May 2020

Offshore Wind Transmission 2020

Prepared by: **Global Transmission Research**

Topics covered in the report

Offshore wind developments

- Key growth drivers
- Cost competitiveness of offshore wind
- Offshore wind's promising attributes
- Targets and mandates for offshore wind
- Policy and regulatory developments

Market size and opportunity

- Existing and projected offshore wind capacity and export
- OSW export cables – top markets by 2030

Offshore wind transmission development routes

- TSO-owned and operated transmission
- Generator-owned links
- Offshore transmission operator (OFTO) model
- Independent offshore wind transmission – competitive solicitation
- Merchant offshore transmission

Offshore wind transmission technology

- Optimal network configurations, HVAC vs HVDC
- Subsea cables, Offshore substations, Structures and foundations; Construction, installation and monitoring solutions; Transmission for floating offshore wind

Key technology players

- Offshore cables
- Offshore transformers/substations
- Offshore structures

Offshore wind transmission costs

- Offshore wind project – transmission capex
- Key factors affecting OSW transmission capex
- Cost trends – cables and transformers
- OSW transmission investment by 2030
- OSW transmission investment in key markets

Offshore wind projects

- Americas; Asia Pacific; Europe

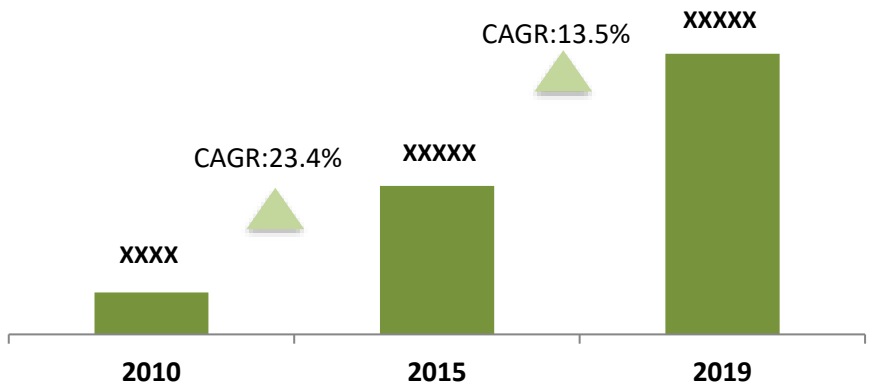
Country profiles

- Brazil
- USA
- Canada
- Belgium
- Denmark
- Finland
- France
- Germany
- Ireland
- Netherlands
- Norway
- Poland
- Portugal
- Spain
- Sweden
- UK
- Australia
- China
- India
- Japan
- South Korea
- Taiwan
- Vietnam

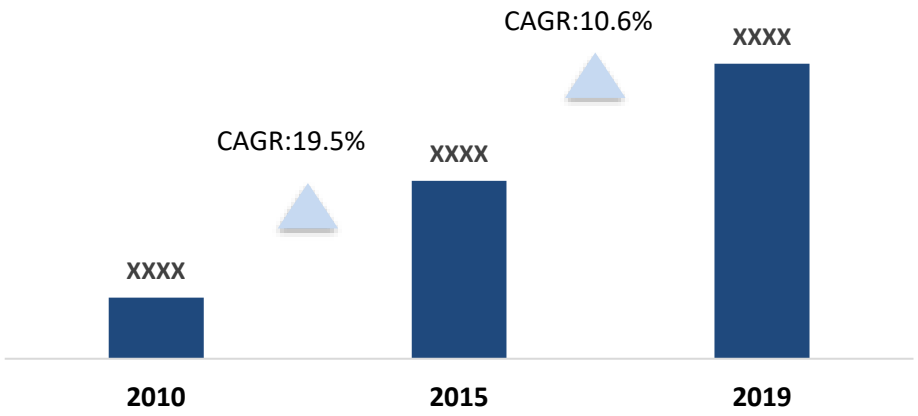
Each country profile file includes
- Industry structure
- Recent policy and regulatory developments
- Existing offshore wind generation and transmission capacity
- Planned or proposed offshore wind generation and transmission capacity
- Existing OWT projects
- Upcoming and planned OWT projects (developer, capacity, technology, expected investment and key contractors)

Executive summary (1/6)

Growth in global OSW capacity, 2010-19 (MW)



Growth in global OSW export cable length, 2010-19 (km)



