Global offshore wind market report, 2019
A report prepared on behalf of Norwegian Energy Partners

August 2019
The Norwegian offshore industry has a long history of innovating to create solutions to complex challenges in the high waters of the North Sea and elsewhere in the world. The Norwegian supply chain delivers world leading expertise throughout the energy value chain and is also utilizing its experience and competence from various engineering discipline to develop innovative solutions for offshore wind.

Our report *Norwegian supply chain opportunities in offshore wind*, published in June 2017 painted a positive picture of the vast opportunities for Norwegian companies with offshore and maritime expertise generated from a long life in the oil and gas business. The Norwegian Government is supporting the industry and has recently announced the opening of new areas for the development of offshore wind farms – with the main purpose of allowing the offshore industry to gain experience in offshore bottom fixed and floating wind. With this, the Norwegian offshore industry has both the background and the means to become a large supporter of the global offshore wind industry enabling further deployment of clean carbon free energy in new regions.

To match the expertise along the value chain with the opportunities globally, we have commissioned BVG Associates to detail the markets for our partners in this *Annual global offshore wind market report*. The report analyses the markets with the most opportunities to 2024 and it maps the opportunities in value terms across the supply chain. It also includes cost analysis, major supplier and owners by country and a general understanding of the supply chain. In addition to this *Annual global offshore wind market report*, Norwegian Energy Partners is publishing detailed analysis of priority projects across the world that we see as of most potential to the Norwegian suppliers over the next five years. The priority projects database includes detailed mapping of projects supply chain. Also available is a presentation of the anticipated contracting structures for these projects. The Global offshore wind priority projects searchable database and contracting structures presentation can be accessed from the NORWEP website.

We believe that the *Annual global offshore wind market report* together with the *Norwegian supply chain opportunities in offshore wind report* and the Global offshore wind priority projects database are valuable tools to partners of Norwegian Energy Partners in understanding the market and identifying potential clients and local partners. We believe that there are ample opportunities for Norwegian suppliers and that, with consistent market presence and efforts, the Norwegian share of the offshore wind market could reach 10% of the global market by 2030, up from the current 5-6%.

That would imply a tripling of the industry’s international turnover over the next ten years with the potential to reach NOK 50 billion by 2030, boosted by floating offshore wind, utilising the special position of the Norwegian industry in this subsector. Therefore, we hope that you find this report, together with the accompanying reports and global offshore wind priority projects database, useful in your market and sales efforts.

### 1.1.1 About the report authors

**BVG Associates:**

BVG Associates (BVGA) provides strategic consulting in renewable energy. We help our clients to do new things, think in new ways and solve tough problems. Our practical thinking integrates the business, economics and technology of renewable energy generation systems. We combine deep wind industry knowledge with skills gained in the world of business consulting. Our purpose is to help our clients succeed in a sustainable global electricity generation mix founded on renewables.

**Panticon:**

Panticon is a management consulting company based in Copenhagen, Denmark, specialising in renewable energy strategy crafting as well as mergers and acquisitions. Panticon is also involved in market research as well as industry analysis.

**Renewable Resources International:**

Virginia based Renewable Resources International LLC (RRI) is drawing from more than 20 years of commercial and operational experience in the US and global energy business, EPC project execution, strategic sourcing, logistics and manufacturing. Resulting from executive positions with ABB, Alstom and GE, the company has built a wide range of trusted contacts and is providing advisory services to advance the US offshore wind industry.
Global offshore wind market report, 2019

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2 Introduction

Norwegian Energy Partners (NORWEP) is a network-based organisation promoting the Norwegian energy industry’s capabilities in overseas markets.

NORWEP commissioned BVG Associates (BVGA) to prepare this report to provide global offshore wind market intelligence and highlight supply chain opportunities between 2020 and 2024 to its partners. Many Norwegian companies have direct experience of supplying offshore wind projects. Others recognise the opportunity and have the potential to diversify from other industries, such as oil and gas, but have not yet entered the market. This report aims to provide the market information to help both groups succeed in offshore wind.

In addition to this report, BVGA has prepared a new global offshore wind priority projects report, which is also available for NORWEP’s partners.¹ The priority project report provides project-specific detail and procurement contacts for upcoming offshore wind projects within Europe, Asia-Pacific and the Americas between 2020 and the end of 2024.

2.1 Structure of the report

The report has the following sections:
- Global offshore wind: a summary
- Europe
- Asia-Pacific
- Americas and
- Emerging markets.

For each region, we identify the market size from 2020 to the end of 2024 and estimate the estimated expenditure associated with supply chain activities. We discuss typical contracting structures and analyse how the developers with the largest operational portfolios have contracted with their supply chains.

Within the European market, we provide market intelligence for (in order of forecasted installed capacity):
- United Kingdom
- Germany
- Denmark
- Belgium
- Netherlands, and
- France

Within the Asian market, we provide market intelligence on:
- China
- Taiwan
- South Korea, and
- Japan

Within the Americas market, we provide market intelligence on the United States.

We also provide an overview of offshore wind developments in the following emerging markets, noting that there is very early development activity in further countries in the three regions:
- Europe
  - Estonia, Finland, Ireland, Lithuania, Norway, Poland, Portugal and Sweden
- Asia-Pacific
  - Australia, India, Singapore, Thailand, Turkey and Vietnam
- The Americas
  - Brazil and Canada

2.2 Methodology and assumptions

Where currencies have been converted to Euro (€) we have used exchange rates from close of business on 23/08/2019.

2.2.1 Market forecasts

For each region and country, we have forecast annual and cumulative installed capacities.

A central, or P50, forecast is used. This means there is a 50% chance that the cumulative forecast will be exceeded within the stated time period. It assumes a steady adoption of technology innovations, such as larger turbine ratings, and that current international and political intentions are achieved.

We also present the compound annual growth rate (CAGR), a measure of average growth in the installed cumulative capacity, from 2020 and 2024.

2.2.2 Turbine demand

For each country we have forecast turbine demand. Where the rating of the turbine to be used on a future project is not known, or a preferred supplier has not been announced, we either assumed or modelled the turbine rating. Where possible for near term projects, we assumed turbine ratings

¹ Global offshore wind priority project updates report is available to NORWEP’s partners at http://www.norwep.com/
based on historical contracting. To model the turbine rating, we used an annual average offshore wind turbine rating.

Turbine demand graphs are shown as year of turbine supply, which is offset by one year from the year of turbine installation.

### 2.2.3 Expenditure and levelised cost of energy

We estimate future expenditure for each main element of supply chain activity.

- Annual expenditure for a CAPEX element like turbines in a given year is calculated by multiplying MW forecast to be purchased in that market in that year by a €/MW cost for that element in that market for that year, and
- Annual expenditure for an OPEX element like planned maintenance by summing the MW installed each year in that market multiplied by a €/MW/year cost for that element in that market for that year of installation.

These costs are derived from our cost model. The model accounts for differences in project specifications, notably wind farm size, turbine rating, water depth and distance to shore (a proxy for distance to construction port / point of grid connection). We also model net capacity factor, project operational life and weighted average cost of capital (WACC). A different set of typical project specifications and input costs have been used for Europe, the US and for each country in Asia, as shown in Table 1, chosen as typical for projects to be installed in the period 2020-2024.

**Table 1 Fixed windfarm input parameters used with the cost modelling.**

<table>
<thead>
<tr>
<th>Region or country</th>
<th>Wind farm size (MW)</th>
<th>Water depth (m)</th>
<th>Distance to shore (km)</th>
<th>Wind speed at 100 m height (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>500</td>
<td>25</td>
<td>40</td>
<td>9.0</td>
</tr>
<tr>
<td>The Americas</td>
<td>500</td>
<td>35</td>
<td>40</td>
<td>8.25</td>
</tr>
<tr>
<td>China</td>
<td>300</td>
<td>10</td>
<td>30</td>
<td>8.0</td>
</tr>
<tr>
<td>Japan</td>
<td>200</td>
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<td>South Korea</td>
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<tr>
<td>Taiwan</td>
<td>500</td>
<td>25</td>
<td>40</td>
<td>9.0</td>
</tr>
</tbody>
</table>

The cost model also considers future innovation and learning in the industry, not just in terms of cost reductions, but also in terms of expected year by year increases in turbine size and increases in energy production. The model, therefore, produces a different set of €/MW and €/MW/year costs for each element of supply for each year of the forecast period for each of these regions or countries.

The cost model uses data held by BVGA and benchmarked through ongoing industry engagement. European expenditure is based on a significant amount of historical data and consensus. For Asia and the Americas there is a shorter track-record and a lower level of certainty about future cost trends, but we have engaged and validated our expenditure figures with industry contacts in each region.

For each main supply chain element the year of spend is offset from the year of installation according to when it would typically be spent. For example, spend on development would be incurred over a period of several years before spend on turbine installation.

Expenditure is expressed in real financial year 2018/19 Euros.

On any particular project there will be further variation based on the specifications of the project, the actual market conditions and the buying power and contractual arrangements of the developer. The figures, however, are a good guide to overall expenditure in a given country, over a period of time.

### 2.2.4 Historical contracting and supply chain

For each region, we discuss the different approaches to contracting.

For each country, we describe how the supply chain is currently working and we analyse the top 15 (or so) large suppliers, based on the total capacity of projects they have supplied or have been contracted to supply. Note that in some countries, such as France and Korea, the industry is not sufficiently established for there to be 15 large suppliers in place. The elements of supply analysed are: turbine supply, foundation supply, array cable supply, transmission supply, turbine installation, foundation installation, array cable installation, transmission installation and operations, maintenance and service (OMS).

China is given special focus in this report. We provide historical contracting information for the top five owners with the largest portfolios (including projects operating and in construction).

### 2.2.5 Owner portfolios

For each country, we analysed the total capacity of owners’ portfolios, by project stage in August 2019. We categorised projects as:

- Operating, where all turbines are commissioned, and grid connected
- Under construction, where onshore or offshore construction is taking place
• Post-FID, where the owner has made the financial investment decision (FID) to proceed on the project. This is the project stage where most main supply chain contracts are placed, and

• Under development, where the owner has received or applied for all necessary consents to construct the project or is in the early stages of project development.

For China, due to policy implications and a slightly different use of the term “post-FID” in reported data, leading to a high number of projects being post-FID, we used a different selection process, with a higher weighting on operating and under construction portfolio, for selecting the top developers to profile.

We also estimated the current annual expenditure for each owner based on their current (August 2019) project pipeline. For each project stage (operating, under construction, post-FID and under development), we assigned an expenditure based on costs discussed above. To calculate a typical annual expenditure for each project stage, we divided the expenditure cost across the typical number of years taken for each project stage. The methodology applied to each project stage was as follows:

• For operating projects, we used the annual expenditure derived for operation, maintenance and service.

• For under construction projects, we used the sum of expenditure costs derived for turbine, foundations, array cables, transmission, turbine installation, foundation installation, array cable installation and transmission installation supply chain activities. We assumed a two-year period for projects under construction.

• For post-FID projects, we used two-thirds of the expenditure costs derived for project development supply chain activity. This reflects that most project development expenditure is spent after an owner reaches FID. We assumed a two-year period for projects post-FID, and

• For under development projects, we used one-third of the expenditure costs derived for project development supply chain activity. This reflects that less project development expenditure is spent by the owner before reaching FID on a project. We assumed a five-year period for projects under development. We note that actual project development timescales (and the order of activities) can vary between countries and projects.

The figures shown provide an indication of the current annual spend made by each owner based on their current portfolio. For example, if an owner had a large project pipeline that is all in the development stage they would have a much smaller annual expenditure than an owner with the same MW of project pipeline that is all in the construction phase.
3 Global offshore wind - a summary

Key messages
Global forecast of 84 GW installed by the end of 2024, up from 30 GW at the end of 2019. Annual global installation rate 17 GW in 2024. For comparison a modern nuclear plant is about 1 GW per reactor.

Offshore wind has emerged as an important part of the future electricity mix across many countries in three continents. For example, the UK and several US north east states are targeting 30% of electricity from offshore wind.

Several recent auctions have been won with zero-subsidy bids (excluding transmission costs), and cost of energy is approaching wholesale price in several other countries, with more cost reduction still to come.

Experienced European developers, engineers and supply chain firms are the driving force behind expansion into new countries.

Installed capacity
Europe: 43 GW installed by the end of 2024, up from 22 GW at the end of 2019. Major markets: UK, Germany, Denmark, Belgium Netherlands and France.

Asia-Pacific: 36 GW installed by the end of 2024, up from 7.1 GW at the end of 2019. Major markets: China (with >70% of Asia-Pacific total), Taiwan and South Korea and Japan.


Technology, supply chain and expenditure
Expenditure of €178 billion across all parts of the supply chain from 2020 to 2024.

The rated power of new turbines being offered to the market continues to increase, as it is the primary enabler of cost of energy reduction. 8MW turbines are being deployed on commercial projects in 2019 and several manufacturers have announced plans to supply 10 MW-plus turbines.

Monopiles can be optimised further and will continue to be widely used. Jacket foundations will be considered for projects with one or more of: deeper waters, larger turbines or rocky soil conditions.

Higher voltage transmission will be increasingly used for larger projects located further from shore, or to connect ‘clusters’ of wind farms into HVDC transmission systems.

For installation, a production line mindset is reducing cycle times and most new offshore wind farms are being delivered under time and under budget. Three new installation vessels for 10 MW-plus turbines and foundations are on order: DEME Offshore’s Orion, Jan de Nul’s Voltaire and from Japanese contractor Shimizu.

Innovation is being applied to maintenance and service, for example, increasing the evolve of conditions for accessing turbines, using drones to inspect turbine blades and applying big data and AI-based techniques to condition-based maintenance and wind farm control.

Commercial floating wind projects are still more than 5 years away. Demonstration projects are increasing in scale and maturity, and site finding for commercial projects is just starting.

Levelised cost of energy
Cost of energy reduction is a key driver of offshore wind expansion. Continuous evolution of more reliable, higher-rated turbines, larger projects, more efficient processes and reductions in risk and hence cost of capital are all sustaining progress.

Competitive auctions have also driven significant cost reduction. Recent auction awards have been far below the previously industry accepted headline cost of energy target of €100/MWh for projects with financial investment decision in 2020. Industry now targets parity with European wholesale prices for projects built in the mid-2020s.

LCOE is higher in the younger Asia-Pacific and Americas markets, but will reduce as regional supply chains are developed and mature.

Owners
In Europe, major international utilities dominate the ownership of projects. Specialist developers and some supply chain companies are also developing projects.

Asia-Pacific projects are mainly owned by state-owned enterprises (SOEs). Taiwan has a greater involvement of European owners than in China or Japan. Japan has a greater number of specialist developers and several local communities hold shares in projects.

In the US, the market less-experienced US developers with sites have often teamed with more experienced European developers.

Offshore wind farms developed by experienced teams using proven technology are routinely debt-financeable.
3.1 Installed capacity

3.1.1 Global

By the end of 2019, we forecast that global installed capacity will be 30 GW and it will reach 84 GW by the end of 2024, as shown in Figure 1. The majority has been installed in European waters up to now, predominantly in the North Sea and Baltic Sea. The UK and Germany are the countries with the most installed capacity, with over 17 GW between them. By the end of 2024, China is expected to become the global market leader with an anticipated 26 GW and overtake the UK, with 17 GW. Asia is forecast to install over 50% of the expected capacity between 2020 and 2024. No significant capacity is expected outside of these three regions within this period.

Figure 1 Forecast global installed capacity.

3.1.2 Europe

Europe is the most mature market for offshore wind globally, and cumulative installed capacity is anticipated to reach 43 GW by the end of 2024, see Error! Reference source not found.. The UK and Netherlands are the markets expected to install over 50% of the new capacity from 2020 to 2024. Belgium, Denmark and Germany will also continue to grow their existing capacity. France is expecting to rapidly increase its capacity by installing 3 GW by the end of 2024, from no commercial projects today.

Figure 2 Forecast installed capacity in Europe.

3.1.3 Asia-Pacific

In the last few years, the Asia-Pacific market has grown rapidly and this growth is expected to continue. China is by far the largest market today and by the end of 2019 it will have 6.7 GW of offshore wind capacity. Cumulative installed capacity in Asia-Pacific is anticipated to reach 36.4 GW by 2024, with China forecast to contribute 65% of installed capacity to the region in the period, see Figure 3, and several other countries adding significant volume.

Figure 3 Forecast installed capacity in Asia-Pacific.

3.1.4 The Americas

The Americas installed their first offshore turbines at the 30 MW Block Island Offshore Wind Farm in 2016. The development of the Americas market by 2024 will be dominated by US East Coast projects, particularly in Maryland, Massachusetts and New York. Cumulative installed capacity is forecast to reach 4.9 GW by the end of 2024, see Figure 4. No other country in the Americas is expected to contribute to the market within this period, although Canada and Brazil are emerging markets.

Figure 4 Forecast installed capacity in the Americas.
3.2 Technology, supply chain and expenditure

Global expenditure for offshore wind activities is estimated to grow from €24 billion in 2020 to €49 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €178 billion.

Figure 5 Estimated global expenditure.

The following sections describe technology and supply chain trends for each supply chain activity and present estimated global expenditure between 2020 and 2024.

3.2.1 Project development

Expenditure

Global expenditure for project development activities is estimated to grow from €2.9 billion in 2020 to €4.3 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €19 billion.

Figure 6 Estimated global expenditure on project development.

Technology

Project development covers the process from the point of site identification to FID. It typically starts between seven and 10 years before the year of first turbine installation.

Improvements in wind resource characterisation, seabed characterisation and wind farm design software have been reducing project LCOE by lowering construction risk and improving the choice of turbine, foundation design and location of turbines and cables.

Supply chain

Utility developers typically complete wind farm design and layout optimisation activities in-house, and place contracts with specialist engineering firms or suppliers for key component design. Geological and wildlife surveys are typically contracted by the developer to specialist data acquisition companies. There are benefits of using suppliers with local knowledge and several companies have successfully diversified from the oil and gas industry. In China, significant project development activity is undertaken by design institutes.

Depending on national processes, either the government or developer will carry out most of the development activity and either the grid operator or the developer will be responsible for the grid connection to the wind farm. Regardless of who is responsible, similar development phase activities will be carried out by the supply chain.

3.2.2 Turbine

Expenditure

Global expenditure on turbines is estimated to grow from €9 billion in 2020 to €19 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €65 billion. It is by far the largest of the supply chain areas.
Technology

The turbine comprises the rotor, nacelle and tower. Most turbines operational at the end of 2018 were rated between 4 MW and 6 MW with a rotor diameter between 110 m and 160 m, and a nacelle mass between 140 and 400 t.

In 2019 the highest rated turbines being manufactured for installation on a commercial basis are the MHI Vestas Offshore Wind (MVOW) V164-9.5MW model for sites in Belgium and the Netherlands for commissioning in 2020. Meanwhile, SGRE is getting ready to install its 8MW, 167 m diameter direct drive model at sites in Belgium, the Netherlands and Taiwan. These are all also for commissioning in 2020.

Higher-rated turbines continue to be developed by turbine manufacturers:

- In 2018, MVOW announced a V164-10MW model, which will be ready for commercial projects from 2021, and in 2019 it announced a V174-9.5MW variant optimised for typhoon zones.
- The first prototype GE Haliade-X at 220 m diameter and 12 MW rating is planned to be installed onshore in the Netherlands during Q3 2019, with plans for a higher rating already announced.
- Siemens Gamesa Renewable Energy have announced a 10 MW, 193 m diameter direct drive model which will be market-ready in 2022. It has also teased that “a new SG 1X platform, which will be a true step-change, not a scaled-up version, is still to come”.
- Goldwind has announced a family of 6-8MW turbines with rotor diameters up to 184 m, with prototypes this year.
- Chinese players CSIC, Goldwind, Ming Yang, Shanghai Electric and XEMC have also all discussed plans for 10 MW+ turbines.
- Korean player, Doosan, is developing an 8MW+ turbine sponsored by the Korea Institute of Energy Technology Evaluation and Planning (KETEP).

- In early 2019 Senvion filed for self-administration and is currently thought to be looking for buyers. It is therefore unlikely that its ambitions to develop a 10 MW offshore platform will be realised as planned last year.

For projects currently in development, turbines with ratings up to 20 MW are being considered within the wind farm design envelope.

Supply chain

In Europe, the supply chain is dominated by two suppliers: Siemens Gamesa Renewable Energy and MVOW Offshore Wind. There has been consolidation in the market with mergers between Areva and Gamesa (to form Adwen) and subsequently, the merger between Siemens and Gamesa (to form Siemens Gamesa Renewable Energy). GE also acquired Alstom's wind energy business. Senvion's difficulties mean that it cannot currently compete for new offshore projects. The market, therefore, is expected to remain concentrated on a few, key suppliers in Europe, although GE's new Haliade X will provide important competition to the market leaders.

In China, Japan and South Korea, there are a number of local suppliers capitalising on onshore wind experience. The experienced European offshore wind suppliers are expected to look to gain a foothold in the Asian markets, with Taiwan starting as the most attractive market because of its lack of home market suppliers. Local content requirements in Taiwan are expected to accelerate European suppliers in other Asian markets as they seek to maximise the value of regional manufacturing investments. We expect these markets will see consolidation as in Europe. SGRE remain active in the Chinese market through its licensing agreement with Shanghai Electric. GE has announced investment plans in China.

In the US, it is expected experienced European suppliers will dominate the market. They are currently accumulating conditional contracts. So far, GE has not been that successful in capitalising on its strong US connections.

The turbine supplier’s contract with the developer usually includes a service-agreement, which is typically 5-15 years, though some developers seek to start their own service operations early. If the operations strategy is to use service operation vessels (SOVs), the vessel is expected to be part of the turbine supplier's scope. Ørsted and Equinor are exceptions in chartering the vessel directly. If the strategy is to use crew transfer vessels (CTVs), these are usually contracted by the developer.

The turbine supply contract usually includes turbine installation, although the main installation vessel and work-to-work vessel (for commissioning) may be contracted separately.
3.2.3 Foundation

Expenditure

Global expenditure on foundations is estimated to grow from €2.5 billion in 2020 to €5 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €18 billion.

Figure 8 Estimated global expenditure for foundations

Technology

The main physical factors for foundation choice include water depth, seabed conditions, turbine loading, rotor and nacelle mass, and rotor speed. To date, all foundations for commercial scale projects have been bottom-fixed (fixed to the seabed, through piles, suction or gravity) and can be categorised under three main groups:

- Monopiles, usually with an associated transition piece
- Non-monopile steel foundations, including jackets and other steel space-frame structures, which are usually secured using piles, and,
- Gravity base foundations made mainly from reinforced concrete.

Monopiles can have a mass of up to 1 500 t. A jacket foundation for a 7 MW turbine has a mass of up to 700 t.

Monopiles are generally the preferred technology (due to overall installed cost), but a jacket or a gravity base foundation becomes increasingly competitive in deeper waters or in areas where piling is difficult, and with larger turbines. Advancements in manufacturing and design, however, have allowed monopiles to be installed in deeper waters and with larger turbines than previously thought viable. Monopile design is considered largely optimised, but there are opportunities to expand the range of water depths and turbine sizes that monopiles may be used for. Refinements are also being made with a better understanding of pile-soil interactions. There are still opportunities for jacket technology optimisation given its relatively limited use to date. For example, in 2018 suction anchors had their first pre-commercial use in offshore wind at the 11 turbine European Offshore Wind Deployment Centre (EOWDC).

In 2018, gravity base foundations (that can be installed without a crane, as opposed to most previous uses that required a barge and crane) were installed at the Blyth Offshore Demonstrator project. Each gravity base foundation used for the project had an installed mass of 15 000 t.

In deeper waters, the use of innovative floating foundations is also being explored and is expected to be used in markets without more cost effective low carbon generation options, such as Japan. In 2017, the world’s largest floating foundation project (Hywind Scotland), was installed. A second floating demonstration in Scottish waters, Kincardine, completed the first part of its installation in second half of 2018. In 2019 the three turbine WindFloat Atlantic project is close to installation, using Principle Power floaters. Four floating demonstration projects in France received consent (Golfe du Lion, Croix & Belle-Île, Gruissan and Provence Grand Large) with construction beginning from 2020. Principle Power is in the early stages of planning its 150 MW project off the West Coast of the US. They have stated that this is a ‘pre-commercial’ project. The first commercial floating projects are now in development in a range of different markets.

Supply chain

There are a number of monopile suppliers. In Europe, monopile (and transition piece (TP)) supply is expected to continue to be dominated by the strong partnerships of Sif Group (the monopile) and Smulders Projects (the TP), and EEW Special Pipe Constructions (the monopile) and Bladt Industries (the TP), Steelwind Nordenham has the capability to produce both monopiles and TPs.

Up to now the Chinese market has been supplied from within China. Emerging markets, such as the USA and Taiwan, are expected to use a combination of some early supply from established European suppliers, followed by local supply by joint ventures involving established European suppliers. For example:

- EEW supplied monopiles for the Formosa 1 phase 2 project in Taiwan
- Sif is looking to partner with Century Steel for future projects in Taiwan, and
- Ørsted has signed a Memorandum of Understanding (MoU) with EEW to work towards establishing a monopile fabrication facility in Paulsboro, New Jersey, for the Ocean Wind project.

TPs have a high labour content and there is a strong temptation for developers to source from Asia, especially as the Asian supply chain matures.

There has been attrition in the jacket foundation market due to unforeseen lack of demand (where projects were thought expected to use jackets but advancements in monopiles meant jackets were not used). Suppliers
inexperienced in serial production with weak balance sheets have also faced financial difficulties. Smulders and Bladt are the market leaders, but they face strong competition from low-cost countries. Developers often split supply to balance supply chain risk and often choose one low risk supplier from the market leaders along with a higher risk-lower cost supplier from Spain, the Gulf of Arabia or East Asia.

Foundation supply can be contracted as a single package by the developer or included within a full balance of plant EPCI (full-EPCI) or a foundation package EPCI (mini-EPCI, this term can also be used for the EPCI of other subsets of the complete balance of plant). The turbine foundation package may include the substation foundations. It is an area of the supply chain where the developer will often be flexible with its package boundaries to maximise competition and value from the supply chain.

3.2.4 Array cable

Expenditure

Global expenditure on array cables is estimated to grow from €0.4 billion in 2020 to €0.8 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €3 billion.

Array cable suppliers also serve other markets, such as oil and gas and low power interconnectors, and as such maintain flexibility to supply these different markets. Most European projects have been supplied by European array cable manufacturers.

There has been significant consolidation, particularly with Prysmian acquiring Draka and General Cable. Other key players include JDR Cable Systems, Nexans and NKT. Further consolidation may occur because increasing turbine size reduces the cable demand per MW, creating more competitive pressure.

Array cable supply can be contracted as a single package but is usually included within a full-EPCI or an array cable installer-led mini-EPCI, depending on the contracting structure chosen by the project developer.

3.2.5 Transmission

Expenditure

Global expenditure on transmission is estimated to grow from €1.2 billion in 2020 to €2.4 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €9.1 billion.

Transmission includes the onshore and offshore substations and export cables. To date, most transmission has been high voltage alternating current (HVAC). For high voltage direct current (HVDC) export, the transmission...
systems often use AC ‘collector’ platforms to step up array cable voltages and feed the offshore converter platform. An HVAC substation typically has a mass of 1 000 t to 2 000 t. HVDC converter substations are more complex, contain a lot more equipment and typically have a mass greater than 10 000 t, although this is expected to be reduced with future designs.

Higher voltages offer lower losses over longer distances and potential savings from reduced use of conductor material. There is a trend of wind farms moving from around 150 kV AC to 220 kV AC. Some wind farms have used up to 400 kV DC. HVDC is expected to be used for wind farms further from the onshore grid connection with long export cables, or where wind farms are ‘clustered’ together and multiple projects connect into a single HVDC converter substation. HVDC transmission has only been used in Germany and its limited use has meant less cost reduction through learning.

HVDC transmission only becomes more cost effective that HVAC for wind farms further from shore, where HVAC losses (or costs in order to reduce these losses) become significant. Ørsted took the novel approach to redesign Hornsea One to avoid HVDC with HVAC technology by introducing a reactor substation platform at a point on the export cable route. It is uncertain whether other projects could benefit from this approach.

There are two forms of HVDC technology: current source conversion (CSC) or voltage source conversion (VSC). VSC has the big advantage that the converter stations are smaller. There are only three European suppliers of VSC technology, ABB, GE and Siemens, prompting concerns about the competition in the market. There are Chinese suppliers that could enter the European market.

HVAC cables are supplied with three cores, one for each phase. HVDC cables are typically single core and supplied in pairs (one for the positive link and one for the negative). The pairs may be bundled together, though this creates challenges during installation.

All HVAC cables are insulated with cross-linked polyethylene (XPLE). XLPE provides excellent electrical insulation and the suitable flexibility for submarine power cables. It is also resistant to thermal variations and is cheaper than alternative insulation materials.

HVDC cables can be mass-impregnated (MI) and insulated using paper. While they perform well for DC systems, MI cables cannot be used for AC systems at high voltages. MI cables are more costly (because the manufacturing process takes longer) but have previously been available in higher voltages than XLPE cables. XLPE cables are now becoming available in progressively higher voltages and so are becoming more popular.

Supply chain

The technical interfaces between the cables and the substations are relatively simple and with no overlap in the supply chain, there is little value in awarding a single contract for both items. In some cases, a cable supplier will form a JV with one of the main electrical system suppliers.

The offshore export cable supply chain is similar to the array cable supply chain. In this market the three market leaders – Nexans, NKT and Prysmian – are joined by LS Cable (Korea) and most recently Hellenic (Greece). The offshore export cable market is attractive to investors because it has higher margins than array cables and the increasing distance of projects from shore increases the value of contracts, but capital investments costs are also higher.

Factories supplying HVAC cables can normally also produce XLPE HVDC cables, that is it is the capability to produce cables at the requisite voltage that is key rather than the transmission technology being used.

Supply has been constrained in the past and the entrance of LS Cable and Hellenic is significant. There has been some consolidation, with the acquisition of ABB cables by NKT.

For offshore substations, the competitive landscape is complex. Packages are typically awarded as a turnkey contract to:

- Electrical system suppliers (such as ABB, GE or Siemens)
- Fabricators (such as Aibel, Bladt or Chantiers de l’Atlantique)
- External systems integrators (such as Petrofac or Semco Maritime), or
- Internal systems integrators (such as Iderdrola or Ørsted).

Developers may choose to contract the substation foundation separately.

Some experienced developers such as Ørsted are specifying substations with some modules being standardised, and so taking cost benefits from shared design costs and optimisation of manufacture and spares holdings. Another option to reduce cost is for extensive redesign to optimise transmission after the contract is placed and when there can be full cooperation from the supplier. Such optimisation may enable the removal of a circuit leading to reduced cabling costs and potentially the removal of a substation.

For countries where the construction of offshore wind transmission assets is managed by the transmission system operator (TSO), such as Germany and Netherlands, the procurement of offshore substations and export cables is primarily managed by the TSO, although in Germany the wind farm developer may build a substation to step up voltage to feed into a collector station.
There are few yards in Europe with the capacity to accommodate an HVDC platform and the work has been awarded to yards in Gulf states on several occasions.

Offshore export cables can either be sourced separately or as part of a supplier or installer-led mini-EPCI.

Onshore export cables and onshore substations are typically sourced as part of an installer-led mini EPCI.

### 3.2.6 Foundation installation

#### Expenditure

Global expenditure on foundation installation is estimated to grow from €1.1 billion in 2020 to €2.3 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €8.3 billion.

![Graph showing estimated global expenditure for foundation installation](Source: BVG Associates)

**Figure 11 Estimated global expenditure for foundation installation.**

#### Technology

For monopile foundations, installation is undertaken either by the jack-up vessels that may be also used for turbine installation or by floating heavy lift vessels. Jacking up and down are lengthy processes. Foundation installation does not need such as stable platform and floating vessels can therefore install more quickly than a jack-up. Installation is usually undertaken in two-stages sequentially and using the same vessel. First, the monopile is driven into the seabed. A transition piece is then bolted or grouted in place. A two-vessel strategy has proved cost-effective in some cases. Here, the main installation vessel installs the monopile and a second vessel is used for transition piece installation. For this to work, the second vessel needs to be significantly cheaper to offset the additional mobilisation costs. Some site conditions allow the transition piece to be replaced by a platform bolted to a flange at top of the monopile. As well as saving steel, this also reduces installation cost.

