 3000 m^2 **Max load:** -	• Foundation Installation (jackets and monopiles)	1983 (converted in 2003)	2177t @ 39.6m	Boom length: 87m Max height (above deck): 105 m	Current: **Calvados (Courseulles-sur-Mer)** monopiles
	**Name:** Saipem 7000 **Type:** DP heavy lift vessel **Dim:** 197.95m x 87m **Deck:** 9000 m^2 **Max load:** 15,000t	• Foundation Installation (jackets) • OSS Foundation installation	1987	7000t @ 45m (14,000t in tandem)	Boom length: 140m	2024: **Dogger Bank B** substation
	**Name:** Sapura 3500 **Type:** DP3 heavy lift vessel **Dim:** 156.5m x 44.8m **Deck:** - **Max load:** 12,253t	• Foundation Installation (jackets and monopiles)	2014	3500t @ 35m	Max height (above deck): 100m	
	**Name:** Gulliver **Type:** DP2 heavy lift vessel **Dim:** 108 m x 49 m **Deck:** 1300 m^2 **Max load:** 4598t	• Foundation Installation (jackets) • OSS Foundation installation	2018	2000t @ 19.5m (4000t in tandem)	Boom length: 85m Max height (above deck): 78.5 m	

Heavy-Lift (Foundation) Vessel Specifications (4/4)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Outreach	Upcoming contracts
	**Name:** Rambiz **Type:** Heavy lift vessel **Dim:** 85 m x 44 m **Deck:** 1500 m^2 **Max load:** 1100 t	• Foundation Installation (jackets) • OSS Foundation installation	1996 (converted in 2000)	1x1600 @ 18m 1x1700 @ 16.5m (3300t in tandem)	Boom length: 82m Max height (above deck): 78 m	
	**Name:** Seaway alfa Lift **Type:** Heavy lift vessel **Dim:** 217.88 m x 56 m **Deck:** 10110 m^2 **Max load:** 50,253t	• Foundation Installation (jackets and monopiles)	2023	3000t @ 30m	Max height (above deck): 108 m	Current: **Dogger Bank A** TP installation **2024: Dogger Bank B and C** monopiles
	**Name:** Seaway Strashnov **Type:** Heavy lift vessel **Dim:** 183 m x 47 m **Deck:** 4000 m^2 **Max load:** 8500 t	• Foundation Installation (jackets and monopiles)	2011	5000t @ 32m	Max height (above deck): 83.8 m	
	**Name:** Seaway Yudin **Type:** Heavy lift vessel **Dim:** 183.2 m x 36 m **Deck:** 2560 m^2 **Max load:** 5000 t	• Foundation installation (jackets and monopiles)	1985	2500t	Max height (above deck): 65.04 m	
	**Name:** Svanen **Type:** Heavy lift vessel **Dim:** 102.75 m x 74.6 m **Deck:** - **Max load:** 5897t	• Foundation installation (jackets and monopiles)	1991 (upgrade in 2024)	5705t	Max height (above deck): 72 m	2024: **Baltic Power** monopiles

Jack-up Vessel Supply

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Jack-up Turbine Installation Vessel Supply

There are 13 vessels currently under construction or with upgrades underway capable of 15 MW turbine installation.