Non-monopile steel foundations (usually space frames such as jackets) may be installed using the same vessels as monopiles. There are distinct requirements, however. Monopiles are heavier and need bigger cranes. Space frames require significant deck space and installation is more efficient with larger vessels or with low-cost feeder barges. Space frames can either be pre-piled using a template or post-piled. Pre-piling is generally preferred, in a departure from oil and gas methods, because a lower-cost vessel can be used and there are a large number of foundations to install in a wind farm, whereas oil and gas jackets are generally single units and there is little value in using separate vessels for the piling and installing.

Significant investments into floating heavy lift vessels have been made by DEME Offshore (Orion, due 2019) and Offshore Heavy Transport (Alfa Lift, due 2021). These have large cranes (3,000 t or above) and large unobstructed decks. Their value to the industry in reducing cost (mainly through faster installation) has been recognised for some time. Market conditions have only recently become favourable for investment because of the increasing size of projects and the increasing size and mass of foundations.

A move towards flexible sea fastenings has allowed for quicker mobilisation and reduced fabrication and steel costs.

Gravity base foundations have been typically installed using sheer-leg crane vessels which lift the foundations from a barge. With recent gravity base designs, such as those used at Blyth Offshore Demonstrator (UK), the foundations use a “float-out and submerge” installation process. A specialist vessel is used to pump seawater into the foundation for ballast. The water is eventually replaced by sand once correctly positioned.

Specialists with innovative equipment and services are expected to be used for services including UXO and boulder clearance, pile driving equipment, grouting, bubble curtains and other noise mitigation solutions and scour protection installation.

#### Supply chain

The contracting structure for foundation installation is different from turbine installation because the installation contractor controls the whole lifting and installing process. It is therefore possible for a marine contractor to deliver a foundation mini-EPCI contract and this is quite common, even for developers that generally favour multi-contracting. There has been little interest in manufacturer-led mini-EPCI contracts because these companies typically have no experience of managing complex projects offshore, where the critical risk is the effective utilisation of the expensive installation vessel.

The supply chain is similar to that for turbine installation, although the pure-play T&I contractors are all focused on jack-up vessels. Those jack-ups with large-capacity cranes (Seajacks Scylla in particular) will continue to be used for monopile installation but they will generally be considered inefficient for space frames because it is unlikely that they could carry more than two structures.

The US Jones Act also applies to foundation installation. The offshore transfer of foundations from feeder vessels is
less of a risk than for turbines. It is therefore possible that European vessels will be used regularly for US projects. A challenge will be the high mobilization costs for European vessels if travelling from Europe.

### 3.2.7 Array cable installation

#### Expenditure

Global expenditure on array cables is estimated to grow from €0.6 billion in 2020 to €1.4 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €4.8 billion.

Figure 12 Estimated global expenditure for array cable installation.

#### Technology

Array cables are usually buried several meters beneath the seabed. Installation is often undertaken using a cable plough that lays and buries the cables in a single process. Alternatively, a vessel can first lay the cable on the seabed that is then buried by a remotely operated vehicle using jetting equipment. A steel tube known as a J-tube routes the cable along the outside or inside of the foundation. This protects the cable from wave action. On the seabed, the point at which the cable enters the J-tube is an area of risk of cable failure, as scour can leave the cable unsupported. Cable and scour protection systems are used to reduce this impact and prevent damage to the cable.

The process of connecting array cables to the turbines and the offshore substation is time-consuming and expensive because each core in the cable must be connected on-site and out of the water. Cost effective quick-connect cable terminations are being developed to complete cable connections in a simplified manner.

Array cable faults are becoming a significant source of downtime and revenue loss for owners. Developers are now installing array cables with monitoring systems, such as partial discharge monitoring systems or distributed temperature sensing systems. These monitor the condition of cables and predict when failures might occur by identifying damaged areas in the cable insulation which could cause total cable failures in the future.

#### Supply chain

Array cable installation can be contracted as a single package, but it is usually included within a balance of plant EPCI or an array cable installer-led mini-EPCI. It can also be included in an installer-led mini-EPCI covering array and export cables, but this is unlikely if the transmission is constructed by a TSO. Array cable installation has different technical requirements than export cable installation. Array cable vessels can be smaller but need to be more manoeuvrable, while export cable vessel need a higher carrying capacity and, ideally, can operate in shallow water.

The array cable installation scope is expected to include route clearance, remotely operated vehicles (potentially subcontracted), cable protection and cable termination (routinely subcontracted).

Array cable installation has been a challenging area of the supply chain with contractors initially struggling to keep to schedule and to avoid damaging cable during installation, especially in shallower water. Difficulties with the cable pull-in were common, in part because of the interfaces between the foundation design, the tower base and cable design.

Several contractors exited the European market, either voluntarily or through company failure. The supply chain has matured significantly now, however, with nearly all active installation vessels now operated by one of the main five EPCI contractors (Boskalis, DEME, Jan de Nul, Subsea7 and Van Oord). The experience of contractors and developers means that these issues are largely resolved in Europe. While European developers can transfer their experience to new markets, there is a risk that inexperienced crews mean that problems resurface.

### 3.2.8 Turbine installation

#### Expenditure

Global expenditure on turbine installation is estimated to grow from €0.4 billion in 2020 to €1 billion in 2024 Total expenditure between 2020 and 2024 is estimated to be €3.4 billion.
Some turbines have been designed to be installed with a full-rotor set-up, meaning the blades are assembled to the hub onshore. Although this reduces the number of offshore lifts, it is more sensitive to high winds and some projects using this strategy have been subject to delay.

Installation strategies are expected to be optimised for different markets because of the available infrastructure and vessels.

Installation activities are primarily constrained by wind speeds. The nacelles and towers contain sensitive electrical equipment, in particular. Blades are designed to catch the wind and excessive movements make installation difficult, risk component damage and are potentially dangerous. Turbine suppliers are developed yokes with tag lines to manipulate and control blades during blade lifts in wind speeds up to 12-13 m/s. Third parties have also been working on technologies to extend the operating window of turbine installation, although a point will come when high wind speeds render deck operations unsafe. A potential area of development is in better understanding of near-term wind speed forecasting to make better use of weather windows.

The vessels used for turbine installation are jack-ups mostly designed specifically for offshore wind use. These are currently suitable for installing up to 8 MW turbines. Some are also used for foundation installation but there is increasing divergence in the fleets because turbines need a taller crane but less lifting capacity than for foundations. There has been significant investment in turbine installation vessels with large decks, long legs, powerful cranes and high transit speeds but many of these vessels need modifications to allow faster installation of 10 plus MW wind turbines.

A significant development in 2019 has been Jan de Nul’s announced investment in the Voltaire. This vessel is substantially larger than the existing jack-ups on the market. As a result, it is well suited to installing 10 plus MW turbines and all forms of steel foundations. Japanese contractor Shimizu also ordered a very large installation jack-up in 2019. A number of tools are being developed to support turbine component lifts offshore, such as lifting yokes and hook stabilisation tools, allowing components to be installed in higher wind speeds than previously.

For the expansion of the US market there may be the need for a Jones Act-compliant vessel (built, flagged and crewed in the US) to be built. The lack of ocean-facing ports without air draft restrictions (due to bridges) is expected to mean that feeder solutions are needed in the short term at least. A Jones-Act compliant installation vessel could cost up to twice that of an Asian-built vessel and if feeder solutions are necessary then the most cost-effective solution could be a global vessel that has been designed to work with feeder vessels. In this case, only the feeder vessels would need to be Jones-Act compliant.

Supply chain

Turbine installation and commissioning is typically part of the turbine supplier’s scope. Even if the developer contracts the installation vessel, the turbine supplier is responsible for the installation strategy and mechanical and electrical completion. The vessel operator is responsible for the operation of the vessel and the lifts. The contractual status of the vessel is down the preference of the developer. The contractual interface is not seen as a problem.

In theory, a full EPCI package could include the turbine, but the choice of the turbine is a fundamental part of wind farm design and the business case for investment so no developer would subcontract this decision. It would also represent a huge risk for the marine contractor that has little technical understanding of turbine technology.

Vessel operators fall into two categories:

- Pure-play vessel operators (such as Fred Olsen Windcarrier, SeaJacks and Swire Blue Ocean) that offer transport and installation (T&I) contracts only, and
- Marine contractors offering EPCI as well as T&I services (such as Boskalis, DEME Offshore, Jan de Nul and Van Oord).

A turbine-EPCI would be generally led by the turbine supplier (and certainly in the US and Europe). A turbine installation vessel would therefore be under a T&I contract unless it forms part of a wider EPCI scope that involves cables and/or foundations. Most of the EPCI contractors have fleets that can install turbines, foundations and cables. They will subcontract to the pure-play vessel operators if necessary.

There has been significant consolidation in the market, most recently with DEME’s acquisition or A2SEA, Van Oord’s acquisition of MPI Offshore and Fred Olsen Windcarrier’s acquisition of the Seafox 5. The fundamental problem facing turbine installation vessel operators is the increasing size of turbines. Not only does it risk the future market for its existing vessels from a technical perspective but also reduces the demand because fewer units/MW are installed. In theory the market would be well served from a relatively small number of large jack-ups with longer legs and taller cranes but other than the Voltaire, the lack of...
new vessels suggests that he business case for investment is not compelling.

Turbine commissioning is now routinely undertaken from walk-to-work vessels. These are similar to SOVs but generally are larger to accommodate the large number of technicians needed on site during commissioning.

The supply chain in most Asian markets differs. The Chinese market is expected to remain distinct, although we may see JVs similar to the one between DEME and COSCO Shipping. There is expected to be use of European vessels in Japan and Taiwan, particularly in Japan where the use of locally manufactured turbines that are smaller than those used in Europe will sustain a demand for vessels no longer competitive in Europe. In time vessels are expected to be built for these markets. In July 2019, Shimizu Corporation announced the construction of a large jack-up vessel with a similar specification to Jan de Nul’s Voltaire, for example.

### 3.2.9 Transmission installation

**Expenditure**

Global expenditure on transmission installation is estimated to grow from €1.4 billion in 2020 to €2.6 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €9.6 billion.

![Source: BVG Associates](image)

**Figure 14 Estimated global expenditure for transmission installation.**

**Technology**

Export cables are installed in a single length where possible and this means vessels are generally larger than array cable installation vessels to accommodate a carousel up to 7,000 t which can hold the length of cable. The vessels are usually self-propelled with dynamic positioning. Ideally, they have shallow drafts so they can operate in shallow water for the near-shore installation.

The beach landing can be challenging. Unlike most other aspects of the wind farm, it is not easy to standardise because the topography and soil conditions for individual projects are unique.

The installation process starts with the installation vessel positioned close to shore. The cable is then pulled to shore with the cable supported by pillow floats or buoys and terminated. The vessel then moves offshore and eventually terminates the cable at the substation.

Most substation platforms are installed on a monopile or jacket foundation using a floating crane vessel with a lifting capacity greater than 2,500 t. One of two types of vessel is used: a sheerleg crane or a heavy lift vessel. These vessels are regularly used in other sectors such as oil and gas. A sheerleg vessel cannot operate in high sea states and hence several weeks may be scheduled for the installation, in order to wait for a suitable weather window forecast. Also, few vessels are available, which may have an impact on project schedules. Options to overcome these are:

- Modular structures so that the individual lifts can be undertaken by a vessel with a lower crane capacity, and
- Float-over, gravity base or floating designs that eliminate the need for an offshore heavy lift.

As a result of the mass of an HVDC substation, these stations may be designed to be buoyant and hence self-installing.

**Supply chain**

Transmission installation may be contracted in a range of ways:

- For countries where the construction of offshore wind transmission assets is managed by the developer, it usually contracts the offshore substation as a mini, supplier-led EPCI which includes offshore substation installation. Export cable installation can be contracted as a single package, but is usually included within a transmission EPCI or an export cable installer-led mini-EPCI. It can also be included in an installer-led cable EPCI covering array and export cables.

- For countries where the construction of offshore wind transmission assets is managed by the transmission system operator (TSO), such as Germany, the procurement of offshore substation and export cable installation is managed by the TSO.

The construction schedule will typically allow for a six-week window for substation installation. The demand for vessels is therefore not that high provided that projects can be flexible over the timing. As a result, the industry has not seen the construction of purpose-built vessels. New suitable vessels will become available – notably DEME’s Orion and Scaldis Salvage & Marine’s Gulliver but these will be used for other purposes and not wholly in offshore wind.

The substation foundation may be installed separately and potentially as part of the turbine foundation installation contract.
The onshore transmission works are similar to those for other upgrades to the onshore networks. All markets therefore have well established contractors and ways of working.

3.2.10 Operations, maintenance and service

Expenditure

Global expenditure on operations, maintenance and service (OMS) is estimated to grow from €3.5 billion in 2020 to €6.7 billion in 2024. Total expenditure between 2020 and 2024 is estimated to be €24.9 billion.

This is split across three categories:

- Wind farm operation and planned maintenance
- Wind farm unplanned service and other OPEX, and
- Transmission OMS, as shown in the following charts.

Figure 15 Estimated global expenditure for operations and planned maintenance.

Figure 16 Estimated global expenditure for unplanned service and other OPEX.

Figure 17 Estimated global total expenditure for transmission operations, maintenance and service.

Technology

OMS covers all activities after the completion of installation works to the start of decommissioning. Key activities include: operations monitoring, planned maintenance (of turbines, balance of plant and transmission), unplanned service (in response to failures or prognosis of upcoming failures of turbines, balance of plant and transmission) and other OPEX (contract management, operations management, onshore facilities, site rent, business rates, transmission use of systems charges and operational phase insurances).

There are two main OMS strategies:

- Onshore-based: for projects closer to port, using crew transfer vessels (CTVs) up to about 26 m long to transport crew and spares the wind farm, and
- Offshore-based: for projects further from shore, using a fixed or a service operations vessel (SOV) up to 85 m long with accommodation for up to about 60 persons.

In both cases, helicopters may be used alongside vessels. For projects located further from shore, SOVs may support two or more neighbouring wind farms, although this may raise contractual issues if the wind farms are under different ownership.

Maintenance and service strategies are rapidly evolving with increasing attention being given to optimising the provision for specific wind farms. SOVs are typically designed to meet the needs of specific wind farms and often have motion-compensated gangways which enable “walk to work”. This ensures that there is no redundant capacity in the vessel, and it works well alongside other vessels or helicopters. It is expected that the hard distinction between CTVs and SOVs will blur.

Most wind farm maintenance and service is undertaken on site by technicians. Automated and remote maintenance systems are developing rapidly in other sectors and are being adapted for use in offshore wind. A significant area of development is aerial inspection of blades using drones.
This is being undertaken in-house by companies that specialise in developing or operating aerial inspections for other industries.

The collection and analysis of big data using advanced analytical tools across the largest possible fleet of similar wind turbines is critical to spotting anomalies and optimising OMS. The wind turbine suppliers, therefore, are competing hard to win this business, or at least retain access to OMS data, so that they can build a better understanding of how their turbines perform and drive efficiencies into their long-term service agreements.

**Supply chain**

Wind farm owners adopt a range of approaches to OMS:

- **Hands-off:** They place a contract with the wind turbine manufacturer for a full package including all balance of plant, covering day-to-day operations management, planned maintenance and unplanned service.

- **Light-touch:** They place a contract with the wind turbine manufacturer for a maintenance and service package for the wind turbine only, and with other specialist contractors for remaining services including electrical balance of plant, foundations, onshore operations base, vessels and helicopter support. The owner then provides some or all of the necessary operations management and may carry out some of the planned maintenance themselves.

- **Hands-on:** They recruit and retain a team of OMS specialists, including wind turbine technicians. They work in partnership with specialist subcontractors, including wind turbine manufacturers, vessel operators and high voltage electrical engineers. In this case the owner takes on more risk but has more opportunity to minimise OPEX and maximise energy production.

For wind turbine OMS, the wind farm owner usually enters into a service agreement with the turbine manufacturer. A light-touch or hands-on owner may opt for a two to five-year agreement at least in the first instance. A hands-off owner may choose a longer agreement, up to 15 years. Shorter agreements may include the transfer or technicians from the supplier to the owner at the end of the period. This provides valuable continuity in service. For CTV projects, the vessels are usually contracted by the owner. This gives the owner the flexibility to use the vessels for other purposes. With SOVs, it is more common for the turbine supplier to contract the vessel. This largely reflects owner’s reluctance to take on the risk of managing a large vessel where it has no experience.

The market for balance of plant OMS is rapidly evolving with several companies extending their capabilities, often my merger or acquisition, to offer a more joined up service to owners.

### 3.3 Levelised cost of energy

#### 3.3.1 Europe

In Europe, recent cost reduction achieved in offshore wind has been demonstrated through a number of competitive subsidy auctions. Recent awards have been close to wholesale electricity prices and this has transformed Governments’ view of the role of offshore wind in energy policy. This cost of energy reduction is a result of an increasingly competitive supply chain (with a reduction in margins), commercialising innovations (especially in large turbines), increasing investor confidence and applying lessons learnt on previous projects to increase efficiencies and reduce finance costs. In the German 2017 auction, the first contract prices of zero were awarded to Ørsted and EnBW for projects to be installed in 2023/2024. In early 2018 two Dutch sites were awarded to Vattenfall, based on a zero-subsidy bid (excluding transmission), and the projects to be built in 2022 are expected to be the first subsidy free offshore wind projects built. In the UK, a CfD allocation round in 2017 saw over 3.2 GW of capacity awarded subsidy for delivery years 2021 to 2023. The results of the third allocation round will be announced in autumn 2019 and competition is expected to drive bids close to wholesale electricity prices (including transmission).

#### 3.3.2 Asia-Pacific

The Asian market is less mature than Europe and while price is important, government emphasis is also on creating a market and driving investment in the supply chain. An attempt by the Taiwanese government in 2019 to reduce tariffs closer to European levels along with imposing local content requirements was partially rebuffed after Ørsted threatened to withdraw from projects.

The region faces difficult conditions in terms of typhoons, earthquakes and both deep water and inter-tidal sites. The impact of this is that in some areas, somewhat different technology will be required; reducing how much learning and best practice can be directly transferred from the European market. The Asian market will need to invest in purpose designed vessels and specially trained crews. While in general Asian markets have lower labour costs than European markets, these factors and generally lower wind speeds may mean that LCOE in Asian countries will remain higher than Europe for a period.

#### 3.3.3 The Americas

Falling auction prices in Europe have had a major impact on the political drive for offshore wind in the north eastern US states. The US faces several challenges in reaching European auction prices, however: lack of investment in supply chain and infrastructure; local content requirements; inexperienced developer teams and suppliers; the protective Jones Act for vessels; and the suitability of US ports for optimal logistics. In 2018, Vineyard Wind secured PPAs at $74 (£66)/MWh and $65 (£58)/MWh with the
Massachusetts government for development phases in 2022 and 2023, prompting hopes that US auction prices could quickly reach those in Europe. In 2019, the Massachusetts government abandoned a requirement that bids to a second solicitation would have to be lower than Vineyard, which suggests greater pragmatism. Only when sufficient volume of projects is available will a competitive local supply chain really establish.
4 Europe

Market size

At the end of 2019, Europe’s forecast shows 22 GW of total installed capacity, reaching 43 GW by 2024, with a CAGR of cumulative installed capacity of 15%. Between 2020 and 2024, the annual installed capacity is forecast to be between 2.1 GW and 5.9 GW, with an average of 4.1 GW. The UK and the Netherlands are forecast to contribute the most installed capacity by 2024, with 35% and 20% respectively. Other countries that will play a key role are Belgium, Denmark, France and Germany.

The temporary slowdown in the capacity installed in 2020 is linked to the German and the UK markets, whose markets have undergone changes to their auctions and subsidy systems. The UK pipeline is due to recover an annual installation rate of between 1.7 GW and 2 GW from 2022. In Germany, unless developers can bring forward their construction plans, after 2020 and 2021 having no new projects, installations will ramp up from 500 MW to over 1 GW per year between 2022 and 2024.

Major utilities, such as EDF, Iberdrola, Innogy, Ørsted and Vattenfall, dominate the ownership in most countries. There are more specialist developers active in the Belgian and Danish markets. In the Netherlands, supply chain companies, such as Van Oord Offshore Wind Projects and Siemens Wind Power (now SGRE), have been significant investors in projects.

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Figure 18 Forecast installed capacity in Europe.

Expenditure and levelised cost of energy

In Europe, the key driver of cost of energy reduction is competition through auctions for developers of projects to secure development rights and subsidies. Technology development is also important and in particular in larger turbines, which means fewer associated components (such as the number of foundations) to install and maintain, which decreases cost, and higher hub heights, which access higher wind speeds. Even with the risks of unproven technology, developers typically choose to use larger turbines whenever possible because the possible rewards with larger turbines are great.

The sites available in European waters such as the North Sea are relatively shallow, with many sites having average water depths of less than 35 m. Of the countries with significant pipelines, France is a notable exception; it has some shallow water in the English Channel (La Manche) but its Atlantic and Mediterranean coasts reach significant depths 20 kilometres from the shore. The wind speeds are typically high in European waters, but super-storms are very rare. Smaller waves are produced by the winds in the North Sea, rather than the swell waves travelling large distances that are faced by ocean-facing wind farms. This means that the loads are lower and access is easier for installation and maintenance activities than in some other world regions.

At the end of 2018, Europe had 80% of global wind capacity and a supply chain that has established over the last 18 years. Developers with large pipelines of operational projects have implement learning from early projects to reduce costs and risks on later projects. In the same way, experienced suppliers have brought to market new technological advances.

Transmission has been mainly high voltage alternating current because grid connections have been relatively short. Germany pioneered the use of high voltage direct current (HVDC) substations for distant wind farms in the North Sea. Technology development and the development of sites further from shore will result in HVDC used in Netherlands and UK projects from 2022.

Expenditure across all supply chain activities in 2024 is estimated to be €22.5 billion

Total expenditure between 2020 and 2024 is estimated to be €83 million.
It is expected that 78% of expenditure between 2020 and 2024 will be development expenditure (DEVEX) and CAPEX and that 22% will be OPEX.

For more information on expenditure methodology see Section 2.2.

Figure 19 Estimated contribution to LCOE for a project installed in 2022 in Europe.

Figure 20 Estimated European expenditure.

Historical contracting

- There are two main forms of contracting: multi-contracting, and engineer, procure, construct and install (EPCI).
- Multi-contracting is typically preferred by the large, experienced utilities, such as Ørsted, Innogy, ScottishPower Renewables (Iberdrola) and Vattenfall. These lead the development, design, procurement and project management, with mostly in-house teams. They award up to 12 main packages for the main components and their installation. The package boundaries will vary to maximise the supply chain value. The most common variation is to combine foundation supply and installation packages.
- EPCI contracting is typically preferred by utilities with less experience (and therefore less confident in managing interface risks), including EDF Energy Renewables, EDP Renewables and SSE, and independent developers. Independents may bring in project management and engineering consultancies to take on many of the roles that the utilities will fill internally.
- A full EPCI contract is rare because the turbine procurement is a major strategic and technical process and needs to take place ahead of other packages. A balance of plant package is therefore awarded separately.
• In most European markets, the grid connection is designed and built by a transmission operator. This may be the main onshore grid operator (such as energienet.dk or RTE) or a publicly appointed offshore grid operator (such as 50Hertz or TenneT). The UK is the main exception, where developers typically choose to build the grid connection themselves and then sell it on to an offshore transmission owner (OFTO) within 18 months, as required by the regulator, Ofgem. Both mechanisms have their advantages and disadvantages. If the grid is contracted separately, the developer does not take on the risk of building the transmission assets but there is a significant risk of project delay or stranded offshore generating assets. In the UK, the developer is better able to control the construction timetable but it may be unable to recoup the full costs when selling on the assets (a price is set independently).

• Contracting for the operational phase shows a similar pattern, with the experienced owner-utilities adopting a hands-on approach with short-service agreements (two to five years, or even less) and awarding a wide range of contracts for various aspects of wind farm operation, maintenance and service. Hands-off developers may opt for a 15-year service agreement.
4.1 United Kingdom

Market size and turbine demand

At the end of 2019, the UK will have about 9.8 GW of installed capacity, the most of any country globally. This is forecast to reach about 17 GW by the end of 2024, with a CAGR of cumulative installed capacity between 2020 and 2024 of 13%. During this period, we forecast the annual installed capacity to be between 680 MW and 2 GW. The UK’s reduced annual installed capacity in 2020-2021 is due to the timing of CfD auctions and the project build schedules for earlier projects. Installation rates of about 2 GW are expected throughout the later 2020s, to meet an industry/government agreed aspiration of 30 GW by 2030.

Projects that are expected to contribute to the forecast installed capacity in this period include: East Anglia ONE and THREE, Hornsea Projects One and Two, Moray East, Neart na Gaoithe, Triton Knoll and Inch Cape. The first of the Dogger Bank projects are expected in 2024.

Regulation

- There is strong political support for offshore wind in the UK. In the past, governments have avoided support for specific technologies and preferred technology-neutral incentives to meet policy objectives. The Offshore Wind Sector Deal, published in March 2019, marked a shift in approach and signalled that it would support a cumulative installed capacity for offshore wind of 30 GW in 2030 in exchange from commitments from industry to support supply chain development. There is sufficient capacity in development to meet this aspiration and high confidence that such volume will be installed.

- The Crown Estate and Crown Estate Scotland separately award development rights and leases for offshore wind sites in UK territorial waters and in the UK Exclusive Economic Zone. They are public bodies with revenues being paid to the UK and Scottish Governments respectively. Both organisations independently have initiated new leasing rounds in 2019 with new competition terms which could bring about a further 10 GW into development, which could be constructed from 2026 onwards.

- Offshore Transmission Owners (OFTOs) bid to own and operate offshore transmission assets that link the wind farm to the GB Grid through competitive tender processes run by the industry regulator the Office of Gas and Electricity Markets (Ofgem). Developers typically take up an option to build the transmission assets, which are sold on to the selected OFTO within 18 months of wind farm commissioning. By taking this option, developers reduce their risk of stranded generating assets.

- Offshore wind projects in England and Wales are defined as nationally significant infrastructure projects and are examined by the Planning Inspectorate. A single consent application is made for onshore and offshore works. The Secretary of State for the Department for Business, Energy and Industrial Strategy grants or refuses consent based on a recommendation made by the Planning Inspectorate. In Scotland, Marine Scotland examines applications and Scottish Ministers grant or refuse consent for the offshore works. It should be noted, however, that Scottish Ministers’ consent was successfully appealed for three recent projects, before being ultimately restored at a further appeal.
Onshore works in Scotland are consented by the local authority. In UK, a small number of projects have been refused planning consent, notably Docking Shoal (bird impacts) and Navitus Bay (visual intrusion).

- The price support mechanism for new projects is through CfDs. The CfDs are funded directly by the UK government but the contracts are placed and administered by the Low Carbon Contracts Company, which is a private company owned by the Secretary of State. CfDs last 15 years and are awarded through competitive allocation rounds. The UK government sets the budget and capacity limit for each allocation round and eligible projects are awarded CfDs on price with as many projects as possible supported within the budget. CfDs are expected to remain the mechanism for support, although modifications are expected to be needed to accommodate subsidy-free bids at or below the expected wholesale electricity price.

- The first allocation round was completed in February 2015 with two offshore wind projects awarded a CfD, East Anglia ONE and Neart na Gaoithe, at strike prices of £120 (€132)/MWh and £114 (€125)/MWh respectively. In 2017, a second CfD allocation round was held for projects to be delivered in financial years 2021/22 and 2022/23. Three projects were awarded CfDs: Hornsea Project Two (1.3 GW at a strike price of £57.50 (€63)/MWh), Moray East (950 MW at a strike price of £57.50 (€63)/MWh) and Triton Knoll (860 MW at a strike price of £74.75 (€82)/MWh).

- The results of allocation round 3 are expected from September 2019 and up to 6 GW will be awarded. Eligible projects include East Anglia THREE (ScottishPower Renewables), Inch Cape (Red Rock Power), Moray West (EDPR and Engie) Seagreen Phase 1 (SSE), Sofia (Innogy), and Teesside A and Creyke Beck A and B (Equinor and SSE).

- The Crown Estate has just completed a plan-level Habitats Regulations Assessment (HRA), enabling a further 2.85 of extension projects in UK waters to progress to award of rights as part of a separate leasing process.

### Capital and operational expenditure

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
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<tr>
<td>Transmission</td>
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<td>Array electrical</td>
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<td>Turbine</td>
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</tr>
</tbody>
</table>

Source: BVG Associates

Figure 23 Estimated expenditure for the United Kingdom.
- The UK owners are predominantly major energy utilities, making up eight of the top 10, including Ørsted, SSE, Vattenfall, ScottishPower Renewables (Iberdrola), Innogy, Equinor, EDPR and E.ON.

- SDIC Power (Red Rock Power, in the UK) is a Chinese sovereign wealth fund.

- Ørsted is the owner with the largest total portfolio, with SSE close behind as the second largest. Ørsted’s large post-FID pipeline is in part due to the Hornsea Two project. Once operational in 2022, it will be the world’s largest wind farm with 1.3 GW operating capacity.

- In March 2018, E.ON reached an agreement with RWE, Innogy’s parent company, on a complex asset swap agreement. This has the objective of making RWE a generation-focused business and E.ON will be a networks and end user-focused business. In August 2019, RWE said it was making “good progress” towards completing the asset swap agreement.

- The top 10 owners account for 69% of the UK operating capacity.

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Ørsted is an energy utility headquartered in Denmark. Ørsted has over 1.7 GW of operating capacity in the UK. Its most recent operating wind farm is Race Bank, located off the Norfolk coast. It is currently has Hornsea One is under construction, which will be the world’s largest wind farm, once commissioned in late 2020, and Hornsea Two, Three and Four are also in development.

SSE is an energy utility headquartered in the UK. SSE owns 50% of the Dogger Bank Creyke Beck A and B and Dogger Bank Teesside A projects in a JV with Equinor, and 100% of the Seagreen (Round 3) projects. SSE also owns shares in the operating Beatrice project located in Scotland with CIP and Redrock, shares in the operating Walney 1 and 2 projects with Ørsted and shares in the operating Greater Gabbard project with Innogy.

Vattenfall is an energy utility headquartered in Sweden. Vattenfall owns the Norfolk Vanguard and Norfolk Boreas offshore wind projects (part of the East Anglia Round 3 zone) under development. In 2018 it commissioned the European Offshore Wind Deployment Centre; a 92 MW demonstration wind farm in Scotland.

ScottishPower Renewables (Iberdrola) is a UK utility and part of the Spanish energy utility Iberdrola. The company owns the East Anglia ONE project under construction in the UK as well as three further East Anglia projects.

Innogy UK is a UK utility and a subsidiary of the German energy company RWE. In March 2018, E.ON agreed to acquire Innogy’s network and retail businesses. In exchange, RWE will receive E.ON’s renewable energy assets as well as retaining Innogy’s renewable assets. In the UK Innogy has joint ownership of the Galloper and Triton Knoll wind farms and Sofia (Dogger Bank Teesside B) project.
Scotland is also suitable for floating wind farms and is playing host to the first floating demonstration project in the UK, with a second demonstration to follow.

- **Equinor** and **Masdar**’s project Hywind Scotland is located near Aberdeen and it was fully commissioned in October 2017. The 30 MW project uses five SWT-6.0-154 turbines on top of a floating vertical spar.
- **ACS Servicios Comunicaciones y Energía**’s project Kincardine is located near Aberdeen. The first turbine installed in 2018 was a 2 MW turbine, supported on a semi-submersible by WindFloat. A further five 9.5 MW turbines will follow.

### Supply chain

<table>
<thead>
<tr>
<th>Company</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bladt Industries</strong></td>
<td>is a manufacturer of offshore steel structures. Its primary activities in the offshore wind industry are the manufacture of steel foundations and assembly of substation jackets and topsides. Bladt Industries has supplied or been contracted to supply foundations for several UK projects, including the Beatrice and Walney Extension projects. It is also a transition piece supplier and topside supplier for Hornsea One and some of the Walney projects.</td>
</tr>
<tr>
<td><strong>Boskalis</strong></td>
<td>is a vessel owner and operator. Its primary activity in the offshore wind industry is the installation of foundations, export and array cables. It has provided array and export cable installation for nine UK projects, including Blyth Offshore Demonstrator and the European Offshore Wind Deployment Centre. It will provide array cable installation for the East Anglia ONE project. It is the array cable supplier for the Moray East project and is contracted to install the foundations for Hornsea One.</td>
</tr>
<tr>
<td><strong>DeepOcean</strong></td>
<td>provides cable installation as an EPCI main contractor or as a nominated subcontractor for individual work packages. It has a fleet of 16 vessels and 40 ROVs and 16 trenching assets. DeepOcean has been contracted for export cable installation for the East Anglia ONE project. It will provide array cable installation for the Hornsea One and Race Bank projects.</td>
</tr>
<tr>
<td><strong>DEME Offshore</strong></td>
<td>is a specialist offshore wind installation contractor. It maintains and operates its own fleet of specially designed vessels and equipment, which allows it to provide foundation and turbine transport and installation. It also provides operations, maintenance and service logistics. Its primary activity in offshore wind is the installation of turbines. A2SEA was acquired by GeoSea (DEME Group) in September 2017. A2SEA has provided turbine installation for almost 3.5 GW of operating UK projects. It has been contracted to provide turbine installation for the East Anglia ONE, Hornsea One, Neart na Gaoithe and Moray East projects. It provided foundation installation for the London Array, Teesside and Thanet projects.</td>
</tr>
<tr>
<td><strong>EEW</strong></td>
<td>is a German manufacturer of steel tubular structures. Its primary activity in the offshore wind industry is the production of monopile foundations, and tubulars and pin piles for jacket foundations. It also includes Offshore Structures Britain, in the UK. EEW was the foundation supplier for the Burbo Bank extension project and has been contracted for Hornsea One as well.</td>
</tr>
<tr>
<td><strong>JDR Cable Systems</strong></td>
<td>is a supplier of subsea cables and umbilicals. Its primary activity in the offshore wind industry is the production of array cables. In 2017, JDR was acquired by Telefonika. JDR has supplied or has been contracted to supply array cables for a range of UK projects, including the East Anglia ONE, Hornsea One and Beatrice projects.</td>
</tr>
<tr>
<td><strong>MHI Vestas Offshore Wind (MVOW)</strong></td>
<td>is the global number two supplier of offshore wind turbines by total installed capacity. It is a JV formed in April 2014 between Mitsubishi Heavy Industries and Vestas. Most of its production facilities are in Denmark, and it operates a UK blade factory. It has recently provided or has been contracted to provide turbines for the Inch Cape, Kincardine and Moray East projects.</td>
</tr>
<tr>
<td><strong>Van Oord’s MPI Offshore</strong></td>
<td>subsidiary, previously part of the Vroon Group, was acquired by Van Oord in July 2018, along with most of its assets, and is a marine contractor that installs turbines and foundations. MPI Offshore pioneered the development of specialist offshore turbine installation vessels and now operates a fleet of two offshore installation vessels and a heavy-lift installation vessel. It provided turbine installation for the Rampion and Teesside projects.</td>
</tr>
<tr>
<td><strong>Nexans</strong></td>
<td>is a supplier of power and communication cables and has commissioned its own cable laying vessel. In the offshore wind industry, its primary activities are the supply of array, export and communications cables. Nexans has supplied a significant number of projects with array and export cables. Recently, it has been contracted to supply the East Anglia ONE, Beatrice and Blyth Offshore Demonstrator projects with export cables and Hornsea One with array cables.</td>
</tr>
<tr>
<td><strong>Company</strong></td>
<td><strong>Description and Activities</strong></td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td><strong>NKT Cables</strong></td>
<td>Supplier and installer of array and export cables, purchased ABB’s high-voltage cable business in 2016. Supplied to Ørsted projects.</td>
</tr>
<tr>
<td><strong>Prismian</strong></td>
<td>Supplier of power and communication cables. Supplied export cables to Ørsted projects and other projects.</td>
</tr>
<tr>
<td><strong>Seaway 7</strong></td>
<td>Has two main subsidiaries: Seaway Heavy Lifting (offshore contractor and vessel owner) and Seaway Offshore Cables (subsea contractor). Supplied array cables to Walney 2 and other projects.</td>
</tr>
<tr>
<td><strong>Siemens Gamesa</strong></td>
<td>Leading international manufacturer of onshore and offshore wind turbines. Supplied over 1,750 turbines to offshore projects.</td>
</tr>
<tr>
<td><strong>Siemens Power Transmission</strong></td>
<td>Part of Siemens Energy, manufactures electrical systems and offers EPC contracts for substations and grid connection services. Supplied offshore substations for projects.</td>
</tr>
<tr>
<td><strong>Sif Group</strong></td>
<td>Manufacturer of steel tubular structures. Supplied foundations for offshore projects.</td>
</tr>
<tr>
<td><strong>Smulders Projects</strong></td>
<td>Fabricator of large offshore structures. Supplied transition pieces to UK projects.</td>
</tr>
</tbody>
</table>
4.2 Germany

Market size and turbine demand

At the end of 2019 Germany will have 7.7 GW of installed capacity. This is forecast to reach 10 GW by the end of 2024. Between 2020 and 2024 the CAGR of cumulative installed capacity will be 7% and the annual installed capacity is forecast to be up to 1.1 GW. This is due to the most recent auction, where bidders had a construction window up to 2025 and developers have opted to wait for the availability of larger MW turbines and other future cost benefits.

Announcements were made in early 2019 that more auctions for offshore wind power would be held, plugging a current gap in tenders for the next three years.

Projects that are expected to contribute to the forecast installed capacity include: Arcadis Ost, Baltic Eagle, Borkum Riffgrund West and West II, He Dreit, Gode Wind 3 and 4, Kaskasi, Wikinger Sud and OWP West.

Figure 26 Forecast installed capacity in Germany.

Figure 27 Forecast demand for turbines in Germany.

Regulation

The German market regulation changed with the introduction of the WindSeeG (Offshore Wind Act) which came into force on 1 January 2017. The WindSeeG introduces a centralised planning approach, which involves an Area Development Plan and a new contract for difference (CfD) support mechanism. A transitional mechanism provides support to projects anticipated to be commissioned between 2021 and 2025. This allows developers of projects in advanced stages of planning to bid for subsidy support before WindSeeG’s competitive auctioning process is fully implemented. The first transitional auction took place in April 2017 with 1.5 GW of capacity to be supported. This first round resulted in the first zero subsidised bids (excluding transmission) for offshore wind projects in Germany (submitted by EnBW and Ørsted). A second auction for a further 1.6 GW of capacity took place in April 2018.

The Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency (BSH)) coordinates the preliminary environmental assessments and allocates offshore grid connections for projects before the project sites are competitively auctioned to developers. The preliminary environmental assessments completed by BSH are not sufficient to secure consent for the wind farm site. Developers still need to undertake detailed environmental surveys, including unexploded ordnance (UXO) surveys, to inform the micro-siting of wind turbines.

Under the WindSeeG, CfDs are awarded through competitive auctions held by Bundesnetzagentur (the Federal Network Agency), which is the electricity regulator. The first auction is planned for 2021, with wind farms commissioned from 2026 onwards. Successful projects will get a 20-year power purchase agreement.

Offshore grid connections are constructed, owned and operated by transmission system operators (TSOs). Up to now these have been built by TenneT (North Sea) and 50Hertz Transmission (Baltic Sea) and may involve TSOs Amprion and TransnetBW in future. Before the WindSeeG, the TSOs submitted an annual Offshore Grid Development Plan to the Federal Network Agency, setting out the plan for transmission assets. Under WindSeeG, this process is incorporated into the Area Development Plan, which outlines the location and construction schedule of future transmission assets, currently out to 2025. Seven offshore grid connections are currently in planning or under construction, with six of these to be constructed by
TenneT in the North Sea and planned to be completed by 2025. The remaining one to be installed in the Baltic Sea by 2022 and constructed by 50Hertz.

**Capital and operational expenditure**

- Expenditure across all supply chain activities in 2024 is estimated to be €3.1 billion
- Total expenditure between 2020 and 2024 is estimated to be €12.4 billion, and
- It is expected that 59% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX and that 41% will be spent on OPEX.

**Owners**

- Major energy utilities dominate the ownership of the German market. Of the top 10 developers, six are major utilities.
- Ørsted has both the largest operating portfolio at almost 672 MW, and the largest development pipeline, with over 1.5 GW of projects that have either applied for consent, has consent approved or under construction.
- In March 2018, E.ON reached an agreement with RWE, Innogy’s parent company, on a complex asset swap agreement. This has the objective of making RWE a generation-focused business and E.ON will be a networks and end user-focused business. In August 2019, RWE said it was making “good progress” towards completing the asset swap agreement.
- HypoVereinsbank is an investor, rather than actively developing projects.

![Figure 28 Estimated expenditure for Germany.](source)

![Figure 29 Top 10 owners by portfolio for Germany.](source)
Ørsted is an energy utility headquartered in Denmark. It has 50% shares in the Borkum Riffgrund 1 and 2, and Gode Wind 1 and 2 projects. It solely owns the Borkum Riffgrund West 1, Borkum Riffgrund West 2, OWP West and Gode Wind 3 and 4 projects.

EnBW is an energy utility headquartered in Germany. It owns the EnBW He Dreight project, which has gained approval in April 2017. The Hohe See and Albatros projects, in which EnBW has 50.1% shares (Enbridge owning 49.9%), are currently under construction and expect to be operational by the end of 2019. EnBW also has majority shareholdings in the operational Baltic 1 and 2 projects.

Northland Power is an independent power producer and specialist developer headquartered in Canada. It has majority shares in the operational Nordsee One project. In 2017, Northland Power purchased and then reached FID on the Deutsche Bucht project, which is currently under construction.

Iberdrola is an energy utility headquartered in Spain. The Wikinger project was commissioned at the end of 2017 and the Baltic Eagle and Wikinger Sud projects are currently under development.

E.ON is an energy utility headquartered in Germany. It owns the operational Amrumbank West project, and it is currently constructing the Arkona project. In March 2018 it reached an agreement with RWE to acquire its network and retail businesses. Under the terms of the deal E.ON will transfer the Innogy renewables business to RWE. Despite approval from the competition authorities in Brussels and Bonn, the two companies have now confirmed an integration plan but this yet to be implemented. European Commission in early March opened an in-depth investigation into the transaction, the outcome of which is still pending. The merger shifts E.ON’s focus from power generation to energy networks and their customers.

Supply chain

50Hertz Transmission is part of the Elia Group, which also owns Elia Transmission, the TSO in Belgium. 50Hertz is one of the four German TSOs, two of which manage high-voltage (220kV to 380kV grids) offshore wind grid connections (50Hertz Transmission and TenneT). 50Hertz Transmission is headquartered in Berlin and is the TSO for offshore wind farms in the Baltic Sea, while TenneT is the TSO for those in the North Sea. It provided the grid connection for the Baltic 1 and Baltic 2 offshore wind projects.

ABB is Swiss-headquartered a supplier and integrator of electrical components, such as transformers for onshore and offshore substations and generators for turbines. It also works in connecting wind farms to the grid and offers design, engineering. It has provided array cables to the Nordsee Ost project, BARD Offshore 1 and constructed the DolWin2 offshore converter. In September 2016, NKT Cables purchased ABB’s high-voltage cable business.

Bladt Industries is a manufacturer of offshore steel structures. Its primary activities in the offshore wind industry are the manufacture of steel foundations and substation jackets and topsides. Bladt Industries has provided over 450 transition pieces to operating German projects. It provided transition pieces to the recently commissioned Arkona project and the Gode Wind 1 and 2 projects. It has also provided both monopile and jacket foundations to the German market, including to the Wikinger project.
<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boskalis</strong></td>
<td>is a vessel owner and operator. Its primary activity in the offshore wind industry is the installation of foundations, export and array cables. It will provide array cable installation for the Arkona, EnBW Hohe See and Albatros projects. It will also provide export cable installation for the Arcadis Ost and Baltic Eagle projects.</td>
</tr>
<tr>
<td><strong>DEME Offshore</strong> (previously Geosea)</td>
<td>offers services associated with turbine installation including installation vessels, heavy lift equipment and self-elevating platforms. GeoSea acquired A2SEA in September 2017. DEME Offshore's main activity in the German market to date is the installation of foundations. It has installed or has been contracted to install over 400 foundations. Most recently it has been contracted for the EnBW Hohe See and Albatros projects.</td>
</tr>
<tr>
<td><strong>EEW</strong></td>
<td>is a manufacturer of steel tubular structures. Its primary activity in the offshore wind industry is the production of monopile foundations, and tubulars and pin piles for jacket foundations. EEW has provided or has been contracted to provide over 450 foundations to German projects, recently for the Deutsche Bucht project currently under construction.</td>
</tr>
<tr>
<td><strong>ENGIE Fabricom</strong></td>
<td>is a Belgian construction contractor. Its primary activity in the offshore wind industry is the installation of turbines. It has installed or has been contracted to install almost 500 turbines across eight German projects, including Borkum Riffgrund 2 and Wikinger which are now fully commissioned, and the Hohe See and Albatros projects, which are under construction. It acquired Blue Tern (previous Seafox 5) in 2018 and in 2019 signed a long-term charter for Jill to undertake offshore wind O&amp;M.</td>
</tr>
<tr>
<td><strong>Fred.Olsen Windcarrier</strong></td>
<td>is a Norwegian vessel operator and installation contractor working exclusively within the offshore wind sector. Its primary activity is the installation of turbines. It has installed or has been contracted to install almost 500 turbines across eight German projects, including Borkum Riffgrund 2 and Wikinger which are now fully commissioned, and the Hohe See and Albatros projects, which are under construction. It acquired Blue Tern (previous Seafox 5) in 2018 and in 2019 signed a long-term charter for Jill to undertake offshore wind O&amp;M.</td>
</tr>
<tr>
<td><strong>Jan De Nul</strong></td>
<td>installs turbines, foundations, array and export cables, and manufactures concrete gravity base foundations. It is a dredging and marine contractor that has acquired 47 new vessels since 2007. In 2015, it entered the turbine and foundation installation market with the acquisition of the Vidar (renamed Vole au Vent) jack-up vessel from HGO InfraSea Solutions. In October 2018 it acquired a jack-up vessel from MPI Offshore (renamed the Tailevent). In April 2019 Jan De Nul placed and order for the Voltaire, a new large jack-up vessel for next generation turbine installation. It notably installed the export cables and turbines for the Trianel Windpark Borkum II project and the foundations for the Borkum Riffgrund 2 wind project.</td>
</tr>
<tr>
<td><strong>Nexans</strong></td>
<td>is a supplier of power and communication cables and has commissioned its own cable laying vessel. In the offshore wind industry, its primary activities are the supply of array, export and communications cables. Nexans has been contracted to supply array cables on six German projects, including the Arkona and Gode Wind 1 and 2 projects.</td>
</tr>
<tr>
<td><strong>Prysmian</strong></td>
<td>is a supplier of power and communication cables. Its primary activities in the offshore wind industry are the supply and installation of export and array cables. It acquired its US rival, General Cable in December 2017 including the subsidiary NSW. Prysmian is supplied both array and export cables to the Wikinger project. It will also provide array cables for the Merkur Offshore project and export cables for the Arkona project.</td>
</tr>
<tr>
<td><strong>Seaway 7</strong></td>
<td>has two main subsidiaries in offshore wind. Seaway Heavy Lifting is an offshore contractor and vessel owner. It is an EPCI contractor. Its primary activity in the offshore wind industry is the installation of foundations and offshore substations. Seaway Offshore Cables (previously Siem Offshore Contractors) is subsea contractor and its primary activity in the offshore wind industry is the installation of array and export cables. Seaway Heavy Lifting has been contracted to install foundations at Borkum West II Phase 2 (Trianel) project. Its main activity in the German market is the installation of offshore substations, for which it has supplied seven projects, including the Wikinger and Borkum West II Phase 2 (Trianel) projects. It has also been contracted to install the substations for the Arkona project.</td>
</tr>
<tr>
<td><strong>Siemens Gamesa Renewable Energy</strong></td>
<td>is a manufacturer of onshore and offshore wind turbines. A merger between Siemens and Gamesa obtained EU approval in March 2017 and took effect in April 2017. Siemens Gamesa has supplied or has been contracted to supply over 900 turbines for German projects. Most recently it was contracted for the EnBW Hohe See and Albatros projects.</td>
</tr>
<tr>
<td><strong>Sif Group</strong></td>
<td>is a manufacturer of steel tubular structures. Its primary activity in the offshore wind industry is the production of monopile foundations and pin piles for jacket foundations. Sif Group has supplied or has been contracted to supply monopiles and/or transition pieces to more than 50 offshore wind projects. It has recently supplied monopiles to the EnBW Hohe See and Albatros projects.</td>
</tr>
</tbody>
</table>
**Smulders Projects** is a fabricator of large offshore structures. Its primary activity in the offshore wind industry is the manufacture of monopile transition pieces and jackets. Smulders Projects has provided or will provide transition pieces for all the German projects where Sif Group has been the main foundation supplier, including Hohe See and Albatros.

**TenneT** is one of four German TSOs, two of which manage high-voltage (220kV to 380kV grids) offshore wind grid connections (50Hertz Transmission and TenneT). TenneT is the largest of the TSOs and since 2006, has been the TSO responsible for offshore wind farms constructed in the North Sea. 50Hertz Transmission is the TSO for projects in the Baltic Sea. TenneT is also a Dutch TSO and is headquartered in Arnhem, the Netherlands. By 2019, TenneT will have a transmission capacity of over 7 GW from renewables in Germany. It has provided six HVDC offshore substations to offshore wind projects in Germany, including BorWin 1 and 2, DolWin 1 and 2, and HelWin 1 and 2. By 2019, it will commission the DolWin 3 and BorWin 3 HVDC substations.

**Van Oord** is a Netherlands dredging and marine contractor. Its primary activity in the offshore wind market is the installation of turbines, foundations, and export and array cables. It recently acquired MPI Offshore from the Vroon Group. MPI Offshore pioneered the development of specialist offshore turbine installation vessels and now operates a fleet of two offshore installation vessels and a heavy-lift installation vessel. Van Oord has been awarded the installation of the turbine foundations for the Arkona and Deutsche Bucht projects.
4.3 Denmark

Market size and turbine demand

At the end of 2019, Denmark will have about 1.9 GW of installed capacity. This is forecast to reach 3.7 GW by the end of 2024. The CAGR of cumulative installed capacity between 2020 and 2024 is 15%. During this period, the annual installed capacity is forecast to be between 80 MW and 600 MW.

Projects that are expected to contribute to the forecast installed capacity in this period include: Kriegers Flak, Thor (Baltic Sea) and Vesterhav Nord and Syd (North Sea).

Regulation

Leasing for offshore wind sites is managed by the Danish Energy Agency (DEA). The DEA is used as a 'one-stop-shop' for all required licences and consenting activities. Energinet.dk is responsible for the electricity infrastructure and acts as a transmission system operator (TSO). Offshore wind leases are normally given for 25 years and can be awarded through two procedures:

- Tender procedure: The DEA announces a site-specific tender for a set project capacity (MW), having completed preliminary environmental investigations through a spatial planning committee and surveys managed by Energinet.dk. There were tenders in 1997, 2007, 2011, 2012, 2015 and 2016. Developers are invited to quote a fixed MWh price for electricity generated. The DEA negotiates with pre-qualified tenderers before awarding the site to the lowest bidder.

- Open-door procedure: The developer identifies a potential offshore wind site and submits a licence application to undertake preliminary environmental investigations. The developer is not guaranteed a licence to construct and operate the wind farm. In the open-door procedure, the developer pays for the grid connection to shore and the transmission of the electricity. The developer receives the same price for electricity generated as for new onshore wind farms, DKK 250/MWh (€34/MWh). Energinet.dk designs, constructs and operates the offshore substation and the export cable.

In 2016, Vattenfall won the tender to build the 600 MW Kriegers Flak project at a price of DKK 372 (€50)/MWh and the Danish Near Shore Wind tender for the Vesterhav Syd and Vesterhav Nord projects with a combined capacity of 350 MW at a price of DKK 475 (€64)/MWh. These feed-in tariffs are guaranteed for 50 000 full-load generating hours for a maximum of 20 years. After this period, the wind farm owner receives the market price.

An energy agreement passed by the Danish parliament in June 2018 supported building an at least an additional 2.4 GW of offshore wind capacity by 2030. This minimum capacity is expected to be awarded through three future tenders. In April 2019, The Danish Energy Agency (DEA) identified new sites for between 12 and 15 wind farms with a total capacity of "at least" 12.4 GW, under a study ordered by the government last year into offshore wind's future potential.
Capital and operational expenditure

- Expenditure across all supply chain activities in 2024 is estimated to be €1.6 billion.
- Total expenditure between 2020 and 2024 is estimated to be €6.7 billion, and
- It is expected that 75% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX and it is likely that 20% will be spent on OPEX and 5% on DECEX.

![Figure 33 Estimated expenditure for Denmark.](image)

Owners

- Denmark has a mix of company types that make up the top 10 owners in offshore wind projects. The largest, Vattenfall and Ørsted, are major energy utilities. Companies with smaller portfolios focused on projects in development include local Danish utilities, such as Sonderborg Forsyning and HOFOR. Other companies with development portfolios include European Energy, Hawind Arhus Bugt and NIBC Bank. There are also pension funds that have bought into operational projects, such as PensionDanmark and PKA.
- Vattenfall has over three times the owner portfolio of Ørsted. In 2015 and 2016, Vattenfall was successful in the Kriegers Flak and Vesterhav Nord and Syd tenders. Versterhav Nord and Syd is under construction, but a three-year extension to the commissioning deadline from 2020 to 2023 was recently requested due to protests and permitting issues. Its operating portfolio comes from its 60% share in the Horns Rev 1 project in a JV with Ørsted and full ownership of the Horns Rev 3 project.
- Ørsted has the largest operating portfolio with approximately 600 MW.
Vattenfall is an energy utility headquartered in Sweden. In Denmark, it secured the project rights to the Kriegers Flak, Horns Rev 3, Vesterhav Nord and Vesterhav Syd offshore wind projects.

Ørsted is an energy utility headquartered in Denmark. In Denmark, Ørsted has almost 600 MW of operational projects including Horns Rev 1 and 2, and Anholt.

European Energy is a specialist developer headquartered in Denmark. European Energy has shares in the Jammerland Bugt and Ome Syd projects, which are under development.

PensionDanmark is one of the largest pension funds in Denmark. It notably has a share in operational projects Nysted and Anholt.

SEAS-NVE Energy Group is a mutual energy company headquartered in Denmark. It owns shares in operational (Redstand 2) and planned offshore wind farms (in early stages of planning) as well as substations and grid connections.

Boskalis is a vessel owner and operator. Its primary activity in the offshore wind industry is the installation of foundations, export and array cables. It will provide array cable installation for Vattenfall’s Horns Rev 3 and Kriegers Flak projects.

DEME Offshore is a specialist offshore wind installation contractor. It maintains and operates its own fleet of specially designed vessels and equipment, which allows it to provide foundation and turbine transport and installation. It also provides operations, maintenance and service logistics. Its primary activity in offshore wind is the installation of turbines. A2SEA was acquired by GeoSea (DEME Group) in September 2017. It has installed almost 450 offshore wind turbines in Denmark. A2SEA will provide turbine and foundation installation for Horns Rev 3 project.

EEW is a German manufacturer of steel tubular structures. Its primary activity in the offshore wind industry is the production of monopile foundations, and tubulars and pin piles for jacket foundations. EEW will provide foundations and transition pieces for the Horns Rev 3 project and foundations for Kriegers Flak.

Energinet.dk is an independent public enterprise owned by the Danish Ministry of Climate and Energy. It owns, operates and develops transmission systems for electricity and natural gas in Denmark. It is awarded offshore wind transmission contracts by the Danish Government. It is currently contracting and constructing the Kriegers Flak interconnector; a combined grid solution (CGS) connecting the not-yet-constructed Danish Kriegers Flak offshore wind farm with the operating German Baltic 2 offshore wind farm. Energinet.dk is working with 50Hertz Transmission for the CGS.

Hollandia Offshore manufactures offshore substation topsides, offshore substation jacket foundations, wind turbine jacket foundations, and modifies vessels. Hollandia Offshore will supply the substation topside for the Kriegers Flak project.
**Capital and operational expenditure**

**HSM Offshore** is part of the Andus Group and manufacturers offshore substation topsides, offshore substation jacket foundations and oil and gas structures in the Netherlands. It supplied the offshore substation topsides for Horns Rev 2 and Horns Rev 3.

**Jan De Nul** installs turbines, foundations, array and export cables, and manufactures concrete gravity base foundations. It is a dredging and marine contractor that has acquired 47 new vessels since 2007. In 2015, it entered the turbine and foundation installation market with the acquisition of the Vidar (renamed Vole au Vent) jack-up vessel from HGO InfraSea Solutions. In October 2018 it acquired a jack-up vessel from MPI Offshore (renamed the Taillevent). In April 2019 Jan De Nul placed and order for the Voltaire, a new large jack-up vessel for next generation turbine installation. It was awarded the installation of the substation foundations for the Kriegers Flak offshore wind project.

**MHI Vestas Offshore Wind (MVOW)** is the global number two supplier of offshore wind turbines by total installed capacity. It is a JV formed in April 2014 between Mitsubishi Heavy Industries and Vestas. MVOW provided turbines for Horns Rev 1 and 3. Most of its production facilities are in Denmark, and it operates a UK blade factory.

**Navantia** is a Spanish shipbuilder and fabricator of large offshore structures. Its primary activity in the offshore wind industry is the assembly of HVAC offshore substation topsides and jackets and manufacture of turbine jackets. Navantia was contracted to supply four foundations for the Nissum Bredning project.

**NKT Cables** is a supplier, installer and EPC contractor for both array and export cables. In September 2016, NKT Cables purchased ABB’s high-voltage cable business. NKT Cables will supply the Nissum Bredning project with array cables. It will provide export cables to the Kriegers Flak project.

**Prysmian** is a supplier of power and communication cables. Its primary activities in the offshore wind industry are the supply and installation of export and array cables. It acquired its US rival, General Cable in December 2017 including the subsidiary NSW. Prysmian (Draka) will supply array cables for Horns Rev 3.

**Scaldis Salvage and Marine (Scaldis)** is a marine contractor and heavy lift specialist, operating two sheerleg cranes, Gulliver and Rambiz. Its primary activity in the offshore wind industry is the installation of foundations and offshore substations. Scaldis provided offshore substation installation for the Northwind and Thornton Bank projects. It is a subsidiary of DEME, Jan De Nul and Herbosch-Kiere. Scaldis installed the offshore substations on Kriegers Flak and Rødsand II.

**Seaway 7** has two main subsidiaries in offshore wind. Seaway Heavy Lifting is an offshore contractor and vessel owner. It is an EPCI contractor. Its primary activity in the offshore wind industry is the installation of foundations and offshore substations. Seaway Offshore Cables (previously Siem Offshore Contractors) is subsea contractor and its primary activity in the offshore wind industry is the installation of array and export cables. Seaway Heavy Lifting will provide offshore substation installation for the Horns Rev 3 project.

**Siemens Gamesa Renewable Energy** is a leading international manufacturer of onshore and offshore wind turbines. A merger between Siemens and Gamesa obtained EU approval in March 2017 and took effect in April 2017. It has supplied almost 400 turbines to a range of offshore projects in Denmark, including Kriegers Flak, and has been contracted to supply turbines to Vesterhav Nord and Syd as well.
4.4 Belgium

Market size and turbine demand

As of January 2019, Belgium had 1.5 GW of installed capacity. This is forecast to reach 2.2 GW by the end of 2021 with no capacity to be installed in 2022, 2023 or 2024. The CAGR of cumulative installed capacity between 2020 and 2024 is 6% and the annual installed capacity is forecast to be up to 480 MW. The turbine forecast shows demand in 2024 for a wind farm to be built in 2025, this depends on the schedule of the current 2 GW leasing round. The Belgian coastline is only 65 km long and it does not extend far into the North Sea as the UK is opposite. There are many competing marine uses so there is unlikely to be space for further offshore wind farms beyond the current leasing round.

Projects that contribute to the forecast installed capacity in this period are all at an advanced stage. They are: Norther – which is currently being commissioned, and Northwester 2 and Seamade (formerly Mermaid and Seastar), which are currently in construction.

Regulation

The Belgische Ministers van Energie (Belgian Energy Ministers) of the Belgische Federale Overheid (Belgian Federal Government) issue leases for offshore wind projects. These projects are all located in a linear group along the north east edge of the Belgian North Sea zone. Existing operational projects have leases for 20 years. For approved projects not yet constructed, leases have been awarded for 20 years (although this is expected to be extended to 22 years for later projects).

Developers of offshore wind farms need the following licences: offshore domain concession; marine protection construction authorisation and operating licence; export cable licence; and onshore cable licence.

Between 2004 and 2010, nine offshore domain concessions were awarded to developers. An environmental permit is not guaranteed with the award of the concession and the developer must still develop the site and complete environmental surveys and studies. The Belgian Energy Ministers grant or refuse environmental permit applications.

The subsidy mechanism for projects constructed from 2014 is a contract for difference (CfD). A CfD was awarded at a fixed price of €138/MWh to several projects; however, due to the falling cost of offshore wind across Europe, three projects already awarded this subsidy but yet to begin construction had their financial support renegotiated to €79/MWh by Belgian Energy Ministers.

In April 2018, the Belgian government announced plans for a further offshore wind zone and an additional 2 GW of capacity by 2025, as part of a draft National Energy and Climate Plan (NECP) to reach 3 GW of offshore wind by 2030. This new zone is located at the south west corner of the Belgian North Sea zone. Projects in the new zone will be offered to developers in a future competitive public tender, with bids at zero subsidy (excluding transmission) being considered as a possibility.

Elia is the transmission system operator (TSO). To date, offshore wind farms have been connected to the grid on a project-by-project basis, with the developer paying two-thirds of the supply and install cost and Elia paying one-third. Elia is currently consulting with stakeholders on the development of a Belgian modular offshore grid, to provide transmission for
several offshore wind farms. The development of a modular offshore grid includes consolidating the onshore grid in coastal areas by laying new underground lines, upgrading substations and strengthening the connections between substations.

**Capital and operational expenditure**

- Expenditure across all supply chain activities in 2024 is estimated to be €1.1 billion.
- Total expenditure between 2020 and 2024 is estimated to be €3.9 billion.
- It is expected that 68% of expenditure between 2020 and 2024 will be DEVEX and CAPEX, and 32% will be OPEX.

![Figure 38 Estimated expenditure in Belgium.](source)

**Owners**

- Compared with other European markets such as the UK and Germany, where major energy utilities dominate the ownership of projects, Belgium has a greater number of specialist developers, such as Parkwind and Elicio, in the top 10 list of owners.
- Otary has the largest operating portfolio, and Parkwind the second largest.
- Otary completed construction of the Rentel project in January 2019 and is developing the Seamade project.
- The portfolios under construction of Elicio, Diamond Generating Europe (Mitsubishi Corporation) and Eneco are all as result of their JV on the Norther project.

![Figure 39 Top 10 owners by portfolio for Belgium.](source)
Otary is a partnership of eight Belgium companies, including: Aspiravi, DEME, Elicio, Power@Sea, Rent-a-Port, Socofe, SRIW Environment and Z-kracht. It wholly owns the Rentel project and owns the majority of the Seamade project.

Parkwind is a specialist developer headquartered in Belgium. Its three shareholders are Colruyt Group, Korys and PMV. It has shares in the operating Northwind and Nobelwind projects. Parkwind also has a 70% share in the Northwester 2 project.

Elicio is a specialist developer headquartered in Belgium. It has 50% share in the Norther project.

Sumitomo Corporation is a trading house headquartered in Japan. It has shares in the operating Northwind and Nobelwind projects. Sumitomo Corporation also has a 30% share in the Northwester 2 project.