Vessel	Operator	Flag	Status	10MW	12MW	15MW	20MW+
Nessie	Cadeler		In construction	✓	✓	✓	✓
Siren	Cadeler		In construction	✓	✓	✓	✓
Wind Ace	Cadeler		In construction	✓	✓	✓	✓
Wind Ally	Cadeler		In construction	✓	✓	✓	✓
Wind Orca	Cadeler	DK	Upgrade	✓	✓	✓	✓
Wind Osprey	Cadeler	DK	Upgrade	✓	✓	✓	✓
Wind Pace	Cadeler		In construction	✓	✓	✓	✓
Wind Peak	Cadeler		In construction	✓	✓	✓	✓
NG20000X 1	Havfram		In construction	✓	✓	✓	✓
NG20000X 2	Havfram		In construction	✓	✓	✓	✓
Voltaire	Jan de Nul	LU	Active	✓	✓	✓	✓
Maersk WIV	Maersk		In construction	✓	✓	✓	✓
Boreas	Van Oord	NL	In construction	✓	✓	✓	✓
Sea Installer	DEME	DK	Active	✓	✓	✓	
Charybdis	Dominion	US	In construction	✓	✓	✓	
Bold Tern	Fred. Olsen	MT	Active	✓	✓	✓	
Brave Tern	Fred. Olsen	MT	Active	✓	✓	✓	
Ventus	Seaway 7	NO	Active	✓	✓	✓	
Blue Wind	Shimizu Corp	JP	Active	✓	✓	✓	
Aeolus	Van Oord NV	NL	Active	✓	✓	✓	
Wind Scylla	Cadeler	PA	Active	✓	✓		
Sea Installer	DEME	DK	Active	✓	✓		
CP-16001	Penta-Ocean	JP	Active	✓	✓		
Wind Zaratan	Cadeler	JP	Active	✓			
Apollo	DEME	LU	Active	✓			
INNOVATION	DEME	DE	Active	✓			
Sea Challenger	DEME	DK	Active	✓			
Blue Tern	Fred. Olsen	UK	Active	✓			
JB - 117	Jack-up Barge	BS	Active	✓			
Vole au Vent	Jan de Nul	LU	Active	✓			
MPI Adventure	Van Oord NV	NL	Active	✓			
Total				**31**	**23**	**20**	**13**

Source: GRIP vessels database, ERM analysis.
[1] Data excludes Chinese suppliers

Supply of jack-up vessels active in turbine installation

- The table shows the current fleet of jack-up vessels active in offshore wind turbine installation.
- Wind Orca and Wind Osprey are currently undergoing upgrades to increase their crane capacities from 1200t to 1600t, which will enable them to install 20 MW turbines. Fred. Olsen upgraded Bold Tern and Brave Tern in 2022 and 2023, respectively.
- DEME upgraded Sea Installer in 2023 to allow the vessel to install 15 MW turbines.
- The fleet of vessels capable of installing 12 MW turbines or less are also active in the operations and maintenance market. However, some of these vessels could receive upgrades to accommodate the growing demand for 15 MW turbine installation.
- Most of the fleet is European and works primarily in the EMEA market. Vessels focused on the APAC and AMER markets are in short supply.
- Vessel operators are focusing on increasing their fleet of jack-ups which have the capability of installing both foundations and turbines. These vessels have been outlined on slide 7.

Heavy-lift Turbine Installation Vessel Supply

Although predominantly served by jack-up vessels, there are 3 heavy lift vessel able to install turbines (in addition to their more common use of jacket installation) resulting in a total of 34 vessels capable of turbine installation.

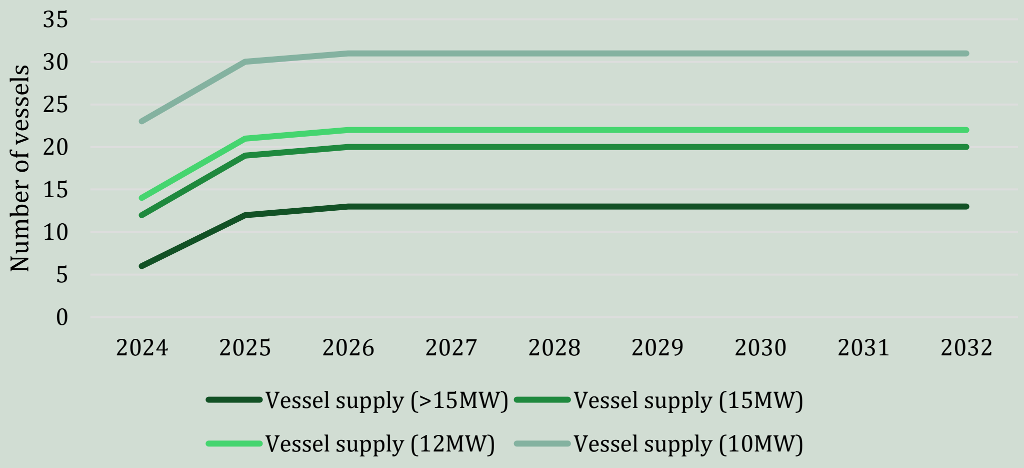
Supply of heavy-lift vessels active in foundation and turbine installation[1]