Eneco is a developer with its headquarters in Rotterdam, but with offices in Belgium. It owns shares in the Seamade and Norther projects.

Supply chain

Bladt Industries is a Danish manufacturer of offshore steel structures. Its primary activities in the offshore wind industry are the manufacture of steel foundations, and substation jackets and topsides. Bladt Industries has recently supplied the substation topside to the Nobelwind and Northwind offshore wind farms. Bladt has also been contracted to supply the foundation, transition pieces and topside for the Northwester 2 project.

Chantiers de l’Atlantique (formerly STX France Solutions) is a shipbuilder and fabricator of large offshore structures from its yard at Saint-Nazaire. Its primary activity in the offshore wind industry is the design and assembly of HVAC offshore substation topsides and jackets. STX France Solutions supplied substation topside for the Rentel offshore wind farm.

DEME Offshore’s Tideway subsidiary is a Netherlands-based subsea contractor. Its primary activity in the offshore wind industry is the installation of scour protection and array and export cables. The company is the dredging, rock dumping and cable laying division of DEME. Tideway provided array cable installation for Northwind and Thornton Bank phase 2.

Elia Group is a transmission system operator. Its core shareholder is Publi-T. In Belgium, Elia Transmission operates the onshore high-voltage (30kV to 380kV) electricity transmission system in Belgium. In 2011, Elia Group acquired 50Hertz Transmission, one of TSOs in Germany and the operator of the offshore transmission assets in the Baltic Sea. It is currently consulting on the development of a modular offshore grid, which would see the construction of two offshore substations in the North Sea (Alpha and Beta) connected by 220kV connections to the Stevin substation to be built near the Zeebrugge port.

Idesa’s primary activity in the offshore wind market is the manufacture of steel foundations and transition pieces. It has facilities in the Ports of Avilés and Gijón in Spain. Idesa supplied 44% of the transition pieces for the Northwind project.
<table>
<thead>
<tr>
<th>Company</th>
<th>Description and Key Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan De Nul</td>
<td>Installs turbines, foundations, array and export cables, and manufactures concrete gravity base foundations. It is a dredging and marine contractor that has acquired 47 new vessels since 2007. In 2015, it entered the turbine and foundation installation market with the acquisition of the Vidar (renamed Vole au Vent) jack-up vessel from HGO InfraSea Solutions. In October 2018 it acquired a jack-up vessel from MPI Offshore (renamed the Taillevent). In April 2019 Jan De Nul placed and order for the Voltaire, a new large jack-up vessel for next generation turbine installation. Jan De Nul supplied turbine, foundation and export cable installation services to the Nobelwind wind farm and provided export cable installation for the Northwind project. Jan De Nul has been contracted to provide turbine, foundation and export cable services for the Northwester 2 project.</td>
</tr>
<tr>
<td>MHI Vestas Offshore Wind (MVOW)</td>
<td>Is the global number two supplier of offshore wind turbines by total installed capacity. It is a JV formed in April 2014 between Mitsubishi Heavy Industries and Vestas. Most of its production facilities are in Denmark and it operates a UK blade factory. MVOW provided turbines for the Nobelwind, Northwind and Norther projects and has been contracted to supply turbines to the Northwester 2 project.</td>
</tr>
<tr>
<td>Nexans</td>
<td>Is a supplier of power and communication cables and has commissioned the build of its own cable laying vessel due to be operational in 2020. In the offshore wind industry, its primary activities are the supply of array (from Hamburg, Germany), export (from Halden, Norway) and communications cables. Nexans has provided export cables to the Nobelwind project and is the export cable supplier for the Nordwind and Rentel wind farms.</td>
</tr>
<tr>
<td>NKT Cables</td>
<td>Is a supplier and installer of array and export cables, with its main manufacturing site in Cologne, Germany. In September 2016, NKT Cables purchased ABB's high-voltage cable business in Karlskrona, Sweden. NKT Cables supplied export cables for the Rentel project.</td>
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<td>Siemens Gamesa Renewable Energy (Siemens Gamesa)</td>
<td>Is a manufacturer of onshore and offshore wind turbines. A merger between Siemens and Gamesa obtained EU approval in March 2017 and took effect in April 2017. Its main offshore turbine production facilities are in Cuxhaven, Germany and Hull, UK. Siemens Gamesa supplied turbines for the Rentel project and is contracted to supply turbines to the Seamade project.</td>
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<td>Sif Group</td>
<td>Is a Netherlands manufacturer of steel tubular structures. Its primary activity in the offshore wind industry is the production of monopile foundations and pin piles for jacket foundations. Sif Group supplied foundations for the Norther, Northwind, Rentel and Seamade projects.</td>
</tr>
<tr>
<td>Smulders Projects</td>
<td>Is a Belgian fabricator of large offshore structures. Its primary activity in the offshore wind industry is the manufacture of monopile transition pieces and jackets. The company is part of the construction company, Eiffage. Smulders Projects provided transition pieces for the Norther, Rentel and Seamade projects.</td>
</tr>
<tr>
<td>Van Oord</td>
<td>Is a Netherlands dredging and marine contractor. Its primary activity in the offshore wind market is the installation of turbines, foundations, and export and array cables. It recently acquired MPI Offshore from the Vroon Group. MPI Offshore pioneered the development of specialist offshore turbine installation vessels and now operates a fleet of two offshore installation vessels and a heavy-lift installation vessel. Van Oord provided turbine, foundation and array cable installation for the Norther project.</td>
</tr>
</tbody>
</table>
4.5 Netherlands

Market size and turbine demand

At the end of 2019, the Netherlands will have 1.1 GW of installed capacity. This is forecast to reach 5.2 GW by the end of 2024, with a CAGR of cumulative installed capacity of 26% between 2020 and 2024. Between 2020 and 2024, the annual installed capacity is forecast to be between 380 MW and 1.3 GW. The majority of the forecast capacity to 2024 will come from the build out of the Borssele zone.

Projects that are expected to contribute to the forecast installed capacity in this period include: Borssele 1 & 2, Borssele 3 & 4, Borssele 5 (Leeghwater Demonstration), Hollandse Kust Zuid Holland I and II and Fryslan.

![Figure 41 Forecast installed capacity in the Netherlands.](source)

![Figure 42 Forecast demand for turbines in the Netherlands.](source)

**Regulation**

- The Ministerie van Economische Zaken (Ministry of Economic Affairs) determines where offshore wind projects should be located. It awards offshore wind projects to developers through competitive tenders. The Government completes preliminary environmental investigations. The Rijksdienst voor Ondernemend Nederland (Netherlands Enterprise Agency (RVO.nl)), an agency of the Netherlands government, completes preliminary environmental investigations, publishes preliminary environmental data and gives final planning consent to build the wind farm.

- For tenders between 2015 and 2019, the Government reserved a maximum of €18 billion for renewable energy subsidies payable over 15 years for projects awarded in period. A maximum price is also set for each wind farm site. The tender is awarded to the lowest price bidder, which must be equal to or lower than the maximum price. The winning developer secures a contract for difference (CfD) subsidy for 15 years, consent to build the wind farm and a 30-year operating licence from RVO.nl.

- In 2016, Borssele 1 and 2 (700 MW) was secured by Ørsted at a contract price of €72.7/MWh and Borssele 3 and 4 (680 MW) was secured by a consortium of Shell, Van Oord Offshore Wind Projects, Eneco and Mitsubishi/DGE at a contract price of €54.5/MWh. These prices exclude transmission.

- On 19 March 2018, the Minister of Economic Affairs and Climate Policy issued permits for Hollandse Kust Zuid Wind Farm Zone Sites I and II (with a total of up to 760 MW of capacity) to Chinook CV, a subsidiary of Nuon/Vattenfall. The new wind farm should be ready in 2022 or 2023, and it will be the first in the world to be constructed with zero-subsidy (excluding transmission). It was awarded through a pre-auction competition open only those willing to bid at zero-subsidy, based on a range of non-PPA-related criteria.

- For the Hollandse Kust Zuid Wind Farm Zone Sites III and IV, tendered in H1 2019, the Ministerie van Economische Zaken (Ministry of Economic Affairs) adjusted the tender rules to reduce the risk of appeals. The aim of this was to keep the Netherlands to the rhythm of one tender per year to keep risk in the supply chain can to a minimum. Submissions are assessed on environmental criteria, expected energy production and price paid as ground rent. Vattenfall won the tender for the Hollandse Kust Zuid Wind Farm Zone Sites III and IV and will pay approximately €2 million/year in ground rent.
In 2014, the Ministry of Economic Affairs appointed TenneT as the transmission system operator (TSO).

**Capital and operational expenditure**

- Expenditure across all supply chain activities in 2024 is estimated to be €2.5 billion. The dip in the spend in the middle of the period is due to the project build schedule.
- Total expenditure between 2020 and 2024 is estimated to be €12.0 billion, and
- It is expected that 86% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX and that 14% will be spent on OPEX.

**Owners**

- Despite the entry of Vattenfall and Ørsted, the Netherlands is unlike other European markets, such as the UK and Germany, where major energy utilities dominate the ownership of projects. This market has a greater number of independent power producers, such as Northland Power, and independent energy companies, such as Eneco, making up the top 10 owners.
- Northland Power has the largest operating portfolio, courtesy of its 60% share in the 600 MW Gemini project. Eneco also has a large operating portfolio from owning Prinses Amaliawindpark and Eneco Luchterduinen.
- Vattenfall and Ørsted both have over double the total portfolio of Northland Power, the owner with the third largest total portfolio. Ørsted was successful in its tender bid for the Borssele 1 and Borssele 2 projects due to be commissioned in 2020. Vattenfall was successful in the tenders for Hollandse Kust Zuid Holland I & II and Hollandse Kust Zuid Holland III & IV, due to be commissioned in 2023.
Vattenfall is an energy utility headquartered in Sweden. It owns Hollandse Kust Zuid Holland I & II and III & IV projects.

Ørsted is an energy utility headquartered in Denmark. It owns the Borssele 1 and 2 projects.

Northland Power is an independent power producer and specialist developer headquartered in Canada. It typically invests in projects once consent is awarded. It has shares in the Gemini projects.

Partners Group is a global private market investment manager with headquarters in Switzerland. It owns a share in the Borssele 3 & 4 projects.

Ventolines BV is a specialist developer headquartered in the Netherlands. It has shares in the Fryslân project.

Supply chain

Bladt Industries is a manufacturer of offshore steel structures. Its primary activities in the offshore wind industry are the manufacture of steel foundations and manufacture of substation jackets and topsides. Bladt Industries supplied transition pieces for the Gemini project and will supply some of the transition pieces for Borssele 1 & 2.

Boskalis is a vessel owner and operator. Its primary activity in the offshore wind industry is the installation of foundations, export and array cables. It provided cable installation for the operating Gemini and Westermeerwind projects. With NKT Cables, it has been awarded export cable installation for the Borssele 1 & 2 and 3 & 4 projects.

EEW is a manufacturer of steel tubular structures. Its primary activity in the offshore wind industry is the production of monopile foundations, and tubulars and pin piles for jacket foundations. EEW supplied monopile foundations for the Gemini project and will supply foundations and transition pieces for Borssele 1 & 2.

ENGIE Fabricom is a construction contractor and part of the ENGIE group. Its primary activity in the offshore wind industry is the assembly of offshore HVAC substation topsides. Fabricom provided substation topsides for the Gemini and Eneco Luchterduinen projects.

HSM Offshore is part of the Andus Group and manufacturers offshore substation topsides, offshore substation jacket foundations and oil and gas structures. It has been contracted to supply the offshore substation foundation and topside for the Borssele 1 & 2 and 3 & 4 projects.

LS Cable and System is a supplier of power and communication cables. In the offshore wind industry, it has only supplied export cable. LS Cable provided export cables for the Eneco Luchterduinen project.

MHI Vestas Offshore Wind (MVOW) is the global number two supplier of offshore wind turbines by total installed capacity. It is a JV formed in April 2014 between Mitsubishi Heavy Industries and Vestas. Most of its production facilities are in Denmark and it operates a UK blade factory. MVOW provided turbines for three operational projects and will supply to the Borselle 3 and 4 projects.
### Global offshore wind market report, 2019

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<tr>
<td><strong>Prysmian</strong></td>
<td>a supplier of power and communication cables. Its primary activities in the offshore wind industry are the supply and installation of export and array cables. It acquired its US rival, General Cable in December 2017 including the subsidiary NSW. Prysmian supplied array and export cable to the Westermeerwind project. NSW provided array cables to the Gemini project. Prysmian will supply array cable to the Borssele 3 &amp; 4 projects.</td>
</tr>
<tr>
<td><strong>Scaldis Salvage and Marine (Scaldis)</strong></td>
<td>a marine contractor and heavy lift specialist, operating two sheerleg cranes, Gulliver and Rambiz. Its primary activity in the offshore wind industry is the installation of foundations and offshore substations. Scaldis provided offshore substation installation for the Northwind and Thornton Bank projects. It is a subsidiary of DEME, Jan De Nul and Herbosch-Kiere. Scaldis provided substation installation for the Gemini and Eneco Luchterduinen projects.</td>
</tr>
<tr>
<td><strong>Seaway 7</strong></td>
<td>has two main subsidiaries in offshore wind. <strong>Seaway Heavy Lifting</strong> is an offshore contractor and vessel owner. It is an EPCI contractor. Its primary activity in the offshore wind industry is the installation of foundations and offshore substations. <strong>Seaway Offshore Cables</strong> (previously Siem Offshore Contractors) is subsea contractor and its primary activity in the offshore wind industry is the installation of array and export cables. Seaway Heavy Lifting has been awarded the installation of both the topside and foundations of the substations for the Borssele 1 and 2 and Borssele 3 and 4 projects.</td>
</tr>
<tr>
<td><strong>Siemens Gamesa Renewable Energy</strong></td>
<td>is a leading international manufacturer of onshore and offshore wind turbines. A merger between Siemens and Gamesa obtained EU approval in March 2017 and took effect in April 2017. Siemens Gamesa provided turbines for the Gemini and Westermeerwind projects. Siemens is contracted to supply turbines to Borssele 1 &amp; 2, Fryslan and Hollandse Kust Zuid Holland 1 &amp; 2 projects.</td>
</tr>
<tr>
<td><strong>Siemens Power Transmission</strong></td>
<td>a group of Siemens Energy, offers EPC contracts for the supply and installation of substations and grid connection services. Siemens will provide substation electricals for Borssele 1, 2, 3 and 4 projects.</td>
</tr>
<tr>
<td><strong>Sif Group</strong></td>
<td>a manufacturer of steel tubular structures. Its primary activity in the offshore wind industry is the production of monopile foundations and pin piles for jacket foundations. Sif Group has supplied monopile foundations for five Dutch projects and will supply monopiles for the Borssele 1, 2, 3 and 4 projects.</td>
</tr>
<tr>
<td><strong>TenneT</strong></td>
<td>the Dutch TSO headquartered in Arnhem, the Netherlands. It is also one of four German TSOs. TenneT is the largest of the German TSO's and since 2006, has been the TSO responsible for offshore wind farms constructed in the North Sea. By 2025, TenneT will tender for five offshore substations for the Borssele and Noord and Zuid Holland projects. Each offshore substation has a capacity of 700 MW. Contracts for Borssele Alpha grid connection were awarded in 2016, and in 2017, it signed a grid connection agreement with Ørsted as the owner of the Borssele 1 &amp; 2 wind farms. In late 2017, TenneT announced contract awards for the Borssele Beta grid connection.</td>
</tr>
<tr>
<td><strong>Van Oord</strong></td>
<td>a Netherlands dredging and marine contractor. Its primary activity in the offshore wind market is the installation of turbines, foundations, and export and array cables. It recently acquired MPI Offshore from the Vroon Group. MPI Offshore pioneered the development of specialist offshore turbine installation vessels and now operates a fleet of two offshore installation vessels and a heavy-lift installation vessel. Van Oord also invests in projects and, in December 2016, it won the tender for the Borssele 3 and 4 projects as part of a consortium with Shell, Eneco and Diamond Generating Europe (Mitsubishi Corporation). Van Oord will provide turbine and array cable installation services to Borssele 3 &amp; 4.</td>
</tr>
</tbody>
</table>
4.6 France

Market size and turbine demand

At the end of 2019, France had only 2 MW of installed capacity in the form of Ideol’s floatgen prototype project. Now that the round 1 and 2 price renegotiation has resolved the fate of six 500 MW projects, we forecast installed capacity will reach 3 GW by the end of 2024. The CAGR of cumulative installed capacity between 2020 and 2024 is 178%. In this period, the annual installed capacity is forecast to grow rapidly from 48 MW to 1 GW.

The majority of the forecast capacity to 2024 will come from bottom fixed projects located in the English Channel and the Bay of Biscay. Much smaller capacity floating demonstration projects will also be built in the Mediterranean Sea and south of Brittany.

- We expect all six of the round 1 and 2 bottom-fixed projects to be installed between 2021 and 2024, these are: Saint-Nazaire, Fécamp, Calvados, Saint-Brieuc, Dieppe le Tréport and Yeu-Noirmoutiers.
- Floating tender (2015) demonstration projects which we expect to be built in this period include: Golfe du Lion, Groix & Belle-Île, Gruissan and Provence Grand Large.

Regulation

Six 500 MW Projects were awarded in France’s offshore rounds 1 and 2 in 2012 and 2014 through a tender process based on a project’s price, technical value, industrial plan, environmental performance and existing activities. As market prices have fallen in the last few years, the French government launched a re-negotiation of the prices in spring 2018. This resulted in an agreement between the government and the consortium EDF Energies Nouvelles - Enbridge - WPD to reduce the project prices from €200/MWh to €150/MWh. It is not expected to impact the original contracts in place with suppliers as the reduction in costs is seen as an act of goodwill by the developers towards the government. A number of legal recourses have been rejected, including at the EU level, and the first EDF Energies Nouvelles project should reach FID during H2 2019.

A new competitive tendering procedure was introduced in 2016. Applicants are pre-selected based on their technical and financial capabilities.

- The Energy Ministry, the Direction Générale de l’Energie et du Climat (DGEC), shortlists bidders and notifies the Commission de régulation de l’énergie (CRE), the independent body in charge of advising and quoting the tender submissions.
- The applicants are then invited to submit their final offer to CRE. The assessment criteria are confidential but are thought to include project profitability, project rated capacity and planning constraint optimization, environmental impact, supply chain plan and investment strategy. The applicants are selected by the Minister according to CRE criteria and granted a feed-in tariff for 20 years.
- The developer is not guaranteed an offshore wind lease, even if it wins the tendering procedure. The leasing for offshore wind is granted by the local prefect after consultations with the local authorities and a public debate procedure monitored.
by the Commission Nationale du Débat Public (CNDP). Offshore wind leases are given for a maximum of 30 years. In addition to the lease, an environment authorisation is necessary, delivered following the submission of initial state studies and environmental follow-up plan.

For offshore grid connections the DGEC consults with the shortlisted applicant, the CRE, Réseau de Transport d’Electricité (RTE, the French TSO) and other stakeholders in order to refine the requirements for proposed site as well as tailoring the specifications of the tender through competitive dialogue. From Dunkerque onwards, RTE will build and operate the grid connection for offshore wind projects, including the offshore substation.

In January 2018, the results from a working group led by the Ministry of Environment were announced, to accelerate the development of wind energy in France, both onshore and offshore. A key decision made was the reduction of recourses at the appeal level, which reduces the appeal options and time spent in courts.

Under the new procedure, the round 3 Dunkerque project in the North Sea was awarded in June 2019 to EDF with Innogy and Enbridge, for a capacity of 600 MW at 44€/MWh price (without offshore substation and grid connection).

A simplified tender process is expected for the tender for the Parc éolien en mer d’Oléron project and a capacity of 1 GW in the English Channel, with a single consenting body.

750 MW floating offshore capacity will be allocated through 3 projects of 250 MW in Brittany, Occitanie and Provence-Côte d’Azur. The first tender is being prepared for Brittany, expected to be awarded in 2021.

Across all forms of offshore wind energy, the Environment Minister recently announced a plan leading to the installation of 1 GW yearly in France after 2024.

### Capital and operational expenditure

- Expenditure across all supply chain activities in 2024 is estimated to be €2.5 billion
- Total expenditure between 2020 and 2024 is estimated to be €9.4 million, and
- It is expected that 96% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX, and that 4% will be spent on OPEX.

![Figure 48 Estimate of expenditure in France.](source: BVG Associates)

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**Owners**
• Projects identified by the government have not yet been leased to developers and are considered as ‘Out to tender’. This includes the Oléron project.

• The only operating project is the 2 MW Floatgen pilot project, with seven JV members. The project is being managed by IDEOL.

• In France, developers have formed consortiums, including EDF Energies Nouvelles and Enbridge to form Eolien Maritime France; Engie, EDP Renováveis (EDPR) and Caisse des Dépôts in Les Eoliennes en mer; and Eole RES and Caisse des Dépôts to form Avel Vor.

**EDF Energies Nouvelles** is EDF’s subsidiary for renewables. EDF is an energy utility and electricity operator headquartered in France. It is 85% state-owned. EDF Energies Nouvelles has a share in the Parc éolien en Mer du Calvados, Parc éolien en Mer des Hautes Falaises, Parc éolien en Mer de Saint-Nazaire, Fecamp and Dunkerque projects, and in the floating pilot project Provence Grand Large.

**Enbridge** is an energy utility headquartered in Canada. It has a share in the Parc éolien en Mer du Calvados, Parc éolien en Mer des Hautes Falaises, Parc éolien en mer de Fécamp and Dunkerque and Parc éolien en Mer de Saint-Nazaire projects.

**Iberdola** is an energy utility headquartered in Spain. It has a share in the Projet éolien en mer de la Baie de Saint-Brieuc.

**Engie** is an energy utility headquartered in France. It has a share in the Les éoliennes flottantes du Golfe du Lion, Les éoliennes en Mer Dieppe - Le Tréport and Les éoliennes en Mer Iles d’Yeu et de Noirmoutier.

**EDP Renováveis (EDPR)** is headquartered in Spain. In a partnership with Engie, it has a share in the Les éoliennes flottantes du Golfe du Lion, Les éoliennes en Mer Dieppe - Le Tréport and Les éoliennes en Mer Iles d’Yeu et de Noirmoutier.
Regarding floating, four floating demonstration projects, each 24 MW, have received consent and are being developed:

- **EDF Energies Nouvelles**'s project Provence Grand Large is located near Faraman. It will install three Siemens SWT-8.0-154 turbines supported by SBM Offshore/IFPEN designed tension-leg platforms.
- **Engie** and **EDPR**'s project Golfe du Lion is located near Leucate. It will use a floating semi-submersible platform, developed by Eiffage and install four Haliade 150 m diameter, 6 MW turbines.
- **EOLFI**'s project Groix & Belle-Île is located near Groix. It will use a semi-submersible platform developed by (DCNS SEAReed) and will install four Haliade 150 m diameter, 6 MW turbines.
- **Quadran**’s Grussian project, the Eolmed consortium is located near Gruissan. It will use a semi-submersible platform developed by IDEOL Damping Pool and install four Senvion 6.2M152 turbines.

### Supply chain

**Bouygues** is a major civil engineering company headquartered in France. It manufactured the floating foundation for the Floatgen project and will manufacture the floating foundations for the Gruissan project.

**GE Renewable Energy** is a supplier of offshore wind turbines. In 2015, GE acquired the power and grid divisions of Alstom. In 2016, GE acquired blade manufacturer LM Wind Power. GE has secured a significant pipeline of 1.5 GW of French capacity in partnership with the consortium EDF Energies Nouvelles, Enbridge (taking over from Ørsted and WPD offshore). It has built a nacelle assembly facility in Saint-Nazaire and has built a blade manufacturing facility (LM Wind Power) in Cherbourg. It will supply the Parc éolien de Groix & Belle-Île and Parc éolien en mer de Saint-Nazaire projects.

**Ideol** is a supplier of floating foundations and supplied the floating foundations for Floatgen. It is developing a floating substation concept as well.

**Naval Group** is an industrial group specialising in naval defence and marine renewable energy headquartered in France. It will supply the foundations for the Les éoliennes flottantes de Groix & Belle-Île project.

**Prysmian** is a supplier of power and communication cables. Its primary activities in the offshore wind industry are the supply and installation of export and array cables. It acquired its US rival, General Cable in December 2017 including the subsidiary NSW. Prysmian has been contracted to supply the Eoliennes Offshore du Calvados, Eoliennes Offshore des Hautes Falaises and Parc du Banc de Guérande project.

**Réseau de transport d’électricité (RTE)** is the French TSO. It was founded in 2000 to operate and develop the French transmission system. In September 2005, RTE became a subsidiary of the EDF Group, and its code of conduct is monitored by the CRE.

**Senvion (formerly REpower)** is a supplier of offshore wind turbines. In early 2019 Senvion filed for self-administration and is currently thought to be looking for buyers. It is therefore unlikely that its ambitions to develop a 10 MW offshore platform will be realised as planned last year. Senvion has been contracted to supply the Gruissan project (24 MW).

**Siemens Gamesa Renewable Energy** is a leading international manufacturer of onshore and offshore wind turbines. A merger between Siemens and Gamesa obtained EU approval in March 2017 and took effect in April 2017. It then integrated Adwen, a 50/50 JV between Areva and Gamesa. The company’s current focus in the French market is a 1.5 GW partnership with Engie, EDPR, Iberdrola and EOLE-RES. The plans involve an assembly plant and a blade plant in Le Havre. It has been contracted to supply the Parc éolien en mer de la Baie de Saint-Brieuc, Parc éolien en mer de Dieppe - Le Tréport, Parc éolien en mer des îles d’Yeu and de Noirmoutier projects as well as the Provence Grand Large floating project.
5 Asia-Pacific

Market size

At the end of 2019, Asia-Pacific is expected to have about 7.1 GW of total installed offshore wind capacity. The current forecast shows a significant increase in capacity, to approx. 36 GW by 2024, with a CAGR of cumulative installed capacity of 34% between 2020 and 2024. Between 2020 and 2024, the annual installed capacity is forecast to be between from 4.3 GW to 8.5 GW, with an average of 5.9 GW per year.

China will contribute the most installed capacity to the region by the end of 2024, with 71% of the market share. The Chinese market will be driven in the short term by developers seeking to install projects before the end of 2021 to receive FIT contracts.

Other countries we expect to play a growing role in the market to 2024 include Taiwan, South Korea, and Japan.

From 2022, India and Vietnam will join Asia-Pacific’s key markets. Thailand, Singapore, and Bangladesh have offshore ambitions but no specific project pipelines yet. These countries are expected to become more active from 2025.

Expenditure and levelised cost of energy

There are a variety of factors driving the use of offshore wind in Asia-Pacific. For China, it is the high demand for clean power from East Coast population centres and a lack of suitable onshore wind sites. For Japan, South Korea, and Taiwan, the phase-out of nuclear generation is a catalyst for offshore wind development. At this early stage of market growth, LCOE reduction efforts are increasing, taking a cue from Europe. In August 2019, China Energy Investment Corporation’s (CHN Energy) China Longyuan bid for as low as CNY 620 (€83)/MWh, in China’s maiden competitive auction to include price, for the 200MW Fengxian Phase 1 offshore wind project in Hangzhou bay off Shanghai Province.

The region has difficult conditions (typhoons and earthquakes (and resulting tsunamis) in parts of China, Japan and Taiwan), river delta seabed sediment movement (China), deep water (for example, Japan) and soft seabed (for example, West Coast of South Korea). Different technologies are needed across Asia-Pacific, meaning that learning, equipment and infrastructure for manufacturing and installation cannot readily be shared across the region. Political considerations are also expected to keep the Chinese market largely independent from the rest of Asia-Pacific.

China has well established supply chains for onshore (and now offshore) wind turbine production; Japan and South Korea have some activity. As Asia-Pacific has had 20% of the global installed volume to the end of 2018, versus 80% for Europe, its supply chain is less mature and has less capacity.

- China is ahead, with both local supply and European-designed offshore turbines (notably by Siemens Gamesa) produced under licence in China, the latter account for a notable share of the installed capacity.
- South Korea has one domestic offshore wind turbine producer, although the entry of European developers such as Equinor is expected to provide an opportunity for European suppliers.
- Japan’s remaining offshore wind turbine manufacturer announced January 2019 that it will discontinue production, though Mitsubishi Heavy Industries is a joint venture partner in MHI Vestas Offshore Wind (MVOW).
- Taiwan has no wind turbine suppliers. SGRE and MHI Vestas expected to dominate and set up local nacelle assembly (most likely SGRE) as FIDs are made.

All Asia-Pacific markets are expected to require significant local component supply. European turbine suppliers will face pressure to localise at least tower and blade production. The balance of plant and logistics supply chains are generally less developed than in Europe, with European expertise increasingly being brought in for both the capital and operating phases of
early projects in several countries. In particular, the Asia-Pacific supply chain is only now investing in purpose-designed vessels and crew training. Over time, we expect significant local capability to establish in many areas.

In general, the operational offshore wind projects are smaller than in Europe, reducing the economies of scale.

Expenditure across all supply chain activities in 2024 is estimated to be €20.5 billion.

Total expenditure between 2020 and 2024 is estimated to be €77 billion.

It is expected that 91% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX and that 9% will be spent on OPEX.

Figure 52 Estimated contribution to LCOE for a project installed in 2022 in Asia-Pacific.

Source: BVG Associates and Panticon

Historical contracting

Most of the installed capacity in Asia-Pacific resides in China. Japan, South Korea, Vietnam, and Taiwan have only small-scale offshore wind farms. Meaningful commercial-scale historical contracting for the Asia-Pacific region is therefore only available for China.

For the other countries in Asia-Pacific, the future contracting will evolve as each country develops its own plans to move from higher initial proportions of imports towards more localised supply chains.

In China, the first two offshore wind farms with an international developer minority shareholding have just been announced in the 51%-49% JV between CHN Energy and EDF. Along with other developments in China, this signifies China is getting...
ready to open its offshore wind supply chain more up to international companies in order to speed up the implementation of the ambitious offshore wind deployment targets of China.

In Taiwan, explicit localisation requirements have been defined by the government and form part of the process to award different offshore wind zones of potential seabed areas to local as well as international developers. Therefore, the contracting is expected to vary and on the part of the international developers, their usual contracting methods are expected to continue with an increased degree of local supplier content.

In South Korea, the offshore wind market has traditionally been dominated by local firms, often associated with national grid operator and power utility KEPCO. The market is now starting to open up for international developers as well and it is expected that contracting structures will evolve as a result.

In Japan, no localisation requirements exist for the supply chain and it is expected that a significant number of the offshore wind components will be imported. International developers are developing projects with local Japanese firms to progress the offshore wind development pipeline as the Japanese legislative environment for offshore wind is maturing. Japanese companies are ramping up to be part of the knowledge-heavy part of the offshore wind farm project development process as well as other tasks such as logistics, port operations, installation, and commissioning.

So far, most projects in Asia-Pacific have been near-shore and only a few projects in China have included an offshore substation. In general, the transmission assets are constructed and operated by the developers.

Due to the relatively small size of the Asia-Pacific operating market, the contracting approach for OMS is still emerging and will depend on the business model of the owner and the wind turbine manufacturer used on the project.
5.1 China

Market size and turbine demand

At the end of 2019, China is expected to have 6.7 GW of installed capacity. This is forecast to reach 25.7 GW by 2024, making China the global leader by installed capacity, with a CAGR of cumulative installed capacity of 28% between 2020 and 2024. Between 2020 and 2024, the annual installed capacity is expected to be between 3 GW and 4.8 GW.

Offshore wind farms will be constructed along the East Coast of China. These can be split into three areas: the Yellow Sea to the north (lowest wind speeds), the East China Sea in the central part of China (medium wind speeds), and the South China Sea and Strait of China/Taiwan to the south (highest wind speeds). Early projects were built near-shore and in river deltas (for example, the Yellow, Yangtze, and Pearl rivers). Future projects currently in development are typically located further offshore, although many would still be considered near-shore projects compared to European projects.

Projects expected to contribute to the forecast installed capacity in this period include, 300 MW Huadian Yuhuan Offshore Wind Farm, 300 MW Three Gorges New Energy Guangdong Shantou Nanao Yangdong, 200 MW Rudong H1-2, 312 MW Fujian Putian City Flat Bay Three (Zone C), 300 MW CTGNE Yangjiang Shapa - Phase III - A1, 100 MW CTGNE Yangjiang Shapa - Phase III - A2, 100 MW CSIC Jiangsu Rudong H3-2 100 MW, 300 MW SPIC Binhai South H3 #, 200 MW Shicheng Fishing Port, 400 MW CGN Huizhou, 200 MW Zhanjiang Wailuo 200 MW - Phase 2, 500 MW Houhu, 300 MW Laoting Yuetuo Island Demonstration (Tangshan - Area 3), 300 MW Huadian Fujian Fujian Strait offshore wind farm project, 100 MW Huadian Caofeidian - Phase 1, 300 MW Zhejiang Jiaxing Jiaxing 1, 300 MW Zhejiang Jiaxing Jiaxing 2, 300 MW Three Gorges Shandong Changyi Laizhou Bay - Phase 1 and 402 MW Liuao Area D.

Regulation

In November 2016, the National Energy Administration (NEA) issued the Wind Power Development Planning targets as part of the 13th Five Year Plan. The plan had a 2020 target for China to have 5 GW offshore wind in operation and another 10 GW in development. To obtain consents to build additional fossil fuel and nuclear power plants, Chinese utilities must develop renewable energy projects.

The consenting process is complicated with many consents required at national, provincial, and county/municipality level. The NEA manages the consenting process at national level. At provincial and country/municipality levels, additional consents are needed from various authorities and state-owned enterprises (SOEs).

The national offshore wind feed-in tariff (FIT) of CNY 750 (€95)/MWh to CNY 850 (€108)/MWh was introduced in June 2014 in the 12th Five Year Plan period. Provincial or municipality FIT top-ups can also be provided to owners. Initially, 44 projects (with a total potential capacity of 10.5 GW) met the FIT criteria although this did not guarantee the approval of consents or permits at province and city level. Additional projects could still apply to receive FITs from the NEA.

Partly to overcome the complicated consenting procedures, the NEA unveiled a new policy in May 2018 – the 2018 Wind Farm Construction and Management Rules. Starting in 2019, onshore and offshore projects compete on price and gain government approval in auctions. Offshore wind projects approved before the end of 2018 and commissioned before end of 2021 can receive the CNY 850 (€108)/MWh FIT. Offshore wind projects approved in 2019 and 2020 receive FIT’s with a new
ceiling of CNY 800 (€101)/MWh and 750 (€108)/MWh, respectively. This policy development led to the recent approval of 40 GW worth of offshore projects in the provinces of Guangdong, Jiangsu, Fujian, Zhejiang, and Shandong.

China aims to localise the supply chain at provincial and country/municipality level in order to create opportunities for Chinese companies. The key companies within offshore wind in China are SOEs overseen either centrally (CSOEs)\(^2\) by the state-owned Assets Supervision and Administration Commission of the State Council (SASAC) or locally (LSOEs) at provincial or country/municipality level.

The grid is divided into six major geographical areas controlled by two CSOEs: State Grid Corporation of China (which is the TSO for five of the geographical areas) and China Southern Power Grid (which is the TSO for one of the geographical areas). For each individual offshore wind project, the transmission assets including the offshore substation are constructed and operated by the developer.

The developer builds the offshore and onshore transmission and connects it into the grid through an agreement with State Grid Corporative of China or China Southern Power.

### The role of the design institutes

Any type of construction in China, including offshore wind farms, must be signed off by a design institute. Design institutes can be either civil or industrial. The former are either privately or state-owned while the latter are generally state-owned.

A portion of the more than 2,000 design institutes in China specialise in offshore constructions, some are further specialised in power generation and a few are ultimately owned by major offshore wind developers. A subset of the design institutes has so far been involved in offshore wind. The design institutes cover different types of construction projects and geographical areas and this guides what they do and who makes use of their services for what part of the offshore wind deployment in China.

Design institutes generally work at two levels. They work nationally at a zoning level for the NEA. They also work on projects, where they address offshore wind farm lay-out, overall project design, and yield calculations.

In the earlier offshore wind farm projects in China, developers had to team up with a construction company, a turbine manufacturer, and a design institute to be eligible to submit a bid for an offshore wind farm project. The design institutes played an important role as certification of wind turbines and balance of plant components were not a government requirement at that time.

For the early offshore wind farm projects in China, design institutes, in some instances, took on a broader role than just design, and this also included procurement, contracting, and in some cases EPCI functions. This depended very much on the experience available with the developer and the scope and scale of the design institute operations, some of which have EPCI capabilities.

In June 2017, in an attempt to create certification standards in China, DNV GL was brought in through a project by the World Bank alongside East China Investigation and Design Institute (ECIDI) and the China Renewable Energy Engineering Institute (CREEI).

China has struggled to transfer its onshore wind success to offshore wind development. This challenge will increase as offshore wind development expands beyond Jiangsu province and as offshore wind development extends further from shore. At the same time, leading power generation CSOEs without prior offshore wind experience are diversifying into offshore wind. These four factors have compelled leading Chinese offshore players to gradually invite international partners to take on similar tasks as the design institutes.

- In June 2013, Sgurr Energy worked alongside GEDI on the Zhuhai offshore wind farm project in Guangdong province and prior to that, Sgurr Energy worked on a project in Jiangsu province as part of a World Bank program.
- PowerChina Huadong Engineering Corporation (HDEC), a design institute, brought in Denmark-based Ramboll to design SPIC’s 400 MW Binhai North Phase 2 offshore wind project, becoming the first non-Chinese company to do so.
- Atkins (part of SNC Lavalin) was brought in by HDEC to design the offshore substation platform at SPIC’s 300 MW Binhai South Phase 3 offshore wind farm.

\(^2\) Central SOE’s are controlled directly by the Communist party in Beijing through the State-owned Assets Supervision and Administration Commission (SASAC) special commission of the State Council
In September 2018, HDEC brought in DNV GL to support the feasibility study of a 1.1 GW far offshore wind farm supported by China’s first VSC HVDC converter station in the Jiangsu province.

Examples of design institutes and tasks carried out are:

- CTG-owned Shanghai Investigation, Design & Research Institute (SIDRI) designed the foundations for the Donghai Bridge demonstration project and chose CCCC Third Harbour Engineering to do the fabrication and installation. SIDRI was also responsible for overseeing the construction and installation processes for the wind turbines of the project.
- HDEC performed the design of the important early Rudong Intertidal Test Wind Farm project foundations on behalf of Longyuan (part of CHN Energy) and chose Nantong Ocean Water Conservancy Engineering and Longyuan Zhenhua to fabricate and install.
- The General Institute of Water Resources and Hydropower Planning and Design (GIWP) design institute under the Ministry of Water Resources worked with NEA on the 2014 legislation within the 12th five-year plan to organise the zoning of the 44 offshore wind farm projects to receive the FIT implemented then.
- China Energy Engineering Group Guangdong Electric Power Design Institute Co. (GEDI) started working with the Guangdong Energy Group (then Guangdong Yudean) on the Wailuo Offshore Wind Farm (also referred to as Zhanjiang offshore wind farm or Zhanjian Wailuo offshore wind farm) in 2012 and GEDI ultimately became the EPCi for the project, Construction started in April 2018.

In June 2018, France’s marine energy engineering specialist INNOSEA Shanghai Investigation signed a MoU with China’s Design & Research Institute (SIDRI) to conduct joint research on offshore wind metocean surveys.

### Capital and operational expenditure

- Expenditure across all supply chain activities in 2024 is estimated to be €10.4 billion
- Expenditure between 2020 and 2024 is estimated to be €44.4 billion and
- It is expected that 89% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX and that 11% will be spent on OPEX.

![Figure 56 Estimated expenditure for China.](image)
All of the top five owners and eight of the top 10 owners in China are CSOEs. In general, the CSOEs create renewable energy subsidiaries that are listed in different stock exchange domains.

In China, multi-contracting is preferred by developers such as China Energy Investment Corporation Limited’s (CHN Energy which includes China Longyuan), State Power Investment Corporation (SPIC), China General Nuclear Group (CGN), China Three Gorges (CTG), and China Huaneng Group.

The developers lead the development, design, procurement and project management, with mostly in-house teams. To gain in-house experience, the large developers tend to award a greater number of individual contracts than is seen in a typical multi-contracting set-up in Europe. Leading Chinese developers typically manage the turbine installation scope instead of the turbine wind turbine manufacturer. They often contract with companies that are capable of delivering EPCI contracts, although the companies are not required to deliver an EPCI scope.

A significant degree of government involvement in projects is coupled with support from major conglomerates, for example, the JV between the state-owned Longyuan (CHN Energy) with the state-owned CCCC subsidiary ZPMC. Most contracts to date have been awarded to domestic suppliers. Emerging provincial markets with ambitious offshore targets, such as Guangdong, Fujian and Shandong, are expected to be more open to collaboration with international suppliers than more established provinces such as Jiangsu. Indeed, the 40 GW projects approved in 2018, which need to be commissioned by 2021 to qualify for the most favourable FIT, can only be realised with international collaboration.

Several wind turbine manufacturers are expanding their scope, most notably Envision, Shanghai Electric, and Ming Yang. All are in the process of becoming developers of offshore wind farms. In addition, these three turbine manufacturers, as well as Goldwind, have research and development centres in Europe.

Note that the definition of “post-FID” may be used slightly differently in China to Europe. For example, in the case of Shanghai Electric, a 9.5 GW commitment was received from a county in Guangdong in exchange for SE putting up a nacelle factory there, which has been widely reported a “Post-FID”. Rather than second guess every project we have stuck with the commonly reported project statuses which should be comparable within China.

The 5 largest owners are profiled in sections 5.1.1 to 5.1.5, the next 5 largest owners are briefly profiled below

**Shanghai Electric Group Co.** is engaged in design, manufacture and distribution of electric power and industrial equipment. Its main business segment is new energy, including the manufacture and sale of wind turbines and components and nuclear
power equipment. It mainly operates its businesses in domestic and overseas markets. It is listed on the Hong Kong Stock Exchange and the Shanghai Stock Exchange.

Shanghai Electric Group Co. has 34 wholly- and partially owned subsidiaries, including:

- Shanghai Electric Group Shanghai Electric Machinery Co. (100%): production and sale of turbine generators and spare parts
- Shanghai Electric Wind Power Group Co. (100%): production and sale of wind power equipment, spare parts and provision of after-sales service
- Shanghai Electric Wind Power Yunnan Co. (100%): production, installation and sale of wind generating set (for more on this, see the entry for Shanhai Electric under Supply Chain)

For the 2018 financial year, Shanghai Electric Group Co.’s revenue and profit before tax were RMB 101.1 billion (€12.8 billion) and RMB 6 billion (€ 0.8 billion), respectively.

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<td>is a CSOE managed by SASAC and is mainly engaged in power generation and the sales of electricity. It operates through four segments, including the development, investment, construction and management of wind power and other renewable energy sources.</td>
<td>has two key wind power generation related subsidiaries: Huadian Fuxin Energy Corporation (Huadian Fuxin) and Huadian Power International Corporation (Huadian Power), in which it owns stakes of 59.6% and 46.8%, respectively.</td>
<td>, in February 2019, is the largest power generation company in Guangdong province. It is owned by the People’s Government of Guangdong Province (76%) and China Huaneng Group (24%).</td>
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<td>China Datang Corporation Renewable Power Co., formerly Datang Chifeng Saihanba Wind Power Generation Co., was established in September 2004 and renamed in March 2009. It was listed on the Hong Kong Stock Exchange on 17 December 2010. It’s controlling shareholder, China Datang Group Corporation, has a 65.61% stake in the company. As of 31 December 2018, its consolidated installed capacity amounted to 9 GW, including 8.8 GW of wind power installed capacity. It has 108 subsidiaries, including 33 wind energy related subsidiaries such as Datang Guoxin Binhai Offshore Wind Power Generation Co. For the 2018 financial year, it’s revenue and profit before tax was RMB 8.3 billion (€1.1 billion) and RMB 1.7 billion (€0.2 billion), respectively.</td>
<td>Huadian Fuxin is a Hong Kong-based investment holding company principally engaged in the generation and sales of power. It is listed on the Hong Kong Stock Exchange. Huadian Fuxin operates through six segments, including the Wind Power segment which constructs, manages and operates wind power plants and generates electric power. As at 31 December 2018, Huadian Fuxin’s consolidated installed capacity amounted to 16.3 GW, including 8 GW in wind power. For 2018 financial year, Huadian Fuxin’s revenue and operating profit was RMB 18.3 billion (€2.3 billion) and RMB 4.8 billion (€0.6 billion), respectively.</td>
<td>Guangdong Energy Group Co. is active in the wind power generation business via holding company Guangdong Electric Power Development Co. Guangdong Electric Power Development Co.’s key wind power-related subsidiaries include Guangdong Wind Power Generation Co.; and Guangdong Yudean Qujie Wind Power Generation Co., Guangdong Electric Power Development Co., is headquartered in Guangzhou, Guangdong Province and is listed on the Shenzhen Stock Exchange. For the 2018 financial year, Guangdong Electric Power Development Co.’s revenue was RMB 27.4 billion (€3.5 billion).</td>
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China Resources Power Holdings Co. (CR Power) is a Hong Kong-based investment holding company principally engaged in the investment, development and operation of power plants. It operates through three segments, including the renewable energy segment which is engaged in wind power generation and other renewables. As at 31 December 2018, CR Power’s operational generation capacity in wind, gas-fired, hydro-electric and photovoltaic power totalled 7.6 GW or 20% of its total generation capacity. For the 2018 financial year, CR Power’s revenue and profit (attributable to owners) was HK$77 billion (€8.8 billion) and HK$3.95 billion (€0.5 billion) respectively.

Regarding floating offshore wind, this technology will be required if China is to harness the China Sea’s full potential. Three floating offshore wind pilot projects off Guangdong province, developed by CTG, Ming Yang, and CSIC, are progressing with possible deployment in 2021.

The five-turbine Shanghai Deep and Far Sea demonstration project in the Donghai Sea off Shanghai is delayed. The project is developed by Shanghai Green Environmental Energy. It had been set for deployment by 2020. Shanghai Investigation Design & Research Institute, a unit of CTG, is to supply the floating foundation while marine contractor CCCC Third Harbor Engineering Co. is responsible for installation. The turbine supplier has not been revealed, though turbine manufacturers Shanghai Electric, Sinovel, and Envision are linked to the project.

Supply chain

China Communications Construction Corporation (CCCC) is a major state-owned EPCI company. It has installed more than 500 offshore wind turbines in China. Its subsidiary, CCCC Harbour Engineering supplied and installed concrete foundations for the Shanghai Donghai Bridge project. Shanghai Zhenhua Heavy Industries (ZPMC), also a CCCC subsidiary, is a ship builder and manufacturer of towers, monopiles, and transition pieces inside and outside China. ZPMC operates a JV with Longyuan (CHN Energy) called Longyuan Zhenhua to perform marine engineering and logistics tasks and it has built several specialised offshore wind vessels for the Longyuan Zhenhua JV. It supplied foundations for the Longyuan Rudong intertidal and CGN projects in China.

China Ocean Shipping Co. (COSCO), a CSOE, operates a JV for wind turbine installation operations with Belgium’s DEME Offshore, initially via subsidiary GeoSea. With a fleet of multi-purpose project vessels, COSCO is active in the domestic and international ocean transport market of wind energy. COSCO also operates a shipyard division which has built wind turbine installation vessels (WTIVs) for the European offshore wind market. In 2017, DEME Offshore placed an order for a next generation installation vessel with COSCO’s shipyard division and the Orion is expected to be delivered to DEME Offshore by the end of 2019. In May 2018, COSCO received its first order for a WTIV that will serve the Chinese offshore wind market from China Railway Construction Corporation. The jack-up vessel, christened Tiejianfengdian01, was launched in July 2019.

China Shipbuilding Industry Corporation (CSIC) Haizhuang is a shipyard as well as a major supplier of wind turbines. CSIC is a CSOE and is headquartered in Chongqing. Track record includes test wind turbines for China Longyuan (CHN Energy) and CGN. It has been announced that CSIC will now be merged with another major CSOE shipbuilding company, CSSC.

Dongfang Electric Corporation (DEC) is a supplier of wind turbines headquartered in Deyang and is a CSOE. Track record includes test wind turbines for China Longyuan (CHN Energy) and CGN. In August 2019, DEC announced it had developed China’s first 10 MW offshore wind turbine set for installation at a project in Fujian Province.

Envision Energy is a turbine manufacturer headquartered in Shanghai and with key production facilities in Jiangsu Province. It has a significant offshore wind track record, including the China Longyuan (CHN Energy) test offshore wind farms. It installed the second highest offshore wind capacity in China and is moving into the offshore wind farm ownership and development space. Envision has an R&D office in Silkeborg, Denmark.

Jiangsu Hantong Ship Heavy Industry is based in Ligang and has its main manufacturing facility in Nantong. The company specialises in shipbuilding. Jiangsu Hantong supplied foundations for the Longyuan Rudong intertidal project.

Jiangsu Haili Wind Power Equipment Technology is a leading supplier of towers and monopiles.

Jiangsu Hengtong Power Cable Co., is a leading supplier of subsea cables in China with a track record exceeding 500 km.
### Jiangsu Longyuan Zhenhua Marine Engineering

is a JV between China Longyuan (CHN Energy) and ZPMC (part of CCCC). It has installed about 250 offshore wind turbines in China. It provided turbine and foundation installation for the 150 MW Longyuan Rudong intertidal project and delivered EPCI contracts for the 300 MW Huaneng Rudong, CGN Rudong, and Putian Nanri projects.

### Jiangzhongtian Technology Co. (ZTT)

is a leading supplier of subsea cables in China and has been active in offshore wind projects, particularly in Jiangsu Province. Clients include developers CGN, SPIC, and China Huaneng. ZTT entered the European offshore wind market in March 2017 when it won a contract from TenneT to supply and construct a 155kV HVAC grid connection between the 497 MW EnBW Hohe See offshore wind farm and the 900 MW BorWin3 DC grid connection system in the North Sea.

### GE Power Conversion

supplies power converters from its facility in Shanghai. In January 2016, it signed a contract with Shanghai Electric to supply 4 MW Fully Fed LV3 wind converters for Shanghai Electric’s offshore turbines totalling 1 GW. In October 2016, the GE Power Conversion business announced it was to supply its 5 MW medium-voltage (MV) converter based on the MV7000 product platform to XEMC Windpower.

### Goldwind (Xinjiang Goldwind Science & Technology Co.)

is a state-owned turbine manufacturer headquartered in Urumchi with a large presence in Beijing. Its key offshore wind production facilities are in the Jiangsu province. Goldwind has a significant offshore wind track record, including for the China Longyuan (CHN Energy) test offshore wind farm. It set up an R&D office in Denmark in 2016. In 2018, Goldwind installed the third highest annual offshore wind capacity in China. In 2018, it became co-owner, together with CTG, of a 300 MW project under construction in the Jiangsu province.

### Huadian Heavy Industries

is a civil engineering company headquartered in Beijing, China. Its primary businesses include engineering systems design, engineering contracting, and the research, development, design and manufacturing of high-end equipment. Huadian Heavy Industries was incorporated in 2008 and entered the offshore wind industry in 2009. Its EPCI scope in offshore wind spans development, construction and O&M. Huadian Heavy Industries owns various vessel types, including installation and O&M vessels. It has built a collaboration track record with both Chinese design institutes (e.g., PowerChina Huadong Engineering Corporation) and international engineering companies (e.g. Denmark’s Ramboll, Holland’s KCI The Engineers). Huadian Heavy Industries has worked on SPIC’s offshore wind projects and secured an EPCI deal in August 2019 for SPIC’s 300 MW Binhai South H3 off Jiangsu Province. For the 2018 financial year, Huadian Heavy Industries’ revenue and net income were CNY 6 billion (€0.8 billion) and CNY 65.3 million (€8 million), respectively.

### LM Wind Power

headquartered in Denmark, is global leader in supply of blades. It is now owned by US-based GE Renewables and has four Chinese manufacturing plants in China. In November 2016, it signed a strategic collaboration agreement with wind turbine manufacturer CSIC HZ Windpower to deliver blades for CSIC’s newly launched H151-5.0MW offshore wind turbine. In October 2017, LM Wind Power announced it is increasing its Chinese manufacturing capacity following supply deals with Chinese turbine manufacturers Goldwind and Envision.

### Ming Yang Smart Energy

is a turbine manufacturer headquartered in Zhongshan with key manufacturing facilities in the Guangdong province. It has a two-bladed 6 MW prototype turbine installed in the Jiangsu province. It is a strong contender for turbine supply, particularly in the Guangdong province projects. In February 2019, the largest turbine by a Chinese turbine manufacturer, MingYang’s MySE7.25-158 semi-direct drive turbine, was successfully installed in Guangdong province. Ming Yang is moving into co-ownership and development of offshore wind farms in China.

### Orient Cable

is a leading supplier of subsea cables in China with a track record exceeding 300 km.

### Qingdao Hanhe Cable

is headquartered in Qingdao and is a Shenzhen stock exchange listed company in the Hanlan Group. It supplied array cables for Donghail Bridge Phase 1 project.

### Shanghai Electric

is a manufacturer of onshore and offshore wind turbines. It closely collaborates with European companies, notably Siemens Gamesa whose 4 MW offshore platform it has been selling under licence in China. The licence was extended to the 7 MW then 8 MW (SGRE 8.0-167) Siemens Gamesa platforms in December 2017 and March 2018, respectively. Shanghai Electric subsequently launched an 8 MW turbine in August 2019 at its factory in Shantou city, Guangdong province. Shanghai Electric installed the second highest offshore wind capacity globally in 2018, ahead of MOW. In February 2019, Shanghai Electric established a European innovation centre in Aarhus, Denmark. Shanghai Electric is transitioning into offshore wind farm ownership and development in China and has a 9.5 GW pipeline of post-FID projects in Guangdong province.
United Power is a supplier of wind turbines headquartered in Baoding and part of CHN Energy. It has experienced large growth in onshore wind in part due to the Guodian/Longyuan (CHN Energy) affiliation, and its offshore wind track record remains mainly at test site level.
5.1.1 CHN Energy

Profile

China Energy Investment Corporation, also known as China Energy (CHN Energy), is a Central State-Owned Enterprise (CSOE) with headquarters in Beijing. It was formed following the 2017 merger of CSOE China Guodian Group into CSOE China Shenhua Group.3

Renewable energy subsidiaries and affiliates

CHN Energy has 83 first-tier branches and subsidiaries across its seven business areas. Two of CHN Energy’s wind-related subsidiaries, Guodian Power Development Co., (GD Power Development) and China Longyuan Power Group Co., (Longyuan), own and have developed the bulk of the wind energy capacity of CHN Energy via their own subsidiaries. GD Power Development and Longyuan belonged to China Guodian Group prior to the 2017 merger. They are engaged in the design, development, construction, management and operation of onshore as well as offshore wind farms.

Wind-related activities

At end of 2018, CHN Energy ranked the largest owner of installed wind power capacity globally, which totalled 39 GW. This included 38 GW onshore wind, of which 99% is in China and the remainder in North America (100 MW) and Africa (244 MW).

CHN Energy owns a 57.3% stake in Longyuan. Longyuan is partially listed on the Hong Kong Stock Exchange. It is the main wind energy vehicle of the CHN Energy companies. As of the end of 2018, 18 GW onshore wind capacity mainly across 27 provinces in China was attributable to Longyuan, making it a stand-alone global leader followed by SPIC and Iberdrola. Longyuan has developed all wind farm projects in-house so far (including onshore wind farms overseas) via its 74 wind power generation-related subsidiaries.

CHN Energy also owns a 46% stake in GD Power Development, which is not a listed company. CHN Energy and GD Power Development each own 39% stakes in Guodian Technology & Environment Group Corp. (Guodian Technology). Guodian Technology is listed on the Hong Kong Stock Exchange. For the 2018 financial year, it had revenue of CNY 11.4 billion (€1.5 billion). One of Guodian Technology’s primary business segments is renewable energy equipment manufacturing and services. This includes Guodian Technology’s 70%-owned subsidiary Guodian United Power Technology Co., (United Power). United Power is a manufacturer of wind turbines (primarily onshore) whose main customers are CHN Energy related companies.

Offshore wind track record and prospects

At end of 2018, CHN Energy’s installed offshore wind capacity was 1.4 GW. Subsidiaries Longyuan and GD Power Development account for 87% and 13% of the offshore wind install base, respectively. The capacity is exclusively off the Chinese East Coast, predominantly in the Jiangsu province. Examples of subsidiaries involved in development of this capacity include: Jiangsu Offshore Longyuan Wind Power Generation Co.; Longyuan Huanghai Rudong Offshore Wind Power Generation Co.; Haian Longyuan Offshore Wind Power Generation Co.; Fujian Longyuan Offshore Wind Power Generation Co. and Longyuan Yancheng Dafeng Offshore Wind Power Generation Co.

CHN Energy has offshore wind projects totalling 600 MW under construction in 2019 off the provinces of Jiangsu (50%), Fujian (12%), Hainan (22%), and Zhejiang (16%). It also has an offshore wind pipeline of 2.6 GW in development and post-FID, including the Longyuan Putian Nanri Island off Fujian Province.

CHN Energy was selected by the National Energy Administration (NEA) of China as the CSOE to enter 51%/49% JV set-ups on two Chinese offshore wind farm projects with a foreign developer partner. In March 2019, during meetings between the presidents of China and France, CHN Energy entered an agreement with France’s EDF Energies Nouvelles (EDF) to co-develop the 300 MW Dongtai 4 and the 200 MW Dongtai 5 projects off Jiangsu Province. EDF had initiated offshore wind partnership talks with CHN Energy in November 2016. The deal between the two state-controlled companies is part of trade and investment collaboration efforts between the two countries across industries such as energy, shipping, and aviation.

Financial information

3 The merger is part of China’s restructuring process for state-owned assets (other recent SASAC driven mergers at the CSOE level relevant to the wind industry in China are COSCO/China Shipping on the shipping front and CSIC/CSSC on the OEM/vessel construction front)
For the financial year ending December 2018, Longyuan’s revenue and EBITDA was HKD 31.3 billion (€3.6 billion) and HKD 18.7 billion (€2.1 billion), respectively.

Contracting

The CHN Energy companies typically use a multi-contracting approach and have largely relied on local suppliers from China. Prior to the 2017 merger, Longyuan set up an EPCI subsidiary JV company with China Communications Construction Co.’s Shanghai Zhenhua Heavy Industries Co. (ZPMC). The EPCI JV subsidiary is called Jiangsu Longyuan Zhenhua Marine Engineering Co. (Longyuan Zhenhua). The Longyuan Zhenhua JV is a major supplier (as is ZPMC) to Longyuan and other Chinese developers. The deal between the two state-controlled companies is part of trade and investment collaboration efforts between France and China across industries such as energy, shipping and aviation.

Figure 59 Share of known supply contracts with CHN Energy.

Figure 60 Share of known installation contracts with CHN Energy.
5.1.2 China General Nuclear Power Corporation

### Profile

China General Nuclear Power Group (CGN), formerly China General Nuclear Power Corporation, is a CSOE with headquarters in Shenzhen, Guangdong Province. It has a major presence in Beijing. It is China’s largest nuclear power plant operator.

### Renewable energy subsidiaries and affiliates

CGN New Energy Holdings Co., (CGN New Energy), is CGN’s non-nuclear subsidiary, primarily focusing on renewables.

It is incorporated in Bermuda and is listed in on the Hong Kong Stock Exchange. CGN New Energy has a wholly owned subsidiary, CGN Wind Power Co. Limited (CGN Wind Energy).

CGN Wind Energy is based in Beijing and provides operation and management services to CGN Wind Energy’s operational power projects as well as power projects under construction.

### Wind-related activities

At end of 2018, CGN ranked global fourth largest owner of installed wind power capacity which totalled 12.96 GW. This included 98% onshore wind, of which 95% is in China, primarily Shandong, Zhejiang, Gansu, and Henan provinces. The remainder is in Europe and stems from subsidiary CGN Europe Energy’s December 2016 acquisition of 14 onshore wind farms in Ireland as well as the July 2018 acquisition of a 75% stake in a 650 MW onshore wind project in Sweden.

### Offshore wind track record and prospects

CGN New Energy operates 201 MW offshore wind capacity and had 1 GW under construction as at end of H2 2019 off the provinces of Fujian and Guangdong.

In addition, it has an offshore wind pipeline of projects in development and post-FID totalling 15 GW, including the CGN Yangjiang Nanpeng Island (off Guangdong Province) and CGN Daishan #4 (off Zhejiang Province) projects.

In December 2013, CGN partnered with France’s nuclear power company AREVA (later Adwen and now assimilated into Siemens Gamesa) to identify commercial opportunities in offshore wind in China and Europe. AREVA was the offshore wind turbine supplier and CGN was the investor, developer and operator of the wind farms. Siemens Gamesa, via its earlier JV with Shanghai Electric as well as the existing licencing partnership, has supplied up to 152 MW of CGN’s operational offshore wind capacity.

CGN has been gaining experience about wind energy based on overseas M&A activity. Besides the onshore wind acquisitions in Europe stated above, CGN has a controlling stake in its European floating offshore wind JV, EOLFI Offshore France, with France’s Eolfi.

### Financial information

For the 2018 financial year, CGN New Energy had revenue and EBITDA of USD 1.36 billion (€1.2 billion) and USD 347 million (€311 million), respectively.
So far, CGN has mostly been contracting with local Chinese players. In September 2012, it signed a deal with Chinese turbine manufacturer Ming Yang to co-develop wind projects, with a focus on offshore. The two agreed to co-develop the Golden Bay offshore wind farm project in Jieyang, Guangdong Province as well as other onshore and offshore wind farms in the Fujian Province. The cooperation also includes research and development. Ming Yang is supplying turbines to at least 1.8 GW of CGN’s offshore wind farms, including the CGN Yangjiang Nanpeng Island (off Guangdong Province), currently under construction.

In November 2017, CGN New Energy launched its first O&M vessel, a CTV, for offshore wind turbines at Yangzhou City’s Yangtze River dock in the Jiangsu Province.

In December 2017, CGN and the government of the city of Jieyang signed an agreement to develop an up to 3 GW deep-water offshore wind farm project off the Guangdong Province in the South China Sea. CGN also plans to set up an engineering and research and development (R&D) centre in Jieyang to develop the deep-water technology needed for the project.

However, as a relative late comer to the wind industry, CGN is open to partnerships with non-local companies.
5.1.3 China Three Gorges Corporation

Profile

China Three Gorges Corporation (CTG) is a CSOE with headquarters in Beijing. It operates the world’s largest hydropower plant, the 22 GW Three Gorges Project on the Yangtze River, Hubei Province. In January 2019, CTG announced that various factors, including high local costs and limited domestic hydro (river) resources, mean that it will not develop any more hydro power plants in China, but rather focus on offshore wind.

Renewable energy subsidiaries and affiliates

Its key subsidiaries in offshore wind business include China Three Gorges New Energy Co., (CTG New Energy). For engineering services related to wind energy, CTG’s key subsidiary is Shanghai Investigation, Design & Research Institute (SIDRI) in which it has a 70% stake. SIDRI is responsible for designing the floating foundation for a planned floating offshore wind pilot project off Shanghai.

Wind-related activities, offshore wind track record and prospects

CTG operates 483 MW of offshore wind capacity in Fujian, Liaoning and Guangdong provinces. In Q2 2019, it had offshore wind projects totalling 708 MW under construction off the provinces of Jiangsu, Fujian, Guangdong and Liaoning. CTG’s offshore wind pipeline capacity is approx. 11.8 GW under development and post-FID, including the Fujing Xinghua Bay-Phase 2 (off Fujian Province) and CTGNE Yangjiang Shapa - Phase 1 (off Guangdong Province) projects.

In March 2018, CTG New Energy signed an investment cooperation agreement with the Tianjin Economic-Technological Development Area to develop a 1 GW offshore wind project in the Nangang Industrial Zone.