Vessel	Operator	Flag	Status	Jackets	Turbines
Green Jade	CDWE	TW	Active	✓	✓ 14 MW
Sleipnir	Heerema	PA	Active	✓	✓ 15 MW
Thialf	Heerema	PA	Active	✓	✓ 15 MW
	Total			**3**	**3**

Source: GRIP vessels database
[1] Data excludes Chinese suppliers

Supply of vessels active in foundation and turbine installation

- The table shows the heavy-lift vessels that are active in both turbine and foundation installation.
- Heavy-lift vessels are not usually chartered for turbine installation. However, Heerema developed a method for floating turbine installation where rotor nacelle assembly takes place on board the vessel.
- The chart below shows the total supply of turbine installation vessels (3 jack ups plus 31 heavy lift).



Jack-up (Turbine) Vessel Specifications (1/9)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Working depth/ leg length	Outreach	Upcoming contracts
 CADELER	**Name:** Hydra **Type**: Jack-up **Dim:** 75m x 36m **Deck:** 900 m^2 **Max load:** 1500t	• Turbine installation	2014	400t @ 18.5m	48m / 84.8m	Boom length: 73m	
 CADELER	**Name:** Kraken **Type**: Jack-up **Dim:** 80m x 36m **Deck:** 900 m^2 **Max load:** 1400t	• Turbine installation	2009	300t @ 16m	48m / 84.8m	Boom length: 70m	
 CADELER	**Name:** Nessie **Type**: Jack-up **Dim:** 184m x 56m **Deck:** 5400 m^2 **Max load:** 11,400 t	• Turbine installation	2024	2600t @ 31m	65m / 109m	Max height (above deck): 149 m	2025: Contract with undisclosed client for turbine installation
 CADELER	**Name:** Siren **Type**: Jack-up **Dim:** 184m x 56m **Deck:** 5400 m^2 **Max load:** 11,400t	• Turbine installation	2025	2600t @ 31m	65m / 109m	Max height (above deck): 149 m	
 CADELER	**Name:** Wind Ace **Type:** Jack-up **Dim:** 152m x 58m **Deck:** 5600 m^2 **Max load:** 17,600 t	• Foundation installation (6 x XXL monopiles)	2026	>3000t @ 30m	70m / 120m	Max height (above deck): 200m	

Jack-up (Turbine) Vessel Specifications (2/9)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Working depth/ leg length	Outreach	Upcoming contracts
 CADELER	**Name:** Wind Ally **Type:** Jack-up **Dim:** 152m x 58m **Deck:** 5600 m^2 **Max load:** 17,600 t	• Foundation installation (6 x XXL monopiles)	2025	>3000t @ 30m	70m / 120m	Max height (above deck): 200m	2026: **Hornsea 3** monopiles 2027 – 2030: Contract with undisclosed client
 CADELER	**Name:** Wind Orca **Type:** Jack-up **Dim:** 161m x 49m **Deck:** 4300 m^2 **Max load:** 11,000 t	• Turbine installation	2012	1200t @ 31m Upgrade to 1600t @ 40m in 2024	60m / 105m	Boom length: 115.2m Max height (above deck): 132m Upgrade height: 160m	2024: **Moray West** turbines 2025: **Baltic Power** turbines 2026: **East Anglia Three** turbines
 CADELER	**Name:** Wind Osprey **Type:** Jack-up **Dim:** 160.9m x 49m **Deck:** 4300 m^2 **Max load:** 11,000 t	• Turbine installation	2013	1200t @ 31m Upgrade to 1600t @ 40m in 2024	60m / 105m	Boom length: 115.2m Max height (above deck): 132m Upgrade height: 160m	2024: **Gode Wind 3** turbines 2025: **Borkum Riffgrund 3** turbines
 CADELER	**Name:** Wind Pace **Type:** Jack-up **Dim:** 152m x 58m **Deck:** 5600 m^2 **Max load:** 17,600 t	• Turbine installation (7 x 15MW or 5 x 20+MW)	2025	2500t @ 46m	70m / 120m	Boom length: 155m (extendable to 175m) Max height (above deck): 180.5m (extendable to 200.5m)	2026: **Hornsea 3** turbines
 CADELER	**Name:** Wind Peak **Type:** Jack-up **Dim:** 152m x 58m **Deck:** 5600 m^2 **Max load:** 17,600 t	• Turbine installation (7 x 15MW or 5 x 20+MW)	2024	2500t @ 53m	70m / 120m	Boom length: 155m (extendable to 175m) Max height (above deck): 180.5m (extendable to 200.5m)	2024: **Sofia** turbines 2026: **East Anglia Three** turbines