Among China’s big five utilities, it is CTG that leads in terms of reaching out to acquire foreign expertise on renewable energy. CTG owns a 23% share of Portugal’s Energias do Portugal (EDP) which it acquired in December 2011. EDP owns 83% of EDP renewable energy subsidiary, EDP Renováveis (EDPR). In May 2018, CTG launched a €9.1 billion bid for control over EDP and in April 2019, EDP’s shareholders blocked CTG’s offer price as too low. In January 2019, CTG completed the acquisition of a 10% stake from EDPR in the 950 MW Moray East offshore wind farm off Scotland.

In June 2016, with intent to gain offshore wind experience, CTG bought an 80% stake in the 288 MW Meerwind Süd/Ost offshore wind farm project in the German North Sea from US private equity firm Blackstone.

Financial information

For the 2017 financial year, CTG’s operating revenue and EBITDA stood at CNY 90 billion (€11.4 billion) and CNY 65.9 billion (€8.3 billion), respectively.

Contracting
In December 2017, CTG signed a strategic cooperation agreement with the Shandong Provincial Government that included development of offshore wind power in Shandong province and forming a new industry cluster in the province.

In July 2018, CTG completed installation of all 14 turbines at its 77.4 MW Xinghua Bay pilot project off Fujian Province. The project involved eight turbine suppliers, including the US’ General Electric Renewable Energy. For its offshore wind projects coming online in 2019, however, the turbine supplier is China’s Goldwind in which CTG has a 16% stake.

Figure 63 Share of known supply contracts with CTG.

Figure 64 Share of known installation contracts with CTG.
## 5.1.4 State Power Investment Corporation

### Profile

State Power Investment Corporation (SPIC) is a CSOE with headquarters in Beijing. It was formed in 2015 following the merger of China Power Investment Corporation (CPIC) and State Nuclear Power Technology Co. (SNPTC). SPIC’s power generation portfolio in China comprises coal, hydropower, nuclear power, and renewable energy resources.

### Renewable energy subsidiaries and affiliates

SPIC is the ultimate holding company of China Power International Development Limited (CPI), a company engaged in investment holdings, generation, and sales of electricity and the development of power plants in China. CPI plans to develop offshore wind power projects and other clean energy projects in the Guangdong and Shandong provinces. CPI is listed on the Hong Kong Stock Exchange.

### Wind-related activities

At end of 2018, SPIC ranked the second largest owner of installed wind power capacity, globally, with a total of 16 GW. This included 15 GW onshore wind, of which 99% is in China and the remainder in Latin America.

### Offshore wind track record and prospects

At end of 2018, SPIC had 854 MW installed offshore wind capacity in China, across five projects and two phases of a demonstration project, in Jiangsu. Turbines have been supplied by: Sinovel, Shanghai Electric and Envision.

SPIC’s offshore wind project pipeline under development and post-FID exceeds 5 GW.

### Financial information

CPI’s revenue and profit for 2018 was CNY 23.2 billion (€2.9 billion) and CNY 1.6 billion (€0.2 billion), respectively.

### Contracting
Via its key EPCI supplier, design institute PowerChina Huadong Engineering Corporation (HDEC), SPIC’s three large projects have led the way in terms of inviting European expertise to join projects in China.

In May 2016, HDEC contracted Denmark’s Rambøll, an engineering, design and consultancy company, to design SPIC’s 400 MW Binhai North H2 project, becoming the first non-Chinese company to do so. The scope included design of 100 steel turbine foundations, a 400 MW substation, concept for the transformers, breakers and cables, as well as developing the design basis for waves, currents and geotechnical conditions.

In June 2017, HDEC appointed Ramboll and the UK’s Atkins (now part of SNC-Lavalin) to design foundations and the offshore substation platform, respectively, for SPIC’s approved 300 MW Binhai South H3 offshore wind farm off Shanghai.

In August 2017, the UK’s Tekmar Energy, a cable protection systems specialist, was contracted to protect array cables on the 400 MW SPIC Binhai North.

Such collaboration with international players is expected to continue.
## 5.1.5 China Huaneng Group Corporation

### Profile

China Huaneng Group Corporation (China Huaneng Group, Huaneng or CHNG) is a CSOE with headquarters in Beijing. It is one of China’s five largest power enterprises. China Huaneng Group is a coal power generation leader. Prior to the 2017 merger of China Guodian Group into China Shenhua Group to form CHN Energy, China Huaneng Group was global leader overall in power-generation facilities (predominantly coal). In July 2017, China Huaneng Group was the subject of a potential merger with SPIC.

### Renewable energy subsidiaries and affiliates

China Huaneng Group subsidiary (52%) Huaneng Renewables Corporation Limited (Huaneng Renewables) is a Hong Kong-based investment holding company principally engaged in wind power generation businesses.

Huaneng Renewables is listed on the Hong Kong Stock Exchange.

Huaneng Renewables’ businesses include the development and operation of wind power and solar power plants, electricity generation, sales of electricity, as well as the provision of related services.

Huaneng Renewables has 95 renewables subsidiaries, including 80 which are wholly owned. For the 15 non-wholly owned subsidiaries, its partners are domestic Chinese companies.

### Wind-related activities

Huaneng Renewables’ subsidiaries include 64 wind power generation companies. As at end of 2018, Huaneng Renewables ranked the sixth largest owner of installed wind capacity globally, which totalled 11.7 GW. This included 99% onshore wind capacity across 16 provinces in China.

### Offshore wind track record and prospects

At end of 2018, its installed offshore wind capacity stood at 140 MW off the Jiangsu and Shandong provinces. In Q2 2019, it had offshore wind projects totalling 900 MW under construction. Huaneng Renewables’ offshore wind pipeline consists of 4.9 GW under development and post-FID, including the Huaneng Yangjiang Shapa project off the Guangdong province.

Meanwhile, China Huaneng Group has a 24% stake in Guangdong Energy Group Co., the largest power generation company in Guangdong province that is increasingly more active in the offshore wind space.

### Financial information

For the financial year ending 31 December 2018, Huaneng Renewables’ revenue and operating profit stood at CNY 11.65 billion (€1.5 billion) and CNY 5.6 billion (€0.7 billion), respectively.

### Contracting
Though it has an extensive track record in onshore wind, it is a relative new entrant to offshore wind and has been collaborating with other Chinese developers to gain experience. In October 2017, it commissioned its first offshore wind project (which it co-owns with China Huadian). The 302 MW project has turbines from three Chinese suppliers: CSIC Haizhuang, Envision and Shanghai Electric.

In May 2019, China Huaneng Group signed a strategic cooperation agreement with the Jiangsu Province to jointly build an offshore wind base in the province that integrates the entire offshore wind farm lifecycle, namely research and development, manufacturing, construction and OMS facilities.

Figure 67 Share of known supply contracts with Huaneng.

Figure 68 Share of known installation contracts with Huaneng.
5.2 Taiwan

Market size and turbine demand

At the end of 2019, Taiwan is expected to have 128 MW of installed capacity. This is forecast to reach 4.4 GW by 2024, with a compound annual growth rate of 42% between 2020 and 2024. Between 2020 and 2024, the annual installed capacity is forecast to be between 300 MW and 1.3 GW.

Most projects are located in the centre of the country’s West Coast in the Taiwan Strait. The Taiwan Strait has high annual mean wind speeds (10.3 m/s to 11.5 m/s) and is a typhoon zone. Many of the projects identified within the zones of potential (ZoPs) are near-shore and in waters of 5 m to 20 m depth. Far-shore projects identified are in water depths of 20 m to 50 m. The seabed is typically softer than the European North Sea and is prone to earthquakes.

Projects that are expected to contribute to the forecast installed capacity in this period include: Changhua Pilot (Changhua Phase I), Formosa Offshore Wind Farm 1 Phase 2, Formosa II, Yunlin I, Taoyuan (Guanyin), Greater Changhua South East, Yunlin II, Greater Changhua South West Phase 1, and ChungFang I & II.

Regulation

In 2015, the Taiwanese government designated 36 ZoPs off the West Coast of the island and invited developers to register interest in particular zones. More than one company were allowed to register interest in the same site but only the first company to get its environmental impact assessment (EIA) approved and to secure an ‘establishment permit’ from the Ministry of Economic Affairs (MOEA) would ultimately be granted the lease. Applications could be made for sites outside these zones on condition that justification was provided. At least five other such sites have also been proposed by developers.

The process of obtaining an electricity licence is a six-step process:

1. Project developer applies for final approval of the EIA by the Environmental Protection Approval (EPA). By April 2018, projects totalling 10.5 GW had received EPA approval.
2. With final EPA Approval, the project developer, with consent letters from various local and national government authorities, applies for Establishment Permit from the MOEA’s Bureau of Energy (BOE). The Establishment Permit is valid for three years, extendable to five years.
3. With the Establishment Permit, the project developer applies to the BOE for recognition of the project as a renewable energy facility.
4. With the Establishment Permit and the BOE recognition, the project developer is required to sign a PPA with the Taiwan Power Company (Taipower) within six months of obtaining Establishment Permit.
5. With or without the Establishment Permit, the project developer applies for Construction Permit from the BOE, but Construction Permit is only granted once the developer has obtained the Establishment Permit. Construction Permit is valid for five years and can be renewed.
6. Project developer applies for Electricity Licence.

Taiwan has a target for grid capacity to accommodate a maximum of 5.5 GW of offshore wind by 2025. The majority of Taipower’s proposed connections with the grid for offshore wind are in Taichung, with good proximity to the majority of the ZoPs.

In April 2018, Taiwan held a grid allocation process for 3.5 GW based on selection criteria emphasising developers’ capabilities in offshore wind farm construction, engineering design, O&M, project financing, and local content support. Capacity totalling 3.8 GW capacity was awarded to seven developers across 12 projects that then qualify for fixed feed-in tariffs (FIT). Developers can opt either for TWD 5 850 (€170)/MWh for 20 years or TWD 7 120 (€200)/MWh for the first 10 years and TWD 3 570 (€100)/MWh for the final 10 years. Taiwan held a grid allocation process for the remaining 1.7 GW in June 2018, in the form of a competitive auction to sell electricity at a lower price in a tender held by Taipower. Only developers who participated in the April 2018 grid allocation process and scored points above a given threshold qualified to participate in the June 2018 auction. The capacity was awarded to two developers across four projects. The winning prices ranged from TWD 2 230 (€60)/MWh to TWD 2 550 (€70)/MWh.

In November 2018, the MOEA proposed a 3 600-annual cap on full-load hours as well as to reduce 2019 FITs by 12.7% from 2018 levels. Threats to withdraw from the market by developers, notably Ørsted, and interference from the Global Wind Energy Council helped convince MOEA to reduce the proposed cut to 5.7%.

By end of 2019, Taiwan is expected to reveal plans for a further 5 to 6 GW offshore wind capacity for grid connection between 2030 and 2035. The plans were initially announced to be revealed before the end of 2018, however no announcement has been made so far.

Capital and operational expenditure

- Expenditure across all supply chain activities in 2024 is estimated to be €2.7 billion
- Total expenditure between 2020 and 2024 is estimated to be €11.5 billion, and
- It is expected that 92% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX and that 8% will be spent on OPEX.

![Figure 71 Estimated expenditure for Taiwan.](source: BVG Associates and Panticon)
The Taiwanese government has suggested that the goal to reach 5.5 GW of operating capacity by 2025 may be reached through collaboration between local and international development companies.

Different collaborations exist where overseas developers, such as Ørsted, WPD, Copenhagen Infrastructure Partners (CIP) and Northland Power have entered the Taiwanese market for offshore wind with local partners. Examples include Denmark’s CIP which has partnered with local CSC.

Local companies such as CSBC Corporation, Taipower and Taiwan Generations Corporation have their own pipelines beyond those shared with their international partners.

Local companies lead national development initiatives in creating a local supply chain for wind turbines/foundations (CSC and Century Iron), creating local installation/marine logistics capability (CSBC), and in making Taichung the national offshore wind hub (TIPC and Taipower).

**Ørsted** is an energy utility headquartered in Denmark. It entered the Taiwan offshore wind market in 2016 when it invested in the 8 MW Formosa 1 Offshore Wind Farm Phase 1, primarily providing advisory services, while Swancor New Energy leads the development and construction of the project. Ørsted emerged as the number one developer in Taiwan following the April 2018 and June 2018 auctions, accounting for 34% of the 5.5 GW awarded. Its 900 MW Changhua 1 and 2a projects secured PPAs and achieved internal FID in April 2019. Ørsted revenue and operating profit (EBIT) for 2018 was DKK 77 billion (€10.3 billion) and DKK 24.7 billion (€3.3 billion), respectively.

**wpd** is an international developer and operator of wind farms, both onshore and offshore, headquartered in Bremen, Germany. It has been involved in onshore wind farm construction in Taiwan for 10 years. wpd emerged as the number two offshore developer and owner in Taiwan following the April 2018 and June 2018 auctions, accounting for 19% of the 5.5 GW awarded with Yunlin 1&2 and Taoyuan projects. In December 2018, wpd secured a PPA with Taipower for the 640 MW Yunlin offshore wind project. In April 2019, it sold 27% equity in the project to a consortium of Japanese companies - Sojitz Corporation, The Chugoku Electric Power Co., Inc., Chudenko Corporation, Shikoku Electric Power Co., Inc. and JXTG Nippon Oil & Energy Corporation. In May 2019, wpd achieved financial close for the project. For the 2016 financial year, wpd’s revenue and EBITDA stood at €389 million and €21 million, respectively.

**Copenhagen Infrastructure Partners (CIP)** is a Danish fund management company. It was established in 2012 and has four funds with around €6.8 billion under management. In Taiwan, CIP owns a forecasted 700 MW share of projects under development. CIP emerged as the number three developer and owner in Taiwan following the April 2018 and June 2018 auctions, accounting for between 11% and 16% of the 5.5 GW awarded. Projects with CIP involvement totalling 900 MW secured PPAs in February 2019.
### Northland Power
Northland Power is an independent power producer and specialist developer headquartered in Canada with majority shares in several European wind farms. It emerged as the number four owner in Taiwan, after its success in the April 2018 round giving it 40% shares in the Hai Long II Phase 1 project and then being allocated Hai Long II Phase 2 and Hai Long III projects in the June 2018 auction. In February 2019, it secured a PPA with Taipower for the 300 MW Hai Long II Phase 1 offshore wind project. Northland Power’s revenue for 2018 was CAD 1.6 billion (€16.6 billion) and its adjusted EBITDA CAD 891 million (€1 billion).

### Taipower
Taipower is a state-owned utility responsible for authorising grid connection agreements for offshore wind projects in Taiwan. It entered the Taiwan offshore wind market in 2012. Taipower has almost 400 MW of projects in development and post-FID. In 2016, Taipower opened a dedicated offshore wind construction office based in the Taichung Power Plant. It is building the 109.2 MW Changhua Pilot, expected to come online by 2020 and a 300 MW project that was successful in the April 2018 round. Taipower’s revenue and profit before tax in 2017 was NT$567 billion (€16 billion) and NT$23.2 billion (€0.7 billion), respectively.

Regarding floating, no floating projects were accepted within the 5.5 GW capacity awarded in April 2018 and June 2018 and floating is expected to have had a slower start than in some other Asian markets, due to the availability of good shallow-water sites.

### EOLFI
Greater China had proposed a 500 MW W1N floating project off the coast of Taoyuan. In December 2017, Taiwan’s Environmental Protection Administration’s (EPA) ad hoc committee rejected the project based on potential clashes with a shipping lane, a proposed zone of potential 2 offshore wind farm and a proposed liquefied natural gas terminal project by CPC Corp. EOLFI hopes to revive the project.

In November 2015, France’s Ideol and Taiwan’s China Steel Corporation (CSC) entered a preliminary collaboration agreement to design, engineer, and construct floating offshore wind turbines using Ideol’s “damping pool” technology.

### Supply chain

#### Century Iron and Steel Industrial’s (CISI)
Century Iron and Steel Industrial (CISI) core business is the fabrication of metal products. It was established in 1987 and entered the Taiwan offshore wind market in 2014. In November 2017, CISI subsidiary Century Wind Power (CWP) signed a MoU with Ørsted to collaborate on turbine foundation manufacturing. CWP signed another MoU, this time with Denmark’s Bladt Industries, to cooperate on fabrication of jacket foundations for the nascent Taiwan offshore wind market. Half a year later, CIP selected CWP and Bladt as preferred suppliers of 150 jacket foundations for its three offshore wind projects in Taiwan. In August 2018, Bladt Industries and CWP formed a JV – Century Bladt Foundation Co.

#### Chin Fong Machine Industrial
Chin Fong Machine Industrial is a leading mechanical press maker in Taiwan for global markets. It was founded in 1948 and is headquartered in Changhua. In October 2018, alongside South Korea’s CS Wind, Ching Fong signed a conditional contract with MVOW to make offshore wind turbine towers from its facilities in Taichung Harbour.

#### CSBC Corporation
CSBC Corporation was established in 1973 and previously known as China Ship Building Corporation. Its core business is shipbuilding and its primary activity in offshore wind is installation services. CSBC entered the Taiwan offshore wind market in 2015 when it was awarded the EPCI contract for the array and export cable supply and installation of the Fuhai Phase 1 and 2 by Taiwan Generations Corporation and for the Changhua Offshore Pilot Project. In December 2017, CSBC Corporation and Belgian offshore wind contractor GeoSea announced they were forming a JV, CSBC-DEME Wind Engineering Co., to bid for turbine installation work off Taiwan’s coasts. In March 2018, Hai Long, a JV between Canada’s Northland Power Inc. and Singapore-based Yushan Energy signed a letter of intent with CSBC-DME Wind Engineering Co. In January 2019, CSBC agreed a MoU with compatriots Yang Ming Marine Transport Corp, Taiwan Navigation Co. and state-run Taiwan International Port Corp (TIPC) to combine the capabilities of Taiwan’s leading shipping and marine engineering companies. In May 2019, CIP, whose 552 MW ChangFang and 48 MW Xidao projects secured PPAs in February 2019, signed a priority contractor deal with CSBC-DME Wind Engineering Co. for turbine installation. In July 2019, CSBC launched Taiwan’s first locally made accommodation barge for offshore wind farms, the CSBC No. 15.

### CSC
CSC is Taiwan’s top steelmaker. In November 2017, it signed a MoU with Ørsted under which the two companies will work jointly to ensure that CSC’s production lines are ready in 2020 to manufacture and assemble foundation substructures. CSC’s manufacturing facility in Singda Harbour, Kaohsiung, is set for completion by end of 2019. In November 2018, Ørsted signed a conditional contract with CSC subsidiary Sing Da Marine Structure Corporation to supply 56 jacket foundations for the first 900 MW Greater Changhua project.
### Global offshore wind market report, 2019

<table>
<thead>
<tr>
<th><strong>Formosa Heavy Industries Corporation</strong> is Taiwan’s largest industrial conglomerate. Through subsidiary Formosa Plastics, it is a blade materials supplier to the wind energy industry. In March 2018, Formosa Heavy Industries Corp signed a MoU with developer Swancor Holding Co. to produce structures for wind turbines for Swancor. In October 2018, Ørsted contracted Formosa Heavy Industries and CSBC Corp. for the manufacture of foundation pin piles for the Changhua offshore wind farm projects.</th>
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<tbody>
<tr>
<td><strong>Hitachi</strong> provides infrastructure products and services, industrial equipment, and energy-saving solutions. It was founded in 1910 and is headquartered in Tokyo, Japan. In April 2018, Taipower contracted Hitachi to supply 21 turbines for the 109.2 MW Changhua offshore wind farm project, Hitachi’s first wind power project outside Japan. The scope included turbine manufacture and assembly as well as turbine O&amp;M. Hitachi then revealed intentions to set up a turbine manufacturing plant in Taiwan only to announce January 2019 that it will withdraw from offshore wind turbine production following delivery of the Taiwan project. Revenue and EBITDA in financial year ending March 2019 was JPY 9 481 billion (€81 billion) and JPY 1.1 billion (€1 billion), respectively.</td>
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<td><strong>Jan De Nul</strong> installs turbines, foundations, array and export cables, and manufactures concrete gravity base foundations. It is a dredging and marine contractor that has acquired 47 new vessels since 2007. In 2015, it entered the turbine and foundation installation market with the acquisition of the Vidar (renamed Vole au Vent) jack-up vessel from HGO InfraSea Solutions. In October 2018 it acquired a jack-up vessel from MPI Offshore (renamed the Tailievent). In April 2019 Jan De Nul placed and order for the Voltaire, a new large jack-up vessel for next generation turbine installation. In April 2018, Taipower contracted Jan De Nul Group and Hitachi with overall work for the manufacturing and installation of 21 wind turbines with 5.2 MW capacity for the 109.2 MW Changhua offshore wind farm project. In May 2018, Formosa Wind Power Co. contracted Jan De Nul Group for the design, procurement and installation of the wind turbine foundations for the 120 MW Formosa 1 Phase 2 offshore wind farm. In June 2019, Jan De Nul secured an EPCI contract for foundations and subsea cables at the 376 MW Formosa 2 offshore wind project. The scope includes design, fabrication and installation of the jacket foundations, as well as for the design, supply and installation of subsea cables. For the 2018 financial year, Jan De Nul’s turnover and EBITDA were €1.7 billion and €277 million, respectively.</td>
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<td><strong>JDR Cable Systems</strong> is a leading subsea cable supplier to the offshore wind industry and is headquartered in Littleport, UK. It was founded in 1994 and was acquired in August 2017 by Poland’s TFKable Group. In June 2018, JDR won a contract to manufacture and supply inter-array, export and land cables for the 120 MW Formosa 1 Phase 2 wind farm. In January 2019, Jan De Nul contracted JDR to supply subsea power cables and accessories for Taipower’s 109.2 MW Changhua Phase 1 project. In July 2019, JDR signed a MoU with Taiwan’s Ta Ya Group, an electric wire and land cable manufacturer, to collaborate on localisation opportunities in Taiwan.</td>
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<td><strong>MHI Vestas Offshore Wind (MVOW)</strong> is the global number two supplier of offshore wind turbines by total installed capacity. It is a JV formed in April 2014 between Mitsubishi Heavy Industries and Vestas. Most of its production facilities are in Denmark and it operates a UK blade factory. In March 2018, it was selected by CIP and CSC as preferred supplier for up to 1.5 GW capacity in Taiwan. For the 2018 financial year, MVOW’s revenue and net profit stood at €1 billion and €26 million, respectively.</td>
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<tr>
<td><strong>Siemens Gamesa</strong> is global number one supplier of offshore wind turbines. It entered the Taiwan offshore wind market in 2015 when it was contracted to supply turbines for the 8 MW Formosa 1 Phase 1 Offshore Wind Farm. Siemens Gamesa is also supplying Phase 2 of the project, was confirmed supplier for wpd and Starwind’s 640 MW Yunlin projects, and is in line to supply the 376 MW Formosa 2 and Ørsted’s 900 MW Changhua 1 and 2a projects. Siemens Gamesa plans to establish a wind turbine assembly site at the Port of Taichung.</td>
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<tr>
<td><strong>Swancor Holding Co.</strong> is a leading supplier of blade materials including epoxy resins, hardeners, adhesives and carbon fibre composites from its manufacturing facilities in China. In July 2019, MVOW signed a conditional contract with Swancor for the purchase of blade materials. The agreement also includes the possibility to export the supply of blade materials to MVOW globally. Swancor plans to set up a local (Taiwan) production site of materials for carbon fibre sheets in cooperation with compatriot Formosa Plastics Group. It plans to set up five production lines by the end of 2020. Swancor Holding Co., is a pioneering developer of offshore wind in Taiwan. However, in June 2019, it unveiled plans to step back from project development via the sale of subsidiary, Swancor New Energy, to New York-based Stonepeak Oceanview Holdings Co, and focus on growing its role as a materials specialist in the offshore wind supply chain.</td>
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</table>
Taiwan Cogeneration Corporation (TCC) was founded in 1992 with a goal of assisting the industry by providing cogeneration technology to enhance energy efficiency and increase power supply in Taiwan. TCC’s 100% owned Star Energy Corp has won and completed successfully several EPC contracts for substations, transmission lines, onshore wind power units and other power related projects. In November 2018, Ørsted contracted Star Energy to establish onshore transformation stations and power transmission systems. In May 2019, Ørsted reiterated that Star Energy would commence construction of two onshore substations for Ørsted 900 MW Changhua 1 and 2a offshore wind projects.

Taiwan International Ports Corporation, (TIPC) was established in March 2012 as a state-owned enterprise affiliated with the Ministry of Transportation and Communication. It is a single, integrated port business cluster. TIPC operates seven international commercial ports (Keelung, Taichung, Kaohsiung, Hualien, Taipei, Suao, Anping) and two domestic ports (Budai, Penghu) in Taiwan. In accordance with the national offshore wind power development policy, TIPC is actively investing in various elements of wind power port infrastructure as well as vessel maintenance and basic safety training services. The Port of Taichung has been designated as the offshore wind power operation home port, and the Port of Taipei has been designated as the underwater operating port to strengthen the wind power capacity of Taiwan’s ports group. To this effect, TIPC subsidiary, TIPC Marine, has entered into several collaboration agreements with various supply chain players including with POSH Kerry Renewables (to operate marine logistics vessels for operation and maintenance of the turbines) and with Siemens Gamesa (to develop areas of Taichung Harbour to support offshore wind construction and turbine manufacture). In August 2018, TIPC launched Taiwan’s first offshore wind crew transfer vessel (CTV) at the Port of Taichung.

Ta Ya Electric Wire & Cable Co., is a Taiwanese cable manufacturer. Its parent, Ta Ya Group is headquartered in Tainan. In August 2018, Ta Ya Electric signed a MoU with Siemens Gamesa aimed at developing a local supply chain. In July 2019, Ta Ya Group signed a MoU with JDR Cable Systems to jointly develop an offshore wind supply chain in Taiwan.

TECO Electric & Machinery is a Taiwanese manufacturer of motors with manufacturing bases in Taiwan, China, Malaysia, and the USA. In August 2018, TECO Electric & Machinery signed a MoU with Siemens Gamesa aimed at developing a local supply chain. In August 2019, it received an onshore substation EPC contract from CIP for the 600 MW Chang Fang and Xidao projects. The contract includes building the onshore substation and supplying submarine cables which will transmit power from the two wind farms.

Woen Jinn Harbor Engineering is a Taiwanese subsea contractor and heavy-lift specialist. Its primary activity in the offshore wind industry is the installation of array and export cables. Woen Jinn entered the Taiwan offshore wind market in 2015 when it was awarded array and export cable installation for the Formosa 1 Offshore Wind Farm Phase 1 project. In December 2017, Woen Jinn signed a MoU with developer Ørsted whereby Woen Jinn would become Ørsted’s preferred offshore cable installation partner for its four Greater Changhua offshore wind farms. In January 2018, Woen Jinn contracted the UK’s Longitude Engineering to undertake a feasibility study of Woen Jinn’s WJ#5 cable lay barge. In September 2018, Ørsted awarded Woen Jinn a contract for inter-array cable installation including a special financial arrangement to allow Woen Jinn to invest in a new cable installation vessel, the WoenJinn#7, set for completion by end of 2020. After Ørsted’s May 2019 FID on its 900 MW Changhua 1 and 2a offshore wind projects, however, Woen Jinn withdrew from the contract, citing financial challenges and failure to complete personnel recruitment and training on time.
5.3 South Korea

Market size and turbine demand

At the end of 2019, South Korea is expected to have 96 MW of installed capacity. This is forecast to reach 2.4 GW by 2024, with a CAGR of cumulative installed capacity of 58% from 2020 to 2024. Between 2020 and 2024, the annual installed capacity is forecast to be between 300 MW and 700 MW. The majority of the forecast capacity to 2024 will come from the build out of projects located around Wido Island, Buan and Anmado Island, Yeongkwang, and around Jeju Island.

Projects that are expected to contribute to the forecast installed capacity in this period include: 200 MW Donghae - MOTIE and Ulsan Metropolitan City Consortium, 110 MW Gunsan Maldo, 400 MW Southwestern Phase 2, 600 MW Wando - Korea South-East Power, 151 MW Yongwang Changwoo, 350 MW Yokjido, 60 MW Samcheonpo, 540 MW Haegi, and 100 MW Gori.

Regulation

In December 2017, South Korea’s Ministry of Trade, Industry and Energy’s (MOTIE) revealed a draft of its 8th Basic Plan for Electricity Supply and Demand. The share of renewables in the country’s installed capacity mix is proposed to increase from nearly 10% or 1.1 GW in 2017 to 35% or 5.8 GW in 2030.

At the June 2018, Strategic Forum for the Industrialisation of Offshore Wind Power Generation, MOTIE revealed that South Korea plans to raise renewable energy power generation’s share from 7% in 2018 to 20% in 2030, an increase of 48.7 GW, in line with the final part of the Renewable Energy 3020 Implementation Plan. Offshore wind makes up 24.6% or 12 GW of the capacity increase.
Capital and operational expenditure

- Expenditure across all supply chain activities in 2024 is estimated to be €1.6 billion.
- Total expenditure between 2020 and 2024 is estimated to be €6.9 billion.
- It is expected that 94% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX and that 6% will be spent on OPEX.

![Figure 76 Estimated expenditure for South Korea.](image)

Owners

State-owned utility **Korea Electric Power Corporation (KEPCO)** and its group of companies make up four out of the top 10 owners in South Korea.

KEPCO and its group of companies also lead in terms of operational offshore wind capacity with a 30% share.

Going forward, the KEPCO group of companies are expected to dominate the capacity coming online for the period up to end of 2024.

The **chaebols** (a large family-owned business conglomerate), including **Doosan, Hyundai, and Samsung**, are expected to be increasingly involved in the rollout of the first offshore wind farms via supply chain and balance of plant. Eventually, in the medium to long term, as the market becomes more established, the chaebols are expected to take up offshore wind farm ownership, thus departing from the China-like ownership model (state-owned) to resemble the Japanese and Taiwanese ownership models (privately owned).

![Figure 77 Top 10 owners by portfolio for South Korea.](image)
Korea Electric Power Corporation (KEPCO) has a virtual monopoly in power generation and distribution in South Korea. It was founded in 1982 and is listed in Seoul and New York. The Government of South Korea and the National Pension Service of Korea hold 51.1% and 7.1% stakes, respectively, in KEPCO.

KEPCO has six fully owned power generating units, namely KHNP, KOSEP, KOMIPO, KOWEPO, KOPSO, and EWP. These units generate power mostly from fossil fuels, have limited operating onshore wind capacity, and have all entered the offshore wind market. Three of these generating units, KOWEPO, KHNP, and KOSEP make it into the top five owners of offshore wind pipeline in South Korea. All six are involved in the 2.5 GW Southwestern offshore wind project.

For the financial year ending December 2018, its revenue and EBITDA stood at KRW 60.6 billion (€45 billion) and KRW 9.8 billion (€7.2 billion) respectively.

Korea Western Power Co, (KOWEPO) is one of KEPCO’s six power generation units. As of December 31, 2017, it operated seven power plants with a total capacity of 11.8 GW (including 63.7% coal and 3.5% renewables) and is involved in the 2.5 GW Southwestern offshore wind project. KOWEPO is headquartered in Taean-gun, South Korea. KOWEPO’s revenue for 2017 was KRW 4.2 billion (€3.1 billion).

Korea Hydro & Nuclear Power Co, (KHNP) is one of KEPCO’s six fully owned power generation units. KHNP is South Korea’s only nuclear power plant operator. As of December 31, 2017, it operated at least nine power plants with a total capacity of 28 GW (including 81.5% nuclear, 19% large hydro and less than 1% other renewables) equivalent to 24% South Korea’s total power generation capacity and is involved in the 2.5 GW Southwestern offshore wind project. KHNP is headquartered in Yangguk-myeon, Gyeongju-si, South Korea. KHNP’s revenue for 2017 was KRW 9.4 billion (€6.9 billion).

Korea South-East Power Co, (KOSEP) is one of KEPCO’s six fully owned power generation units. As of December 31, 2017, it operated seven power plants with a total capacity of 10 GW (88% coal) and is involved in the 2.5 GW Southwestern offshore wind project. KOSEP is headquartered in Jinju, South Korea. KOSEP’s revenue for 2017 was KRW 298 billion (€0.22 billion).
Regarding floating, South Korea is investing in floating demonstration and innovation projects to help support the exploration of their deeper waters.