Jack-up (Turbine) Vessel Specifications (3/9)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Working depth/ leg length	Outreach	Upcoming contracts
 CADELER	**Name:** Wind Scylla **Type**: Jack-up **Dim:** 139m x 50m **Deck:** 4600 m² **Max load:** 8000t	• Turbine installation • Foundation Installation	2015	1540t @ 31.5m	65m / 105m	Boom length: 105m Max height (above deck): 132m	
 CADELER	**Name:** Wind Zaratan **Type**: Jack-up **Dim:** 108.7m x 41m **Deck:** 2000 m² **Max load:** 3600t	• Turbine installation	2012	800t @ 24m	55m / 85m	Max height (above deck): 92m	
 DEME	**Name:** Apollo **Type:** Jack-up **Dim:** 87.5m x 42m **Deck:** 2000 m² **Max load:** 4500 t	• Turbine installation	2018	800t @ 36m	70m / 84.2m (extendable to 106.8m)	Max height (above deck): 140m	2024: **Moray West** transition pieces
 DEME	**Name:** INNOVATION **Type:** Jack-up **Dim:** 147.5m x 42m **Deck:** 3400 m² **Max load:** 8000 t	• Turbine installation • Foundation installation	2012	1500t	65m / 89m	Max height (above deck): 120m	Current: **Fécamp** turbines 2024: **Noirmoutier** monopiles
 DEME	**Name:** Neptune **Type:** Jack-up barge **Dim:** 60m x 38m **Deck:** 1600 m² **Max load:** 2000 t	• Turbine installation • Foundation installation • O&M	2012	600t @ 23m	45m / 80m	Boom length: 85m Max height (above deck): 94m	

Jack-up (Turbine) Vessel Specifications (4/9)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Working depth/ leg length	Outreach	Upcoming contracts
 DEME	**Name:** Sea Challenger **Type:** Jack-up **Dim:** 132.4m x 39m **Deck:** 3350 m^2 **Max load:** 6000t	• Turbine installation • O&M	2014 (upgraded in 2022)	700t @ 28m	55m / 82.5m	Boom length: 115m	
 DEME	**Name:** Sea Installer **Type:** Jack-up **Dim:** 132.4m x 39m **Deck:** 3350 m^2 **Max load:** 6000t	• Turbine installation	2014 (upgraded in 2023)	1600t @ 35m	60m / 82.5 m	Max height (above deck): 160m Boom length: 140m	Current: **Vineyard Wind 1** turbines
 Dominion Energy	**Name:** Charybdis **Type:** Jack-up **Dim:** 143.9m x 56.1m **Deck:** 5400m^2 **Max load:** 11,500t	• Turbine installation	2025	2200t @ 29m	65m / 109m	Boom length: 130m	2025: **Sunrise Wind** and **Revolution Wind** turbines 2026: **CVOW Commercial** turbines
 Fred. Olsen	**Name:** Blue Tern **Type**: Jack-up **Dim:** 151m x 50m **Deck:** 3750m^2 **Max load:** 8750t	• Turbine installation • O&M	2012 (upgraded in 2021)	800t @ 30 m	65m / 106m	Boom length:108m Max height (above deck): 127 m	Current: **Neart Na Gaoithe** turbines 2024: **Baltic Eagle** turbines
 Fred. Olsen	**Name:** Bold Tern **Type:** Jack-up **Dim:** 132m x 39m **Deck:** 3200 m^2 **Max load:** 9500 t	• Turbine installation	2013 (upgraded in 2022)	1600t @ 31m	60m / 92.4m	Boom length: 105m Max height (above deck): 157.5m	Current: **Changfang** and **Xidao** turbines