- A consortium comprising Korea East-West Power Co. (EWP), Ulsan Technopark, Ulsan City, KR, Seoul National University, Korea Maritime and Ocean University, Ulsan University, and Changwon National University, have a 200 MW floating offshore wind project in the pipeline with plans to expand it to 1 GW. The planned project location is near Ulsan in 50~200 m deep waters with construction planned between 2020 and 2023.

- Korea Research of Ships & Ocean Engineering (KRISO) is developing a floating wind and wave hybrid energy platform near Jeju Island to be equipped with four offshore wind turbines.

- Swedish Hexicon AB finalised a deal with Korean integrated service provider COENS Co. in April 2018 to form a JV to develop offshore wind farms in Southeast Asia. The COENS-Hexicon JV aims to move the Hexicon’s steel floating platform concept into serial production in South Korea. In June 2018, Hexicon AB signed a MoU with Busan Techno Park and Renewable Energy Center for the development of floating offshore wind in South Korea.

- In June 2018, Macquarie Group signed a MoU with South Korea’s Gyeongbuk Floating Offshore Wind to develop a 1 GW floating offshore wind project 50 km off the coast of Pohang/Ulsan in South Korea.

- In June 2018, EWP revealed plans to establish a 200 MW floating wind farm at state-owned Korean National Oil Corporation’s (KNOC) gas field platform in the East Sea once the gas field platform’s operational life expires.

- In February 2019, Norway’s Equinor signed a MoU with KNOC to build commercial floating wind projects off Korea. In July 2019, Equinor, KNOC, and EWP established a consortium to develop the 200 MW Donghae 1 floating offshore wind project near KNOC’s existing Donghae gas platform off Ulsan City.

- In November 2018, Canada’s Northland Power signed a MoU with KEPCO E&C to jointly develop offshore wind projects, including floating offshore wind projects, in South Korea and abroad.

- In January 2019, the industrial port City of Ulsan signed a MoU with consortia comprising local and international companies to construct and service a combined 1 GW of floating offshore capacity off South Korea as well as create a local supply chain. The consortia are:
  - SK Group’s gas and power company SK E&S (South Korea) and Denmark’s CIP
  - Oil and gas company Shell (Holland and UK) and CoensHexicon (South Korea and Sweden);
  - Macquarie Group’s Green Investment Group (GIG) (Australia and UK), and
  - Wind Power Korea (South Korea) and Principle Power (USA).

- In June 2019, Macquarie Group’s GIG installed South Korea’s maiden floating Lidar unit at the site of the 1.4 GW Ulsan floating wind power project it is developing. The same month, it signed a deal with South Korean renewable energy fund manager Energy Infra Asset Management to finance the project.

**Supply chain**

**CS Wind Corporation** (Choong San Wind Corporation until 2007), manufactures wind towers and wind tower components for the global onshore and offshore wind markets. Its customer portfolio includes the top global wind turbine manufacturers. CS Wind also serves the offshore wind turbine foundations market segment and supplied offshore foundations for the Nobelwind NV offshore wind project in Belgium. CS Wind was founded in August 2006 and is headquartered in Cheonan, South Korea.

**Doosan Heavy Industries & Construction Co.** (Doosan Heavy), the core company of Doosan Group, operates in business areas including power generation. It was founded in 1962 and is headquartered in Changwon, South Korea. Doosan Heavy has been involved in the construction of most of the nuclear power plants in South Korea. Doosan Heavy offers offshore turbines. It supplied the 30 MW Tamra offshore wind project and is supplier for the 60 MW demonstration project. Doosan Heavy’s product portfolio includes 3 MW and 5.5 MW offshore wind turbines. In June 2018, Doosan Heavy was selected to lead a four-year project to develop an 8 MW offshore wind turbine that would meet South Korean demand and compete globally. The project is backed by the state-owned Korea Institute of Energy Technology Evaluation and Planning (KETEP). In July 2019, Doosan Heavy received a type certificate for its 5.56 MW offshore wind turbine from the international certification agency UL DEWI-OC, the first time a Korean company has received a type certificate. Revenue and EBITDA in financial year ending December 2018 was KWR 14.8 billion (€1.1 billion) and KWR 1.1 billion (€0.8 billion).
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<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
<th>Details</th>
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<tbody>
<tr>
<td><strong>Hyundai Steel Co.</strong></td>
<td>manufactures and sells steel products and is the second-largest steelmaker in South Korea. It is headquartered in Incheon, South Korea, and was founded in 1953 as Korea Heavy Industry and was renamed Incheon Heavy Industry in 1962. Hyundai Steel became a subsidiary of Hyundai Motor following the 1997 Asian currency crisis. In June 2019, Hyundai Steel and compatriot Samkang M&amp;T were contracted by Ørsted to supply 27 and 28 jackets, respectively, for Ørsted’s 900 MW Changhua 1 and 2a offshore wind projects in Taiwan. Revenue and EBITDA in financial year ending December 2018 was KWR 20.8 billion (€15.3 billion) and KWR 2.6 billion (€1.9 billion), respectively.</td>
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<td><strong>LS Cable &amp; System</strong></td>
<td>is among the largest global manufacturers of cables. It is headquartered in Anyang, South Korea and was founded in 1962. In October 2018 it was contracted by Ørsted to supply 350 km high voltage onshore cables for the 1.4 GW Hornsea offshore wind project in the UK. In January 2019, LS Cable won a contract from wpd to supply 170 km of subsea cables for the 640 MW Yunlin offshore wind project in Taiwan.</td>
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<tr>
<td><strong>POSCO</strong></td>
<td>produces steel products and is South Korea’s largest steelmaker. Surging competition from China has led POSCO to diversify to, among other segments, energy. POSCO supplied jacket foundations for the 30 MW Tamra offshore wind farm in South Korea. It has plans to mass-produce jacket foundations and develop offshore wind projects in the Asia-Pacific region. POSCO was founded in 1968 and is headquartered in Pohang, South Korea. Revenue and EBITDA in financial year ending December 2018 was KWR 65.0 billion (€48 billion) and KWR 8.7 billion (€6.5 billion).</td>
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<td><strong>Samsung Heavy Industries Co. (SHI)</strong></td>
<td>one of South Korea’s top-three shipbuilders. It was founded in 1974 and is headquartered in Seongnam, South Korea. SHI produces and sells vessels, plant and power systems. From its Geoje shipyard in South Korea it has delivered offshore wind turbine installation vessels to the European offshore wind market. This includes the Pacific Orca to Swire Blue Ocean in 2012, and the Scylla to SeaJacks in 2015. SHI previously developed a 7 MW turbine but then withdrew from the market. Revenue and EBITDA in financial year ending December 2018 was KWR 5.3 billion (€3.9 billion) and KWR 114 billion (-€84 million).</td>
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<tr>
<td><strong>Taihan Electric Wire Co.</strong></td>
<td>is a Korean-based company mainly engaged in the manufacture of electric wires and cables. It operates an optical fibre business, optical cable business and new medicine business. Taihan Electric Wire is a supplier of subsea cables for the 60 MW demonstration offshore wind project, and is based Dongan-gu, South Korea.</td>
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<tr>
<td><strong>Unison</strong></td>
<td>founded in 1984, is a leading supplier of onshore wind turbines in South Korea. After four consecutive years of operating deficits in 2010-2013, it was placed under supervision by the Korea Exchange in 2014. However, it escaped delisting when it recorded profits in 2014 and 2015. It has been engaged in the wind energy industry since 2001, eight years after it was listed on Kosdaq market. Japanese conglomerate Toshiba became Unison’s largest shareholder in 2012 with a 34% which has since more than halved to 15.6%. In October 2018, Unison installed a prototype of a new U136-4.2MW turbine platform for type certification tests. The turbine is adapted from a design from Germany’s Aerodyn. Unison is targeting the South Korean and Japanese onshore and offshore wind markets. Alongside Doosan and Gyeongnam Technopark, it is linked to the 350 MW Yokjido offshore wind project.</td>
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</table>
### Market size and turbine demand

At the end of 2019, Japan is expected to have 82 MW of installed capacity. This is forecast to reach 2.6 GW by 2024, with a CAGR of cumulative installed capacity of 109% from 2020 to 2024. Between 2020 and 2024, the annual installed capacity is expected to be between 56 MW and 1.2 GW. The majority of the forecast capacity to 2024 will come from the build out of projects located within the Sea of Japan (to the north west of Japan) and the Pacific Ocean (to the south east of Japan).

In July 2019 several authorities in Japan jointly designated 11 areas off five prefectures as offshore wind promotion zones. Projects that are expected to contribute to the forecast installed capacity in this period include: 22 MW Goto Sakiyama Oki Oki, 100 MW Ishikari, 94 MW Kashima Port-South, 60 MW Mutsu Ogawara, 220 MW Kitakyushu Port-Hibikinada and 455 MW Mitane.

![Figure 79 Forecast installed capacity in Japan.](image)

### Regulation

Japan introduced renewable energy FITs in July 2012 under the Renewable Energy Act. Japan’s Ministry of Economy, Trade and Industry (METI) is responsible for the FIT scheme. In March 2014, METI approved an offshore wind FIT of 36 JPY (€0.306)/kWh. Since then, several policy changes have been made.

In December 2017, the Japan Wind Power Association (JWPA) requested the Japanese government to:

- Prepare a law that would allow construction of offshore wind farms outside port-related sea areas
- Harmonise environmental impact regulations with grid connection
- Introduce guaranteed long-term site leases of up to 30 years, and
- Introduce a bidding system to select offshore wind project developers.

In March 2018, the Cabinet of Japan decided on the Bill for the Act of Promoting Utilisation of Sea Areas in Development of Power Generation Facilities Using Maritime Renewable Energy Resources to establish basic rules for development of offshore wind power in the general common sea area, and thereafter submitted the draft legislation to the National Diet.

In June 2018, the National Diet, during its 196th session, dismissed the Bill for the Act of Promoting Utilisation of Sea Areas in Development of Power Generation Facilities Using Maritime Renewable Energy Resources due to political differences.

In July 2018, the Government of Japan set a target of 10 GW onshore and offshore wind capacity in its Fifth Basic Energy Supply Plan as part of the 22-24% renewable energy power generation targets by 2030.

In November 2018, the Cabinet of Japan re-introduced the Bill for the Act of Promoting Utilisation of Sea Areas in Development of Power Generation Facilities Using Maritime Renewable Energy Resources to the 197th extraordinary National Diet session. The same month, the lower (House of Representatives) and upper (House of Councils) houses approved the Bill to be put into effect in the spring of 2019.

- At the same time, policy was switched from unsolicited project bids to auctions.
The offshore wind FIT was maintained, but the goal is to bring it to as low as 6JPY (€0.05)/kWh by 2030.

In March 2019, the Cabinet of Japan approved the Cabinet Order and the Enforcement Order for specifying the effective date of the Act of Promoting Utilisation of Sea Areas in Development of Power Generation Facilities Using Maritime Renewable Energy Resources as 1st April 2019. Some key steps outlined in the Act are as follows:

- METI and Ministry of Land, Infrastructure, Transport and Tourism (MLIT) consult with the Ministry of Environment (MOE), the Ministry of Agriculture, Forestry and Fisheries, prefectural governments, fishing groups, academics, and other concerned stakeholders
- METI and MLIT designate offshore wind Promotion Zones
- METI and MLIT prepare bidding guidelines
- METI and MLIT invite developers/operators to competitively bid based on tariff and zone occupancy suitability, among other factors
- Developers/operators submit bids to METI and MLIT
- METI and MLIT select winning bidders and approve their bid plans
- Based on approved bid plans, developers/operators apply for FIT approval to METI
- METI issues approvals
- Based on approved bid plans, developers/operators apply for zone development permit to MLIT, and
- MLIT issues zone development permit for up to 30 years.

In July 2019, METI, MLIT and Port Authority of Japan jointly designated 11 areas off five prefectures as offshore wind Promotion Zones. These are:

- Akita prefecture: Noshiro (Mitane and Oga), Yurihonjo (north and south), Happou and Noshiro, and Katagami
- Aomori prefecture: Nihon sea (north), Nihon sea (south), and Mutsu bay
- Nagasaki prefecture: Goto (floating) and Saikai (Ejima)
- Tokyo prefecture: Choshi, and
- Niigata prefecture: Murakami & Tainai.

Four areas, Noshiro (Mitane and Oga), Yurihonjo (north and south), Choshi, and Goto (floating) are at advanced stages and ready to start preparations for wind measurements and geological surveys.

Electricity transmission in Japan is divided into two regions: East and West. Each region runs at a different mains frequency and transmission between the regions requires converters. This creates challenges for intermittent power generation such as offshore wind. Japan’s offshore wind resource-rich regions (Hokkaido, Tohoku, and Kyushu) are located far away from regions of high demand (mainly Tokyo). There are plans to reform Japan’s electricity system, which would nearly double the capacity of the East-West grid connection by 2020.
- Expenditure across all supply chain activities in 2024 is estimated to be €3.9 billion.
- Total expenditure between 2020 and 2024 is expected to be €10.2 billion and
- It is expected that 97% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX and that 3% will be spent on OPEX.

Owners

The top 10 owners in Japan are primarily large trading houses or construction companies such as Marubeni Corporation, Obayashi Corporation, and Renova. Unlike in China and European countries, the owners are not large utilities.
Marubeni Corporation is one of the largest trading houses in Japan. It is active in engineering, procurement and construction (EPC) of power generation plants (including renewable energy) both in Japan and abroad. Marubeni was the consortium lead for the Fukushima FORWARD offshore wind project. It has projects totalling 1 GW under development in Japan including shares in the Akita and Noshiro Port projects. With Ørsted, Marubeni is a co-owner of Gunfleet Sands offshore wind farm in the UK. In May 2012, Marubeni (together with the Innovation Network Corporation of Japan) acquired Seajacks (from Riverstone Holdings LLC). Marubeni is also involved in OMS and safety management of power plants. Revenue and EBITDA in financial year ending March 2019 was JPY 7 400 billion (€63 billion) and JPY 286 billion (€2.4 billion).

Obayashi Corporation was one of the first major construction companies to enter the renewable energy sector. Obayashi is involved in three offshore wind projects, including the Mitane project (totaling 455 MW) in the Akita prefecture with commissioning expected between 2021 and 2023. Together with Toa Corp. Obayashi is in the process of building a wind turbine installation vessel. Revenue and EBITDA in financial year ending March 2019 was JPY 2 040 billion (€17.4 billion) and JPY 173 billion (€1.5 billion).

Renova Inc. owns, operates and develops renewable energy power plants including wind energy power. It was founded in May 2000 and is headquartered in Tokyo, Japan. Renova’s portfolio of offshore projects under development includes the Yrihonjo (Yuri Honjo) project. In March 2019, it announced that utility Tōhoku Electric Power Co., Inc. will invest in the project. The project has already been undergoing EIAs and is located in one of the four advanced designated zones selected by METI, MLIT and Port Authority of Japan in July 2019. Revenue and EBITDA in financial year ending March 2019 was JPY 17 billion (€143 million) and JPY 9.5 billion (€81 million).

Wind Power Co. (Komatsuzaki) is based in Kamisu City, Japan. It is one of Mitani Corporation’s major subsidiaries. Mitani Corporation is headquartered in Fukui, Japan. Wind Power Co. owns the Kashima Port South project. For the financial year ending March 2019, Mitani Corporation’s total sales and total profit amounted to JPY 418 billion (€3.6 billion) and JPY 14.2 billion (€120 million).

Electric Power Development Co. (J-Power)'s business segments include electric power. The segment focuses on wholesale electric power and wind power plant businesses. J-Power was founded in 1952 and is headquartered in Tokyo, Japan. It holds a 40% share in the Kitakyushu Port – Hibikinada project. In September 2018, J-Power signed a MoU with France’s ENGIE to a non-exclusive collaboration for power projects with focus on large-scale commercial offshore wind projects in Japan, Europe and other markets. Revenue and EBITDA in financial year ending March 2019 was JPY 897 billion (€7.6 billion) and JPY 159 billion (€1.4 billion).

Regarding floating, Japan is a front runner, current projects involve both international developers as well as consortiums of large Japanese players.

A consortium compromising of state-owned New Energy and Industrial Technology Development Organisation (NEDO), Marubeni, Hitachi Zosen, Mitsubishi, and Tokyo University is leading developments in the floating Fukushima three phase project. This includes smaller floating demonstrations previously installed as well as a 1 GW project planned for the third phase.

France’s Ideol and Japan’s Hitachi Zosen entered an agreement in June 2015, to promote Ideol’s ‘damping pool’ semisubmersible floating platform design for Japan’s floating offshore wind market. In September 2018, a consortium comprising Hitachi Zosen, Marubeni, University of Tokyo, and NEDO is expected to grid connect a 3 MW floating demo project off Hibikinada Sea in waters of 50 metres depth. It features Aerodyn’s 3 MW SCD two-bladed turbine installed on Ideol’s “dampening pool” floating platform built by Hitachi Zosen.

In May 2017, Principle Power of the US and Japan’s Mitsui Engineering & Shipping signed a collaboration agreement to promote Principle’s WindFloat design for Japan’s floating offshore wind market.

In 2018, Norway’s Equinor established offices in Japan with plans to work on the Hywind pipeline. Equinor had teamed up with Japan’s Hitachi Zosen back in 2012 to focus on offshore wind.

In May 2018, France’s Ideol signed a MoU with Australia’s Macquarie to develop a floating “several hundred megawatt” offshore wind farm (the world’s first commercial-scale) off Japan with construction set to start in 2023.

In June 2019, Ideol and Japanese renewable energy developer Shizen Energy finalised a deal to jointly construct a “several hundred megawatt” floating offshore wind project in the East China Sea.
In July 2019, France’s **Naval Energies** agreed with Japan’s **Hitachi Zosen** to cooperate on a feasibility study to jointly design and build floating wind turbines using Naval Energies’ semi-submersible floater solution off Japan.

### Supply chain

**EXSYM (SWCC Showa Cable Systems)** is an export cable supplier and supplied export cables for the Choshi offshore wind project. EXSYM merged with SWCC Showa Cable Systems, a subsidiary of SWCC Showa Holdings, in October 2015.

**Furukawa Electric** is a Tokyo-based company that supplies array and export cables. Furukwa Electrics was one of the 11 consortium members for Fukushima Offshore Floating project for which it supplied array and export cables.

**Hitachi**, through its subsidiary Hitachi Power Solutions, is the leading offshore turbine manufacturer in Japan. Its largest offshore turbine is rated at 5.2 MW. It acquired the wind turbine manufacturing division of Fuji Heavy Industries (FHI) in July 2012. Following its acquisition of FHI, Hitachi’s turbines now account for the largest share of installed offshore wind capacity in Japan. It partly owns one of the two 125 MW Kashima Port projects and was tipped to supply both projects (which are located close to its turbine manufacturing base). In January 2019, however, Hitachi announced that it will discontinue producing offshore wind turbines and instead reinvigorate its alliance with Germany’s Enercon for Japan’s onshore wind market. Since 2015, Hitachi has owned 51% of the Hitachi ABB HVDC Technologies JV company with Swiss based ABB. In December 2018, ABB announced a divestment of 80.1% of its Power Grids division to Hitachi and this transaction will be completed in 2020.

**Hitachi Zosen** (not to be confused with Hitachi) is a designer and developer of floating offshore wind farms. It is registered on stock exchanges in Japan, Germany, and Switzerland. It is working actively with international players in developing floating foundations technology. Hitachi Zosen Corp. was founded in 1881 and is headquartered in Osaka, Japan. Revenue and EBITDA in financial year ending March 2019 was JPY 378 billion (€3.2 billion) and JPY 17 billion (€144 million), respectively.

**Japan Marine United Corporation (JMU)** is a ship building marine engineering and service company headquartered in Tokyo. It was created in 2013 by integration of two companies, Universal Shipbuilding and IHIMU, which were the leaders in the shipbuilding industry in Japan. JMU was one of the 11 consortium members for Fukushima Offshore Floating project. It supplied floating foundations for an offshore substation and for the 5 MW Hitachi floating turbine. JMU built the wind turbine installation vessel for Penta-Ocean, christened in January 2019, and is now building an offshore wind turbine installation vessel for Shimizu Corp.

**Kajima Corporation** is a major Japanese construction company. Kajima Corporation installed the Mitsubishi Heavy Industries’ 2.4 MW offshore wind turbine on a gravity foundation at NEDO’s Choshi offshore project in 2013.

**MHI Vestas Offshore Wind (MVOW)** is the global number two supplier of offshore wind turbines by total installed capacity. It is a JV formed in April 2014 between Japan’s Mitsubishi Heavy Industries (MHI) and Denmark’s Vestas. Prior to the JV, MHI was the leading turbine manufacturer in Japan (onshore and offshore combined). Both MHI and Vestas have supplied offshore turbines to Japan’s still emerging offshore wind market. In June 2017, MVOW announced plans to open a branch in Japan in 2018. Hitachi’s withdrawal leaves MHI, via the MVOW JV, as the only “Japanese” turbine manufacturer to make it into the European offshore wind market, as well as the only Japanese offshore wind turbine maker.

**Mitsui Engineering and Shipbuilding (MES)** is a Tokyo-based heavy industry manufacturer established as the Shipbuilding Division of Mitsui in 1917. It has four manufacturing works in Japan and many group companies worldwide. Its product portfolio includes shipbuilding, EPC of various plants including medium sized power plants, and offshore equipment. In 2013, MES successfully deployed its own semi-submersible floating offshore wind foundation (Fukushima Mirai) as part of the Fukushima FORWARD. In May 2017, MES signed a collaboration agreement with Principle Power to promote WindFloat projects in Japan.

**Nippon Steel and Sumitomo Metal Co. (NSSMC)** is a company engaged in steel-making and steel fabrication, and is headquartered in Tokyo. NSSMC was one of the 11 consortium members for the Fukushima Offshore Floating project where it did foundation works. NSSMC is expected to supply jackets for the 299 MW Hibikinada offshore wind project.
**Penta-Ocean Construction** is a marine engineering specialist based in Hiroshima. In September 2016, Penta-Ocean revealed plans that it had ordered a wind turbine installation vessel. The vessel was delivered in December 2018, three months behind schedule, and was christened CP-8001 in January 2019. It is equipped with a fully revolving crane with a maximum lifting capacity of 800 t at 26 m radius. It can install turbines of up to 10 MW capacity at water depths of up to 50 m. Penta-Ocean is expected to install turbines at the 299 MW Hibikinada offshore wind project.

**Shimizu Corporation Contractor** provided cable installation and oceanic surveys for the Fukushima Recovery Experimental offshore wind project. In July 2019, it revealed plans to build a wind turbine installation vessel designed to install 8 MW+ wind turbines in Japan in water depths of 10 m up to 65 m. Other vessel specifications include 50 m with, 142 m total length, 28 000 t displacement, and a maximum lifting capacity of 2 500 t for a crane with maximum lifting height of 158 m. Japan Marine United Corporation is responsible for detailed design and construction. Vessel delivery is planned for 2022.

**Siemens Gamesa Renewable Energy** is a supplier of onshore and offshore wind turbines. It supplied a 3 MW turbine to the Eurus Akita Port Wind Farm in Japan. In June 2019, Siemens Gamesa signed a preferred supplier agreement with Obayashi Corporation for the latter’s 455 MW Northern Akita offshore wind project.

**Toda Corporation** engages in the provision of construction services. It operates through the following business segments: Building Construction, Civil Engineering, Real Estate, and Other. Toda Corporation is headquartered in Tokyo, Japan. In May 2018, Toda Corporation, in collaboration with compatriot Yoshida Co., and support from the country’s Ministry of Environment, launched a semi-submersible vessel designed for installation of floating offshore wind turbines. Toda is also active in offshore wind development. For the financial year ending March 2019, revenue and EBITDA was JPY 510 billion (€4.3 billion) and JPY 36.8 billion (€313 million).

**VISCAS Corporation** is a Tokyo-based JV between Furukawa Electric Co. (50%) and Fujikura (50%), founded in 2001. It supplied array and export cables for the Fukushima Recovery Experimental offshore wind project. VISCA’s subsea and underground cable business was transferred to Furukawa Electric Co. in September 2016.

**Toyo Construction** is a civil engineering and construction company headquartered in Tokyo, Japan, and is one of Japan’s leading marine contractors. It has experience in the fields of dredging, reclamation and port construction and energy-related offshore structures both locally and abroad. It is a potential supplier of foundations and is part of a seven-member consortium with Hitachi Zosen and Sumitomo Corporation developing a 300 MW project.
By the end of 2019, the 30 MW Block Island will remain the only offshore windfarm operating in the Americas. Offshore wind installations are forecast to approach 5 GW by 2024, with a compound annual growth rate of almost 200% between 2020 and 2024. Between 2020 and 2024, the annual installed capacity is forecast to grow to the 2 GW range.

Power offtake agreements, mostly in the form or Power Purchase Agreements (PPAs) are about to exceed 5 GW with anticipated installation dates for the associated projects between 2021 and 2025.

Formalised offshore wind State policies are already exceeding 20 GW, fuelling a continued need for additional lease areas. This trend has also been confirmed by the lease auction in Massachusetts late 2018, where BOEM auctioned off three additional lease areas, increasing the lease area potential by ~6 GW (3 x 2 GW), at an auction price tag of 3 x USD 135 million.

2019 is developing towards a bold validation of offshore wind along the US East Coast and most observers’ expectations have been exceeded in all areas: State policy, offtake agreements and federal lease areas.

The US West Coast, Canada and Brazil are still at an early stage but may equally surprise with significant activity building up. Within the forecast period, however, all installations are off the US North East coast with one small project in the Great Lakes.

Evolving policies, committed market entrants and supply chain / infrastructure investments are expected to drive the 2035 cumulative capacity towards 30 GW.

Expenditure and levelised cost of energy

Although still a new market, the US East Coast is challenged to address infrastructure and supply chain building, enabled through local economic benefit commitments and driven by operational project execution needs. States, developers and tier one suppliers have engaged in comprehensive infrastructure analysis to evaluate investment decisions and to support the ambitious construction schedules of the first commercial scale projects. The majority of the interest remains in the states with the strongest business cases (favourable wind resource, close to coastal load centres with clean energy needs and high-power pricing peaks). The boldest offshore wind strategic plans are in Massachusetts, New York and New Jersey.

The cost of energy is expected to remain higher than in Europe in the short term, but then drop to being similar:

Initially, to mitigate the currently limited US industrial base for offshore wind, most components are sourced globally, adding importation and logistics costs. Coastal staging of components, installation, commissioning and service must be performed locally and will be spread over several port facilities to maximise local content and to address early limitation in coastal infrastructure. Over time, the situation is expected to improve.

Jones Act compliant marine logistics form an integral part of the sourcing and port strategy, with the first projects depending on European vessels (with high mobilisation costs) and the limited availability and size of Jones Act jack-up feeder barges. It can be expected, however, that in time, innovative and US specific marine logistic solutions will evolve to address the significant port limitations and the rapidly growing turbine size and resulting hub heights.
Many of the early stage projects are expected to use monopile foundations to maximise the European learning curve and existing cost competitive sourcing, but with importation costs. Deeper waters, environmental considerations and local content requirements will drive alternative solutions such as jackets or gravity-based foundations. They use less steel than monopiles but are initially more expensive to manufacture and install, increasing the overall cost of energy. One benefit is that jacket and gravity-based foundations represent a better fit to existing US businesses and workforce which could enable a quicker and more mobile localisation of scope and lower investment requirements.

In general, the multi-step development process is more costly and risky than in other markets. Specifically, the four “hurdles” can be summarised as follows: Succeed in a lease area auction; secure power offtake agreement; reach an interconnection agreement and obtain permits, including demanding stakeholder management.

The US floating market is evolving on both the West and the North East Coasts. Despite this, with the exception of demonstration projects, the floating market is not expected to reach commercial scale before 2025.
Contracting

Experienced European developers, such as Ørsted and Equinor, are expected to multi-contract with mature, global suppliers, which may collaborate with US partners in an effort to localise, transfer knowledge and minimise logistics costs.

EPCI contracting is expected to be preferred by smaller or more conservative developers or those seeking project finance in order to mitigate / distribute risk and minimise interfaces.

Many supply chain and project structure decisions will also be driven by local economic and environmental benefit commitments made to states or regions.
6.1 The US

Market size and turbine demand

By the end of 2019, the US will remain at 30 MW of installed capacity with no increase in the year beyond Ørsted’s Block Island offshore wind farm. Despite this, US capacity is forecast to reach 5 GW by the end of 2024, with a CAGR of cumulative installed capacity of almost 200% between 2020 and 2024. In the same period, the installation rate is forecast to grow to the 2 GW range annually.

As the annual installed capacity grow, significant logistic and supply chain challenges / opportunities will need to be mastered in only a small number of years.

Projects that are expected to contribute the majority of the forecast installed capacity include Ocean Wind and Sunrise Wind (Ørsted); Empire Wind (Equinor) and Vineyard Wind (CIOP/Avangrid).

Figure 87 Forecast of installed capacity in the United States.

Figure 88 Forecast demand for turbines in the United States.

Regulation

Lease areas in federal waters are managed by BOEM (Bureau of Ocean Energy Management), part of the US Department of Interior.

A developer can either qualify to participate in a lease area auction or place an unsolicited bid for a new lease area, which usually results in an auction process. To date, 15 federal lease areas have been auctioned off, the most recent three in Massachusetts at record pricing of $135 million (€121 million) each. Once a developer secures a lease area, there are still significant steps remaining, such as interconnection, state and federal permitting, and most importantly, a power offtake agreement. The current 15 federal lease areas already provide sufficient area for at least 28 GW, illustrating that lease areas are (not yet) limiting the growth. A surplus in lease areas will benefit ultimately the rate payer as it increases competition. This is one of the reasons why NYSERDA has been promoting several new lease areas offshore the coast of New York.

Further BOEM lease area auctions are expected early 2020 for New York, followed by other areas such as California, the Gulf of Maine and possibly the Carolinas.

Transmission remains, for the time being, the responsibility of the developer to secure and reach a coastal interconnection point. With the rapid growth of volume, bottlenecks will have to be addressed, especially along the New York coastline.

While energy policy is typically implemented on state level, there are federal production tax credit (PTC) and investment tax credit (ITC) programmes in place. Based on a 2015 decision, the PTC/ITC program will be phased out in 2019, with a reduced available tax credit of 12% for a 2019 “safe harbour” project. Once safe harbour status is reached, the implementation window is typically 4 years to secure the tax credit.

State-driven energy policy and usually higher PPA levels position the evolving US market as an attractive alternative for mature European developers. Many of the pioneering states have already increased their offshore wind legislation or targets: Massachusetts legislation now mandates 3.2 GW by 2035, New York increased the committed 2.4 GW by 2030 to a
bold 9 GW by 2035, Maryland’s offshore wind renewable energy credits (OREC) program has been upgraded to 1.2 GW, and Connecticut has implemented a 2 GW plan. New Jersey’s 3.5 GW program is unchanged from the last report.

State-driven offshore wind commitments already exceed 21 GW by 2035. Additional commitments are anticipated, currently forecasted at 7 GW, driving the forecast to the 28 GW range as illustrated in Table 2.

Table 2 State policy targets and BVGA forecast comparison.

<table>
<thead>
<tr>
<th>State</th>
<th>State 15-yr policy target (GW)</th>
<th>BVGA forecast (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massachusetts (MA)</td>
<td>3.2</td>
<td>3.2 **</td>
</tr>
<tr>
<td>Rhode Island (RI)</td>
<td>0.4</td>
<td>0.4*</td>
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<td>Connecticut (CT)</td>
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<tr>
<td>Virginia (VA)</td>
<td>2 **</td>
<td>2 ***</td>
</tr>
<tr>
<td>North Carolina (NC)</td>
<td>-</td>
<td>2.4 ****</td>
</tr>
<tr>
<td>Anticipated future plans in multiple states</td>
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<td>~4.5</td>
</tr>
<tr>
<td>Total</td>
<td>21.3</td>
<td>~28</td>
</tr>
</tbody>
</table>

* Includes 30 MW Block Island Wind Farm

** 2018 Virginia Energy Plan calls for 2 GW of offshore wind by 2028.

*** Includes 12 MW CVOW demonstration project.

**** Based on Avangrid interconnection requests in the PJM Interconnection (regional transmission organization) power grid queue.
State policy driven turbine installation targets

- Expenditure across all supply chain activities in 2024 is estimated to be €5.9 billion
- Total expenditure between 2020 and 2024 is estimated to be €18 billion, and
- It is expected that 97% of expenditure between 2020 and 2024 will be spent on DEVEX and CAPEX and that 3% will be spent on OPEX.