Jack-up (Turbine) Vessel Specifications (5/9)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Working depth/ leg length	Outreach	Upcoming contracts
 Fred. Olsen	**Name:** Brave Tern **Type:** Jack-up **Dim:** 132m x 39m **Deck:** 3600 m^2 **Max load:** 9500t	• Turbine installation	2012	800t @ 26 m Upgrade to 1600t @ 31m in 2024	60m / 92.4m	Boom length: 102m Upgraded boom: 105m Max height (above deck): 119m Upgraded height: 157.5m	Current: **Saint-Brieuc** turbines 2026: **Thor** turbines
 HARREN & PARTNER	**Name:** Thor **Type:** Jack-up **Dim:** 108m x 40m **Deck:** 1850 m^2 **Max load:** 2700t	• Turbine installation • O&M	2010	500t @ 15m	50m / 82m		
 HARREN & PARTNER	**Name:** Wind Lift 1 **Type:** Jack-up **Dim:** 115m x 45m **Deck:** 2224 m^2 **Max load:** 2000t	• Turbine installation • Foundation installation • O&M	2010	500t @ 31m	45m / 74m	Max height (above deck): 121m	
 Havfram	**Name:** Havfram WTIV 1 **Type:** Jack-up **Dim:** 151m x 58m **Deck:** 5600m^2 **Max load:** 16,100t	• Turbine installation • Foundation installation	2024	3250t	70m / 120m	Max height (above deck): 158m	2026: **Hornsea 3** turbines
 Havfram	**Name:** Havfram WTIV 2 **Type:** Jack-up **Dim:** 151m x 58m **Deck:** 5600m^2 **Max load:** 16,100t	• Wind turbine installation • Foundation installation	2025	3250t	70m / 120m	Max height (above deck): 158m	

Jack-up (Turbine) Vessel Specifications (6/9)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Working depth/ leg length	Outreach	Upcoming contracts
 J-UB JACK-UP BARGE	**Name:** JB-115 **Type:** Jack-up barge **Dim:** 55.5m x 32.2m **Deck:** 1000 m^2 **Max load:** 1250 t	• Turbine installation • O&M	2009	300t @ 22m	40m / 78.8m	Boom length: 90m Max height (above deck): 73	
 J-UB JACK-UP BARGE	**Name:** JB-117 **Type:** Jack-up barge **Dim:** 75.9m x 40m **Deck:** 2500 m^2 **Max load:** 2000t	• Turbine installation • O&M	2011	1000t @ 22m	45m / 80m	Boom length: 98m	
	**Name:** Vole au Vent **Type:** Jack-up **Dim:** 140.4m x 41m **Deck:** 3535 m^2 **Max load:** 6500 t	• Turbine installation • Foundation installation	2013	1500t @ 21.5m	50m / 90m	Boom length: 108m Max height (above deck): 120m	2026: **Dieppe - Le Tréport** turbines
	**Name:** Voltaire **Type:** Jack-up **Dim:** 181.78m x 60m **Deck:** 7000 m^2 **Max load:** 14000t	• Turbine installation • Foundation Installation	2022	3000t @ 26m	80m / 130m	Boom length: 140m Max height (above deck): 162.5m	Current: **Dogger Bank A, B and C** turbines
 MAERSK SUPPLY SERVICE	**Name:** Maersk WTIV **Type:** Jack-up **Dim:** - **Deck:** - **Max load:** -	• Turbine installation • Foundation installation	2025	-	60m / -	Max height (above deck): 180m	2025: **Empire Wind 1 and 2** turbines 2028: **Beacon Wind 1 and 2** turbines

Jack-up (Turbine) Vessel Specifications (7/9)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Working depth/ leg length	Outreach	Upcoming contracts
	**Name:** Obayashi WTIV **Type:** Jack-up barge **Dim: -** **Deck: -** **Max load: -**	• Turbine installation • Foundation installation	2024	1250t			
	**Name:** CP-16001 **Type:** Jack-up **Dim:** 120m x 45m **Deck: -** **Max load:-**	• Turbine installation • Foundation installation	2022	1600t @ 35m	65m / -	Max height (above deck): 160m	Current: **Kitakyushu Hibikinada** jackets and turbines
	**Name:** Seaway Ventus **Type:** Jack-up **Dim:** 142m x 50m **Deck:** 4600 m^2 **Max load:** 9800t	• Wind turbine installation	2023	2500t @ 35m	65m / 109m	Boom length: ~140m Max height (above deck): 116.5m	2024: **Gode Wind 3** turbines 2025: **Borkum Riffgrund 3** turbines
	**Name:** Blue Wind **Type:** Jack-up **Dim:** 142m x 50m **Deck:** 4600 m^2 **Max load: -**	• Wind turbine installation (7 x 8MW or 3 x 12MW)	2023	2500t	50m / 90 m	Max height (above deck): 158 m	
	**Name:** Aeolus **Type:** Jack-up **Dim:** 140m x 44.6m **Deck:** 3775 m^2 **Max load:** 7250t	• Foundation installation • Wind turbine installation	2014 Upgraded in 2018 and 2023	1600t @ 32m	45m / 81m	Boom length: 133m Max height (above deck): 151 m	Current: **South Fork** turbines 2024: **Sofia** monopiles

Jack-up (Turbine) Vessel Specifications (8/9)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Working depth/ leg length	Outreach	Upcoming contracts
	**Name:** Boreas **Type:** Jack-up **Dim:** 175.1m x 63m **Deck:** 7150m^2 **Max load:** 20,000t	• Wind turbine installation	2024	3200t	70m / 126m		2026: **Nordseecluster** foundations
	**Name:** MPI Adventure **Type:** Jack-up **Dim:** 138.55m x 40.8m **Deck:** 3600 m^2 **Max load:** 6000t	• Wind turbine installation • O&M	2011	1000t @ 25m	40m / 70.62m	Max height (above deck): 72.5 m	
	**Name:** MPI Resolution **Type:** Jack-up **Dim:** 130m x 38m **Deck:** 3200 m^2 **Max load:** 4000t	• Wind turbine installation • O&M	2003	600t @ 25m	35m / 70.5m		
	**Name:** Wind **Type:** Jack-up **Dim:** 55m x 18m **Deck:** 430m^2 **Max load:** 220t	• Wind turbine installation • O&M	1996	30t @30m	35m / 50m	Max height (above deck): 100 m	
	**Name:** Wind Pioneer **Type:** Jack-up barge **Dim:** 56m x 28m **Deck:** 530 m^2 **Max load:** 650t	• Wind turbine installation • O&M	2010	150t @19m	34m / 50m	Boom length: 78m Max height (above deck): 78 m	

Jack-up (Turbine) Vessel Specifications (9/9)

Image	Vessel Specs	Capabilities	Delivery Year	Crane lifting capacity	Working depth/ leg length	Outreach	Upcoming contracts
 ZITON	**Name:** Wind Server **Type:** Jack-up barge **Dim:** 79.6m x 32.2m **Deck:** 1000 m^2 **Max load:** 1500t	• Wind turbine installation • O&M	2014	400t @ 20m	45m / 75m	Boom length: 87m Max height (above deck): 96 m	
 ZITON	**Name:** Wind enterprise **Type:** Jack-up **Dim:** 100m x 40m **Deck:** 2850 m^2 **Max load:** 4500t	• Wind turbine installation • O&M	2012	800t @ 25m	45 / 78.6m	Boom length: 102m Max height (above deck): 115 m	

Potential Supply / Demand Bottlenecks

Sustainability is our business

Foundation Vessel Supply and Demand

Shortage of vessels (predominantly heavy-lift) capable of installing monopiles expected from 2032.