 Owners
As of 2019, there is only one operational project, the 30 MW Block Island wind farm which Ørsted acquired from Deepwater Wind.

Developers with PPAs represents the first 4.9 GW of the market, ref. Figure 91.

Ørsted, Equinor and COP/Avangrid are the three major developers in terms of portfolio with offtake agreements in place, with, nearly 3 GW, 0.82 GW and 0.8 GW planned for implementation in the early 2020s.

Ørsted is the developer with the largest potential capacity with regard to its acquired lease areas, totalling nearly 10 GW.

Ørsted is headquartered in Denmark and develops, constructs and operates offshore and onshore windfarms. Globally it employs over 6,000 people with a revenue of about €10 billion. In the US, Ørsted has established a strong presence in Boston and has further localised along the East Coast, aligning its development teams with the locations of its lease areas. Ørsted acquired Deepwater Wind in 2018 for USD 510 million (€458 million), which included, in addition to Block Island, secured project developments in NY, RI, CT and MD for 850 MW. By the middle of 2019, Ørsted increased that portfolio to about 3 GW through additional development with off-take agreement in NJ, NY and CT. Additionally, the group has EPC responsibility for Dominion’s 12 MW Coastal Virginia demonstration project with a construction target of 2020.
**Equinor** is an international energy company headquartered in Norway. It successfully acquired the first New York State lease area and secured a first off-take agreement for 816 MW to initiate implementation of New York's commitment to 9 GW of offshore wind as part of the state's Clean Energy Plan. Equinor further secured a $135 million (€121 million) lease area in MA to position itself to compete in the New England market to serve MA, RI and CT. Equinor’s US offshore wind business is based in Stamford CT, supplemented with a presence in Washington DC. The group is developing oil, gas, wind and solar energy in more than 30 countries worldwide and employs about 20,000 people.

**Eversource** transmits and delivers electricity and natural gas and supplies water to approximately 4 million customers in Connecticut, Massachusetts and New Hampshire. Recognized as the top U.S. utility for its energy efficiency programs by the sustainability advocacy organization Ceres, Eversource harnesses the commitment of its more than 8,000 employees across three states to build a single, united company around the mission of safely delivering reliable energy and water. Eversource has teamed up with Ørsted to pursue large offshore wind projects such as the Sunrise Wind project in New York.

**Copenhagen Infrastructure Partners (CIP) / Copenhagen Offshore Partners (COP)**. Copenhagen Infrastructure Partners is a fund management company founded in 2012, including offshore wind, onshore wind, solar PV, biomass, waste-to-energy, transmission and distribution, as well as other energy assets such as reserve capacity and storage. It currently has four funds and around € 6.8 billion under management. Copenhagen Offshore Partners (COP) is a leading and experienced provider of project development, construction management, and operational management services to offshore wind projects.

CIP/COP entered the US market with a lease area purchased from Offshore MW and as Vineyard Wind, together with Avangrid, successfully secured an additional USD 135 million lease area and 800 MW PPA in Massachusetts.

CIP/COP and its projects have offices in Copenhagen, the UK, the US, Germany, and Taiwan. CIP/COP’s main US office has been established in Boston. Vineyard Wind is gearing up to execute the nation’s first commercial scale offshore windfarm in MA (800 MW).

**Avangrid Renewables** is part of the Iberdrola Group. Headquartered in Portland, Oregon, it has more than €10 billion (€9 billion) of operating assets totalling more than 6 GW of owned and controlled wind and solar generation in more than 20 states.

Avangrid Renewables with its partner, Copenhagen Infrastructure Partners, are the owners of the Vineyard Wind JV. Vineyard Wind controls two lease areas in the Massachusetts Wind Energy Area. The JV is developing the first large-scale offshore wind farm in the United States which has been awarded an 800 MW power purchase agreement with Massachusetts utilities. Avangrid Renewables won the Kitty Hawk offshore wind area bid from the federal government to lease 122,405 offshore acres (495 km²) off the coast of North Carolina and Virginia and has begun studying the area in more detail as part of early stage project development.

Regarding floating, the US, for the most part, has deeper waters than Europe. We expect the North East (Gulf of Maine) and the West Coast to host the first pre-commercial and commercial floating projects in the US.

BOEM has initiated three Call Areas in California (Humboldt, Morro Bay and Diablo Canyon), where 14 global developers have shown interest for a future auction, anticipated for 2020.

**Principle Power’s** project (Humboldt County) is currently in early planning stages, supported by a power offtake agreement for 150 MW, but requiring a lease. The technology intended for the project a floating semi-submersible by WindFloat, a steel construction floater. A 2 MW WindFloat prototype was deployed in 2011, 5 km off the coast of Aguçadoura, Portugal (decommissioned in 2016 and now installed in Scotland).

California will be a complex market, with good wind regimes in the North and most consumers in the South and much solar and onshore wind capacity. Several new organisations are evolving to advance the floating industry at the West Coast. One of them being the Pacific Ocean Energy Trust (POET), hosting an offshore wind conference in fall 2019. Additional new groups, such as Offshore Wind California, are forming, supported by developers and other stakeholders, complementing other activities driven by AWEA and The Business Network for Offshore Wind.
The Block Island project was supported by:

- **Bluewater Shipping** (logistics and transport services provider)
- **Fred Olsen Windcarrier** (vessel operator and installation contractor)
- **GE Renewables** (wind turbines supplier)
- **Gulf Island Fabrication** (providing fabrication, maintenance and servicing of foundations, facilities and vessels) and
- **Keystone Engineering** (engineering resources provider).

Vineyard Wind's 800 MW Massachusetts project will be the first commercial scale windfarm in the US, ambitiously targeting a completion in 2021. Tier one suppliers for the project are mostly known and as follows:

- **Bladt Industries** to build and deliver the substation including jacket foundation
- **MVOW** for the turbine supply (9.5 MW turbines)
- **Prysmian** has been selected for the cabling scope.
- **SIF** will fabricate monopile turbine foundations
- **Windar** will manufacture the towers, and

Due to schedule and aggressive LCOE positioning of this first major project the localisation of manufacturing will be minimal and the developer will draw from mature global supply channels. The next wave of projects however in NY and NJ have committed to significant local economic benefit and will initiate further localising of the supply chain.
7 Emerging markets

The markets included in Sections 4, 5 and Error! Reference source not found. are those we expect to play a leading role in installing offshore wind capacity in the global market to 2024. There are still many areas across the globe with unexploited wind resources. This provides a great opportunity for countries to reduce their dependency on fossils fuels in a cost effective way as well as increasing their energy security and creating local industry. Few of these markets, however, as expected to provide any capacity by the end of 2024 due to the time it takes to establish regulatory frameworks and then develop projects within these frameworks.

7.1 Europe

In addition to the key European countries discussed in Section 4, there are several European countries establishing offshore wind markets.

7.1.1 Estonia

Offshore wind development in Estonia has slowed in the last year. Projects off the island of Hiiumaa were delayed by Estonia’s top court in August 2018. It ruled that a plan for multiple projects in the area had not properly addressed environmental impact concerns at a strategic level, so the offshore wind aspect of the multi-sector plan was revoked.

In addition, the Estonian Government ruled against providing a permit for a 600 MW project off the Island of Saaremaa, this time citing reasons of national security, understood to be air defence radar. This means that currently, there are is no clear path to construction of any projects before 2024, even though there are 3 GW of projects in early stage of development, the majority bottom-fixed, with approximately 10% of this capacity floating.

7.1.2 Finland

Finland currently has the 42 MW Tahkoluoto offshore wind plant in operation, though this is close to shore. This is a research-oriented wind farm to demonstrate technology designed specifically for icy weather conditions, including blade de-icing and ice resistant foundations. Prior to this, Finland installed 32 GW of demonstration projects although the majority of this capacity has now been decommissioned.

Elsewhere, it has about 3 GW of offshore wind in the early stages of development (all bottom-fixed, rather than floating). Political intent and national frameworks for leasing, consenting and power purchase for offshore wind are all relatively weak. Little capacity is expected to be installed before 2024, with the most advanced projects currently Suurhiekan merituulipuisto (400 MW) and Tomio, Röyttä merituulivoimapuisto (70 MW).

7.1.3 Ireland

In 2014, the Irish government published its Offshore Renewable Energy Development Plan setting targets for offshore wind development for 2030. Following the plan, Ireland would install a minimum of 800 GW of capacity, with medium and high scenarios of 2.3 GW and 4.5 GW also envisioned by 2030. In June 2016, Ireland signed a letter of intent alongside other EU nations to facilitate cost-effective deployment of offshore renewable energy, although no binding commitments were made.

In July 2018, the Irish government approved its Renewable Electricity Support Scheme (RESS). Renewable energy auctions, in which offshore wind will compete for subsidy against other renewable energy technologies, will now be held annually from 2019-2025 with auction capacities ranging from 1 GW to 4 GW. The scheme replaces the renewable energy feed-in tariff support framework and will be based on market-orientated auctions. As of July 2019, the Irish renewable energy industry is awaiting confirmation from the Government as to the final design and requirements of the RESS auction scheme and whether the first auction will be held in 2019 as planned.

In June 2019, the Irish Government published its Climate Action Plan (CAP). The CAP is a wide-ranging policy document that sets out how the Irish Government intends to approach climate impact reduction across a wide range of sectors. In relation to electricity generation, the CAP sets out an ambition to increase Ireland’s renewable energy generation from a 2018 baseline of 30% of electricity demand to 70% of demand by 2030, by adding 12 GW of new renewable energy capacity. Of this 12 GW, the CAP sets a target of at least 3.5 GW of new offshore wind capacity to be operational by 2030. The CAP commits the Government to increasing the volume and frequency of RESS auctions in order to enable the 2030 target.

The first offshore wind farm in Ireland was the 25 MW Arklow Bank project installed in 2004. No further offshore wind farms have been installed since this but several projects in Irish waters are consented or are in development. Two wind farms have consent authorised. These are:

- Arklow Bank Phase 2 at 500 MW and Codling Wind Park at 1.1 GW
- 4 further projects have submitted consent applications, with a total installed capacity of 2 GW, and
7 further projects are at a concept / early planning stage.

Project developers with known offshore wind pipeline projects or ambitions in Irish waters include Energia, ESB, Fred. Olsen Renewables, Innogy, Parkwind, SSE and Statkraft.

7.1.4 Lithuania

There are a small number of early stage development projects in Lithuania, however, they can’t be considered as portfolio assets until the Energy Ministry has finished its studies on the area. The Energy Ministry is expected to re-tender the projects and none will be ready by 2024.

Klapedia University conducted a study in 2019 for the Energy Ministry which concluded that 3.35 GW of offshore wind energy would be feasible in Lithuanian waters.

7.1.5 Norway

To date, Norway has only 2 MW of offshore wind capacity, the Hywind Norway floating demonstrator project.

In 2016, the Power for Change. Energy policy by 2030 white paper written by the Standing Committee on Energy and the Environment called for the Norwegian Government to provide a subsidy scheme for offshore wind demonstration projects and other marine renewable energy technologies by the end of 2017.

A strategy for the commercial development of floating wind turbines was published in 2018, calling for a domestic offshore wind market to build supply chain capabilities for the global market. It also set out a long-term ambition to develop offshore wind in Norway, although it was not considered economic at the time. One exception to this is developing offshore wind to supply oil and gas plants, which is considered a potential route to market, plus it is a way to demonstrate pre-commercial scale floating offshore technology for early commercial projects elsewhere. Two such offshore wind farms are currently under development: the 88 MW Hywind Tampen project supplying to the Gullfaks and Snorre fields, and 350 MW Havsul 1 project, potentially supplying to the Nyhamna gas plant.

In July 2019, the government proposed to open two new areas for applications for offshore wind development, Utsira Nord (500 MW to 1.5 GW) and Sandskallen Sørøya (125 to 374 MW). In addition, they have asked for feedback on opening the southern area of Sørøya II for development (1 to 2 GW). Feedback is requested by 1st November 2019. It is however unlikely that projects will be built in any of these development zones before 2024.

The Ministry has also proposed a regulation to supplement the Ocean Energy Act that clarifies the licensing process. The public consultation is due to end November 2019.

The Norwegian Prime Minister announced in July 2019 that she wants input from industry on how to ensure Norway takes a leading role in the development of floating offshore wind. Previously, industry has cited lack of support systems and a framework from the Government as barriers to this.

7.1.6 Poland

Poland does not have any offshore wind capacity operating or any formal targets for offshore wind but has reasonable political intent and frameworks and a strong pipeline of activity. In 2018, the government confirmed the rules for offshore wind auctions.

Polish utilities Polenergia and PGE are expected to play a key role. Polenergia has a 50:50 partnership with Equinor for its 4 GW pipeline of projects, Bałtyk, I, II and III. The most advanced 2.4 GW of this capacity now has planning consent.

PGE, with a 3.5 GW pipeline has also initiated a partnering selection activity but has not yet announced the results. It has not yet applied for consent for any of its projects.

PKN Orlen, a Polish oil and gas company, is at an early stage of developing the Baltic Power project, with up to 1.2 GW installed capacity.

Other players aggregated together have a similar size pipeline to each of the above, all at early stage of development, so we do not anticipate capacity to be operating before the end of 2024.

Furthermore, Poland has well-established steel making and steel fabrication industries and is looking at how it can take a greater share of current export and future domestic offshore wind markets.

4 https://renews.biz/54448/lithuania-maps-offshore-potential/
Global offshore wind market report, 2019

7.1.7 Portugal

In 2012, Portugal installed its first offshore wind demonstration project; the 2 MW WindFloat project, now decommissioned and moved to Scotland. There are plans in place to develop WindFloat-Atlantic, initially to 25 MW, then to full commercial scale. Plans to finance the first phase of activity are advanced, with €60 m debt from European Investment Bank (EIB), €30 milion from the EC NER300 programme and €6 million from the Portuguese Government (via its Carbon Fund).

Although government industrial and energy strategy includes offshore wind, it does not foresee further public subsidy to support this and leasing and permitting frameworks are relatively unproven. This means that currently, there are no other significant projects in development, with industry concerned that it will be into the 2030s before floating offshore wind could compete with onshore wind and solar, for example.

7.1.8 Sweden

Sweden has almost 200 MW of offshore wind capacity installed to date, with the first project installed in 2006. No new capacity has been installed since 2013.

In 2016, the Swedish Government announced its intention to pay grid connection costs for offshore wind projects in order to stimulate activity in the market to reach its target to be 100% reliant on renewable energy by 2040, but this has had little impact, as Sweden operates technology neutral auctions with no technology-specific support for offshore wind. Until offshore wind can compete directly with onshore wind and biomass, significant market developments are unlikely.

Despite this, pipelines are well stocked, with over 2 GW projects consented, a further 2 GW in the consenting process and many others at an early stage – all bottom-fixed. The players with the largest pipelines are Rewind Offshore and Svea Vind Offshore (both local specialist developers) and Swedish state-owned utility Vattenfall. Amongst other projects, Vattenfall is developing Kriegers Flak 2 (640 MW) in Swedish waters next to its project currently in construction in Danish waters, Kriegers Flak 1 (605 MW) and EnBW’s Baltic 2 project in German waters. It is however unlikely that any projects will be operational before the end of 2024.

7.2 Asia-Pacific

7.2.1 Australia

Before 2015, the Government did not support the offshore wind industry. In 2015, the Australian Government established the Clean Energy Innovation Fund to provide AUD $1 billion (€606 million) to support offshore technologies (including offshore wind) from demonstration to commercial-scale deployment. It is managed by the Clean Energy Finance Corporation and the Australian Renewable Energy Agency.

In 2017, Australia announced plans for its first offshore wind project, the 2.2 GW Star of the South Energy Project, off Gippsland, Victoria. In November 2017 the original developer, Offshore Energy, formed a partnership with Denmark’s Copenhagen Infrastructure Partners to jointly undertake all future development. In March 2019, the Australian government granted a license for the developers to undertake a resource exploration process for the project.

Australia’s current coalition government, which came to power in May 2019, is not pro-renewables, implying that the progress of offshore wind and renewable energy in general will depend on state-level policy. There are no central government or state subsidies or regulations for offshore wind yet. Many states have vast onshore wind and solar potential compared to demand.

7.2.2 India

With a very strong growth in energy demand for the second most populous country in the world, India’s dependency on coal fired power plants has caused widespread pollution but also a strong lobby in favour of coal due to the number of people employed and size of the investments made. The government of India has an ambitious renewable energy policy scheme and targets of 5 GW of offshore wind by 2022, increasing to 30 GW by 2030, were announced. The states of Gujarat and Tamil Nadu are the locations where the initial offshore wind efforts are directed by the government of India. There is already 36 GW onshore wind in operation in India.

Through a 2018 expression of interest exercise for the initial 1 GW of offshore wind in India, local as well as international players registered their interest in developing the nascent Indian offshore wind market. Whereas international players have voiced concerns about grid capabilities and legislation, a relatively strong onshore wind supply chain for wind turbines exists and is made up of domestic as well as international wind turbine and component manufacturers. The offshore wind supply chain, however, is yet to be developed and little prior experience is available especially when it comes to the offshore wind balance of plant components like cables, foundations, and offshore substations, and offshore operations.
7.2.3 Singapore

The government of Singapore has announced plans for Singaporean companies to be active in offshore wind as well as plans (albeit not yet concrete) for Singapore to embrace offshore wind domestically. Several government-owned companies with links to the sovereign wealth fund, Temasek, are in the forefront of diversifying into the offshore wind industry. In addition, other local companies are getting involved in offshore wind across Asia-Pacific as well as in Europe. Such companies also include conglomerates from other countries, listed on the Singapore stock exchange.

In October 2016, Singapore-based upstream energy company Enterprize Energy, via wholly owned subsidiary Yushan Energy, and Canada's Northland Power (with respective shares of 40% and 60%), launched an inaugural offshore wind farm project in the Taiwan Strait, the Hai Long offshore wind farm project. Taiwan's Bureau of Energy has awarded 1 GW of the project in the April 2018 and June 2018 rounds. In June 2018, Enterprize Energy sold half of its 40% stake in the Hai Long project to Japan's Mitsui & Co.


7.2.4 Thailand

Thailand’s energy needs and current energy mix warrant a shift towards offshore wind. Beyond general renewables targets for 2021 and 2036 respectively, however, no tangible plans or targets have yet been set. An academic study has derived potential of up to 7 GW of offshore wind with a large portion situated in the Bay of Bangkok.

Thai companies are slowly starting to get involved in the wind energy industry with offshore wind fabrication for the Taiwanese market. In May 2018, Thailand’s oil and gas company CUEL signed its first offshore wind contract with Belgian contractor Jan De Nul Group to fabricate and supply 20 transition pieces for the Formosa 1 Phase 2 offshore wind farm in Taiwan. CUEL has since fabricated the transition pieces at its Laem Chabang yard on the Eastern coast of the Gulf of Thailand. The transition pieces were shipped to Taiwan in May 2019.

In addition, Thai companies are making selective outward investments in onshore wind in Laos and Australia as well as nearshore offshore wind farms in Vietnam.

7.2.5 Turkey

With 7 GW onshore wind in operation, in 2018, the Ministry of Energy and Natural Resources (MENR) announced its plans to develop offshore wind and this policy is unchanged. Turkey has targets of 65% of all electricity production from indigenous and renewable sources by 2023 and 16 GW wind (onshore and offshore) capacity by the end of 2026. Drivers are seeking to reduce dependency on imported gas and coal, increasing security of supply and creating economic benefit through local supply chain growth. Turkey has companies with capabilities to build foundations, towers and other wind farm components. Global leader LM Wind Power manufactures blades for onshore projects 60 km north of Izmir.

MENR carried out early project development work and then auctioned a first 0.8-1.2GW capacity during 2018, but, according to some developers, a combination of lack of availability of site measurements and low ceiling price led to a failed process and no award. MENR is now planning to do further EU-funded wind resource assessment, progressing towards publicly funded site investigations and re-engaging with stakeholders to define the next steps. MENR’s Wind Energy Potential Atlas in 2007 showed shown around 10 GW offshore wind potential for fixed foundations in Turkish territorial waters with greater potential for floating technologies.

7.2.6 Vietnam

Vietnam has the most short-term potential of the emerging markets discussed here. It has almost 100 MW of capacity installed in the Bac Lieu offshore wind farm, installed in phases between 2013 and 2015. A further 100 MW is currently under construction in the first phase of the Khai Long project, with the potential for an additional 200 MW to be developed at that site. In 2016, Mainstream Renewable Energy and GE Energy Financial Services agreed to develop projects with capacity up to 800 MW in the Soc Trang province. This agreement has been formalised and was expected to reach financial close in 2018, however, no announcement has been made so far.

In 2016, the Vietnam Power Development Plan (PDP7) stated wind energy targets (covering onshore and offshore wind) of 800 MW by 2020, rising to 6 GW by 2030, because of the exceptional offshore potential. Due to the complexity of the permitting process and the immaturity of the market, however, development has been slow.
In September 2018, the Prime Minister approved a draft decision (Decision No. 39) to raise onshore and offshore FITs to VND 1 920 (€0.74)/kWh and VND 2 183 (€0.085)/kWh, respectively, effective 1 November 2018 and applicable to projects commencing operations before 1 November 2021. Post 1 November 2021, the tentative plan is to transition to an auction system. In January 2019, the Ministry of Industry and Trade provided updated guidelines (Circular No. 02) on developing onshore and offshore wind power projects in Vietnam effective 28 February 2019. The updates provide clarification, though not full clarity, on the PPA model structure and Vietnam Electricity's (EVN) obligations. Further clarification is needed to address investor uncertainty.

Meanwhile, the momentum for offshore wind is slowly building. In January 2018, Danish-Japanese offshore wind turbine manufacturer MVOW, global technology group DNV GL, Singapore companies Enterprize Energy and Renewable Energy Global Solutions, as well as Vietnamese consortium PetroVietnam (comprising Petroleum Equipment Assembly & Metal Structure and VietSovPetro) formed an alliance targeting offshore wind development off Southern Vietnam. The parties entered exclusive agreement including feasibility, environmental, development, and financing planning through implementation. The alliance will focus on an area it has named the Ke Ga Offshore Wind Development Zone (Ke Ga OWZD) from where it plans to deliver utility-scale offshore wind energy development within government’s price expectations. The Ke Ga OWZD is an area outside of the current oil and gas production areas of the Cuu Long Basin, between 20 and 70 kilometres offshore Southern Vietnam’s Bình Thuận province in the South-Central Coast region and Bà Rịa Vũng Tàu province in the South East region. The PetroVietnam consortium has shipyards in Bà Rịa Vũng Tàu province where fabrication of turbine foundations and offshore electrical substation platforms is planned.

The proposed Phu Cuong project is also progressing through development, backed by Phu Cuong Group, GE Energy Financial Services and Mainstream Renewable Power. It is located within the intertidal zone along the SouthEast Coast of Vietnam in the Mekong River Delta region, approximately 180 km south-southwest of Ho Chi Minh City in the province of Soc Trang, along the coastline nearest to the town of Vĩnh Chau. This area has low exposure to storms and typhoons and is close to electrical demand. It is foreseen as two tranches of 400 MW each and tenders for turbines and balance of plant for the first 400 MW tranche is expected in late 2019.

In March 2018, South Korea’s Doosan Heavy and Vietnam’s state-run utility EVN signed a MoU to jointly develop a 3 MW pilot offshore wind project off Vietnam. Under the terms of the MoU, Doosan will supply the wind turbine, storage systems, EPC package, and, alongside Korea South-East Power Co. (a 100% subsidiary of South Korea’s state-owned utility KEPCO), operations and maintenance. EVN will provide the site for the pilot project and will work on obtaining all the necessary project-related licences and approvals.

### 7.3 Americas

#### Brazil

Offshore wind was mentioned formally for the first time in Brazil’s National Energy Plan published in 2018 and the Brazilian research office (EPE), supporting the Ministry of Mines and Energy (MME) is planning to publish a roadmap for offshore wind by the end of 2019. The country has much to do to establish an offshore wind industry, especially leasing and consenting frameworks, but with 15 GW onshore wind operating and a strong resource, it understands the role offshore wind could play, though expected to start in volume only during the 2030s.

Currently, it anticipates decreasing reliance on hydro, adding new wind, solar and gas capacity. Offshore wind resource is located on the North East Coast (in areas expected to suffer from grid constraints) and off Rio de Janeiro (hence close to the Southern demand centre).

Despite lack of frameworks and offshore wind knowledge within consenting stakeholders, two commercial-scale projects and two small projects have been submitted to Brazilian Federal Environmental Agency (Ibama) for environmental permitting.

#### Canada

Currently, Canada does not have any installed offshore wind projects.

Canada is a vast country with a low population density and an abundance of natural resources. In 2017 hydro-electric power made up 60% of the 652 GWh of electricity generated. The Canadian Hydropower Association says the country has the technical potential to generate double this amount of hydro electric energy, although not all of this would be environmentally acceptable or cost effective. Its low density also means that it has large areas which could be used for further onshore wind energy, which remains cheaper than offshore. Canada exports electricity to the USA and imports from it, with a net export of 48 GWh in 2017.
Canada has a CAD 200 million (€135 million) emerging Renewable Power Programme to support technologies such as offshore wind which are proven in other markets but not in Canada. It is managed by Natural Resources Canada, as part of the 2016 infrastructure programme Investing in Canada. To date no offshore projects have received funding. There is no funding scheme for commercial offshore wind projects.

Project development activity to date has been backed by two strong developers, but is faltering:

- Global market leaders Ørsted had an agreement with Naikun Wind Energy Group for a project with a first phase of 300 MW to 400 MW off the British Columbia (Pacific) coast. This was terminated in late 2018 so that Ørsted could focus on shorter term opportunities off the US East Coast. Naikun is exploring other partnership options. Meanwhile, its Investigatory Use License has expired and needs to be renewed.

- CIP has an agreement with Beothuk Energy to develop projects off the Nova Scotia (Atlantic) coast through a JV called Atlantic Canada Offshore Developments. A handful of projects are being progressed with a total potential of more than 3 GW, of which the front runner is St George’s Bay (180 MW).

A potential outcome is for these projects to export their energy to the densely populated US East and West coast states, if they can offset the additional cost of long transmission (500 km minimum) against the benefits of higher wind speeds and colder, denser air.
Appendix A - Supply chain area definitions

The supply chain area definitions used in section 3.2, Technology, supply chain and expenditure, and in the expenditure calculations are described in Table 3.

Table 3 Supply chain area definitions.

<table>
<thead>
<tr>
<th>Type</th>
<th>Element</th>
<th>Definition</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX</td>
<td>Development</td>
<td>Project development, consenting and project management work paid for by the developer up to WCD. Includes:</td>
<td>€/MW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Internal and external activities such as environmental and wildlife surveys, met mast (including installation) and engineering (pre FEED) and planning studies.</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>- Further site investigations and surveys after FID</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>- Engineering (FEED) studies</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Environmental monitoring during construction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Project management (work undertaken or contracted by the developer up to WCD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Other administrative and professional services such as accountancy and legal advice</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>- Any reservation payments to suppliers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Development costs of transmission system</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Excludes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Construction phase insurance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Suppliers own project management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Turbine</td>
<td>Includes:</td>
<td>€/MW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Payment to wind turbine manufacturer for the supply of the tower, nacelle and its sub-systems, the blades and hub, and the turbine electrical systems to the point of connection to the array cables</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Delivery to nearest port to supplier</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Warranty</td>
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<tr>
<td></td>
<td></td>
<td>- Commissioning costs</td>
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<tr>
<td></td>
<td></td>
<td>Excludes</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>- Turbine OPEX</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- RD&amp;D costs</td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Element</td>
<td>Definition</td>
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</tbody>
</table>
| **Foundation**   |                               | Includes:  
• Payment to suppliers for the supply of the support structure comprising the foundation (including any piles, transition piece and secondary steel work such as J-tubes and personnel access ladders and platforms)  
• Delivery to nearest port to supplier  
• Warranty  
Excludes:  
• Tower  
• Foundation OPEX  
• R&D costs                                                                 |
| **Array electrical** |                               | Includes:  
• Delivery to nearest port to supplier  
• Warranty  
Excludes:  
• OMS costs  
• RD&D costs                                                                 |
| **Transmission** |                               | Includes:  
• Payment to manufacturer for the supply of onshore and offshore export cables and onshore and offshore substations  
• Warranty  
Excludes  
• Development of transmission system  
• Installation of onshore and offshore substations and onshore and offshore export cables  
• Contingency and insurance for the transmission asset.                                                                 |
| **Turbine installation** |                               | Includes:  
• Installation of turbine  
• Generic installation elements:  
  • Transportation of components from each supplier’s nearest port  
  • Pre-assembly work completed at a construction port before the components are taken offshore  
  • Construction phase insurance cover, from start of construction until operation start, including all construction risks & third party  
  • Commissioning work (including snagging post WCD)                                                                 |
<table>
<thead>
<tr>
<th>Type</th>
<th>Element</th>
<th>Definition</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td><strong>Foundation installation</strong></td>
<td><strong>Includes:</strong></td>
<td>• Installation of foundation&lt;br&gt;• Generic installation elements, see turbine installation, above&lt;br&gt;• Scour protection</td>
<td>€/MW</td>
</tr>
<tr>
<td><strong>Array cable Installation,</strong></td>
<td><strong>Includes:</strong></td>
<td>• Installation of array cables&lt;br&gt;• Generic installation elements, see turbine installation, above&lt;br&gt;• Scour protection&lt;br&gt;• Subsea cable protection mats etc., as required</td>
<td>€/MW</td>
</tr>
<tr>
<td><strong>Transmission installation</strong></td>
<td><strong>Includes:</strong></td>
<td>• Installation of onshore and offshore substations and export cables&lt;br&gt;• Generic installation elements, see turbine installation, above</td>
<td>€/MW</td>
</tr>
<tr>
<td><strong>Insurance and contingency</strong></td>
<td><strong>Includes:</strong></td>
<td>• Construction phase insurance cover, from start of construction until operation start, including all construction risks &amp; third party&lt;br&gt;• Construction and other CAPEX phase contingency that is, on average, spent by the developer</td>
<td>€/MW</td>
</tr>
<tr>
<td><strong>Operation, maintenance and service (OMS)</strong></td>
<td><strong>Operation and planned maintenance</strong></td>
<td>Operation and planned maintenance includes:&lt;br&gt;• Operational costs relating to the day-to-day control of the wind farm&lt;br&gt;• Condition monitoring&lt;br&gt;• Planned preventative maintenance, health and safety inspections</td>
<td>€/MW/year</td>
</tr>
<tr>
<td><strong>Unplanned service and other OPEX</strong></td>
<td><strong>Unplanned service includes:</strong></td>
<td>• Reactive service in response to unplanned systems failure in the turbine or electrical systems&lt;br&gt;Other OPEX covers fixed cost elements that are unaffected by technology innovations, including:&lt;br&gt;• Site rent&lt;br&gt;• Operations phase insurance&lt;br&gt;• Contributions to community funds.&lt;br&gt;• Monitoring of the local environmental impact of the wind farm</td>
<td>€/MW/year</td>
</tr>
<tr>
<td>Type</td>
<td>Element</td>
<td>Definition</td>
<td>Unit</td>
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<tr>
<td>------------------</td>
<td>---------------</td>
<td>---------------------------------------------------------------------------</td>
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</tr>
</tbody>
</table>
| Transmission OMS | Transmission OMS includes: | - Planned maintenance and unplanned service of transmission assets  
|                  |               | - Grid use charges                                                       | €/MW/year |