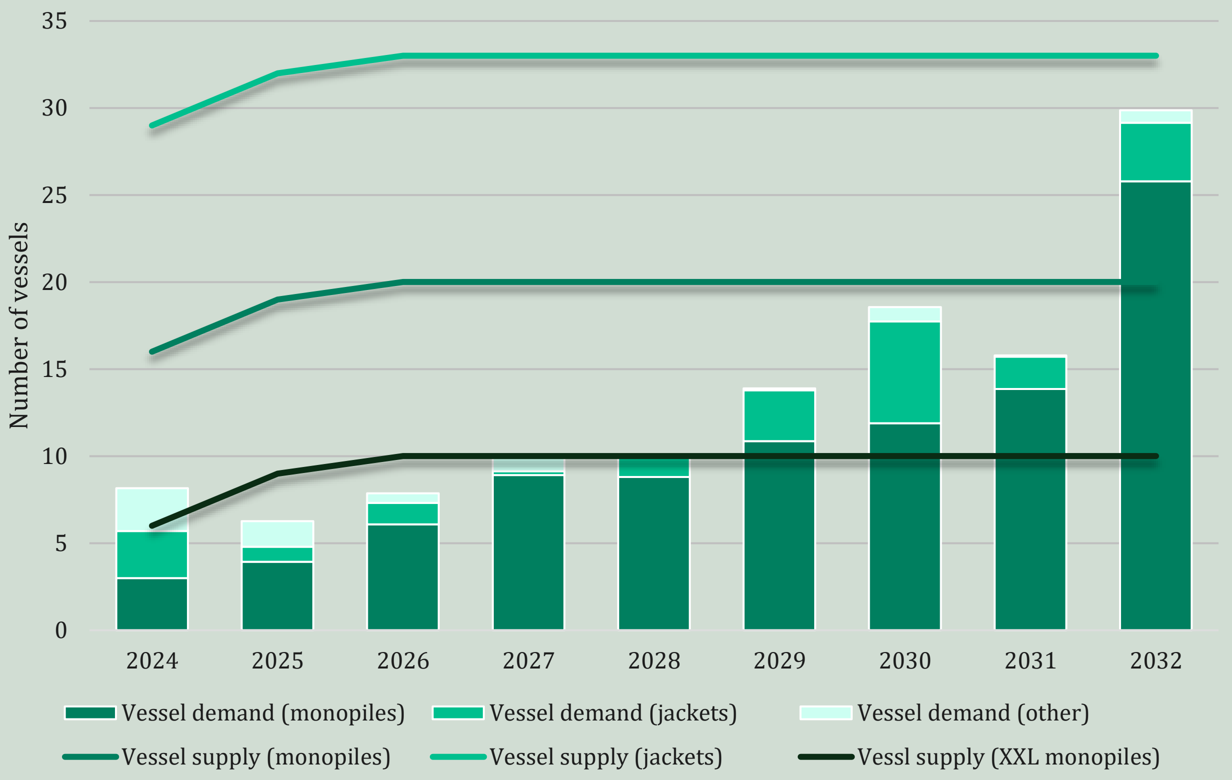
Methodology

- ERM and Brinckmann modelled the number of foundations being installed globally until 2032 (excluding China). FIV demand in vessel days assumes an average installation of 2.5 days per monopile, 3 days per jacket with vessel availability of 260 days a year (source: Clarksons).
- FIV supply has been modelled using public information on vessels active in offshore wind foundation installation.
- Jack-up vessels usually install turbines; however, as some install both turbines and foundations those vessels are included in the supply for both FIVs and WTIVs.

Results

- A shortage of monopile installation vessels is expected after 2032.
- The surplus jacket installation vessels may be upgraded to allow them to also install monopiles.
- AMER and APAC may see shortages as the fleet is mostly EU. EU fleet may move to APAC to fill the demand. In the US, the Jones Act will prevent foreign vessels and there are currently no US flagged FIVs in operation.
- Increasing water depths and turbine sizes will lead to larger monopiles. Only 6 vessels will be capable of XXL monopile installation by end of 2024.

Foundation installation vessel supply and demand (excl. China)



Source: GRIP vessels database, Brinckmann and ERM analysis.

Turbine Vessel Supply and Demand

Shortage of vessels (predominantly jack-up) capable of installing turbines larger than 15 MW expected from 2029 onwards.

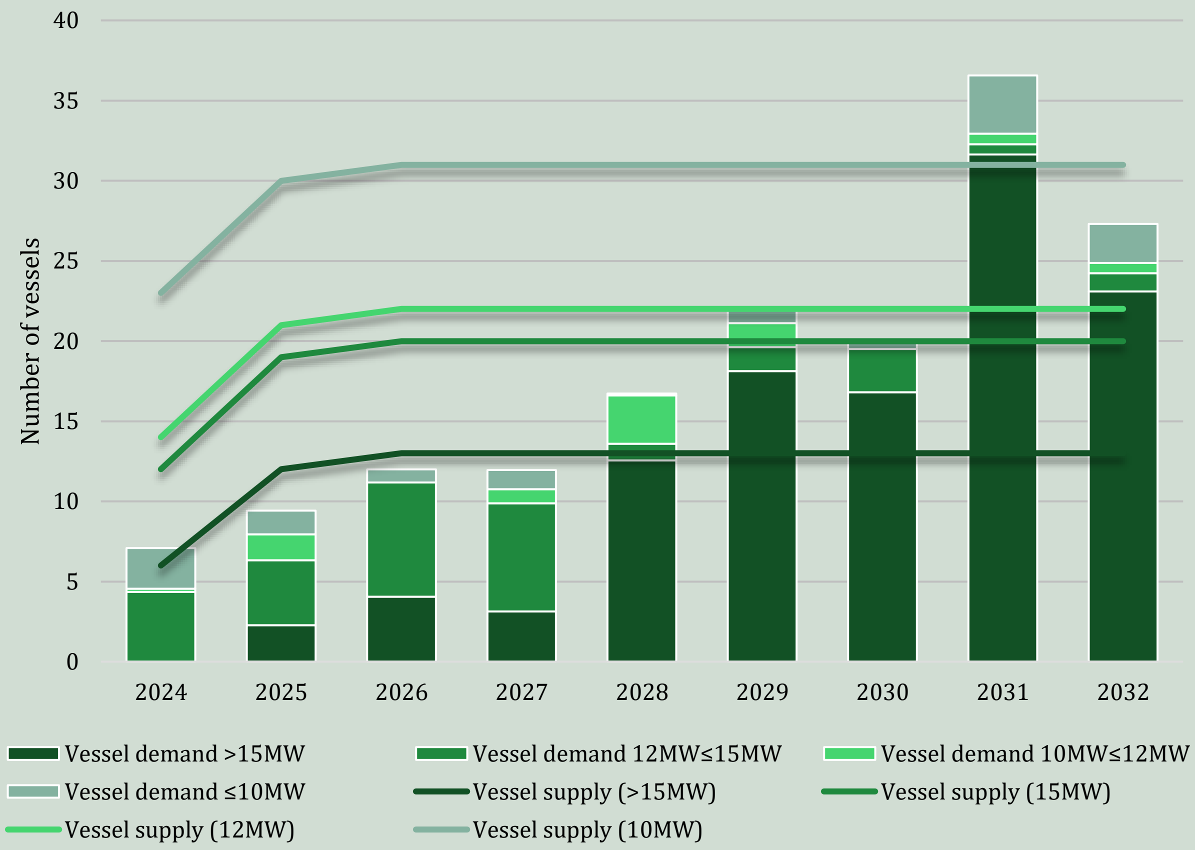
Methodology

- ERM and Brinckmann modelled the number of foundations installed globally until 2032 (excluding China). WTIV demand in vessel days assumes an average turbine installation rate of 3 days per turbines and vessel availability of 260 days a year (source: Clarksons).
- WTIV supply has been modelled using publicly information on jack-up vessels active in the offshore wind sector.
- Heavy-lift vessels usually install foundations; however, as some install both turbines and foundations those vessels are included in the supply for both FIVs and WTIVs.

Results

- Analysis of WTIV supply and demand shows a shortage of vessels capable of installing turbines larger than 15 MW from 2029 onwards.
- Due to the surplus of vessels capable of installing < 15 MW turbines, it is likely vessel operators will upgrade vessels to allow them to install larger turbines.
- AMER and APAC will likely see shortages as the WTIV fleet is mostly European. This could lead to some of the European fleet moving to the APAC markets. The Jones Act in America requires US flagged vessels. However, there is only one US flagged WTIV (Charybdis) which is scheduled for delivery in 2025.

Wind turbine installation vessel supply and demand (excl. China)



Source: GRIP vessels database, Brinckmann and ERM analysis.

Thank you

If further information is
required, please contact:

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