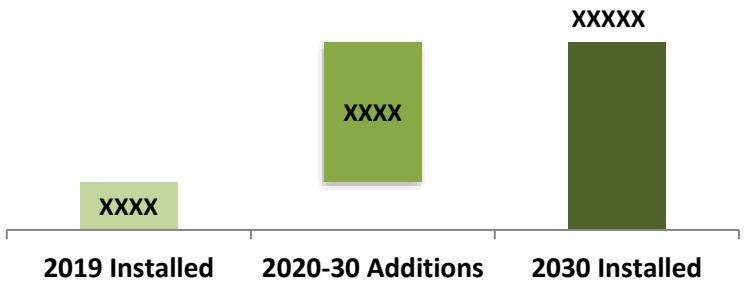
Source: Global Transmission Research

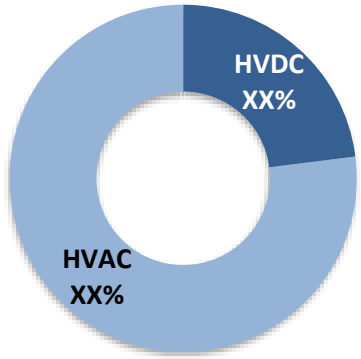
- The global installed offshore wind (OSW) capacity reached close to XX GW by the end of 2019, growing at a CAGR of 13.5% between 2015 and 2019.
- Supportive government policies and regulations have provided a big impetus to the development of OSW in recent years. This growth has been led by Germany, the UK and the Netherlands in Europe, and by China in the Asia Pacific.
- Export cables are an important element of the OSW project. The rapid expansion of the OSW sector has translated into a growth of almost 10.6%, between 2015 and 2019, in the associated export cable network The cumulative installed export cable length is estimated to be around XXXX km as of end-2019.

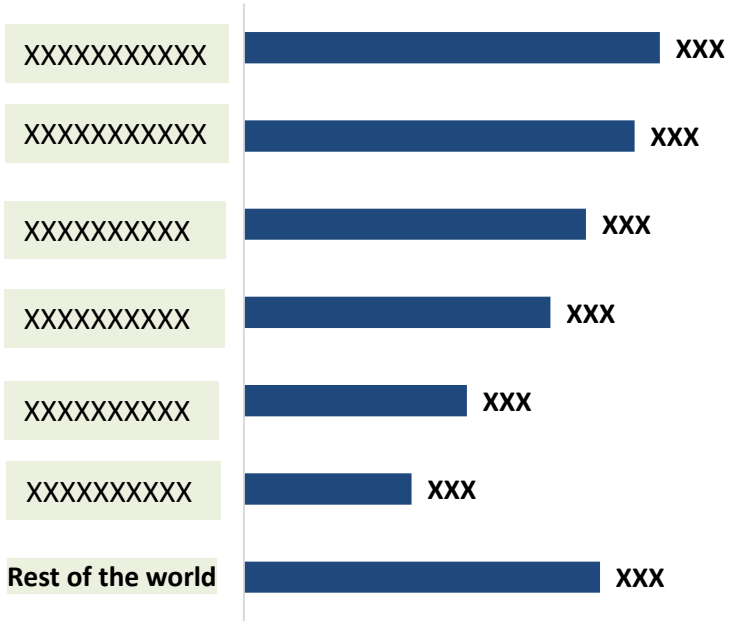
Executive summary (4/6)

- Expanding OSW industry is creating a huge demand for export cables, which in turn depends upon several factors, primarily the OWF's distance to shore and its size. The initial OWFs were built closer to shore. However, in recent years, the newer plants have moved farther into the sea waters. This trend is expected to continue to exploit better and more reliable wind resources found deeper into the oceans.
- About XXXXX km of OSW-related export cables would be needed for the planned OSW projects up to 2030. Of these, about XX% are expected to be HVDC cables, primarily for projects in Germany, the UK and the Netherlands.

Expected export cable length addition, 2020-30 (km)







Note: Rest of the world include: Poland, Ireland, Sweden, Norway, France, Canada, Finland, South Korea, Belgium, Australian, Denmark, Portugal and Japan
Source: Global Transmission Research

Executive summary (6/6)

- The expected expansion of the OSW industry presents huge investment opportunities, almost worth USDXXX billion by 2030.
- Of this, transmission-related investment is expected to be anywhere between USXX billion and USDXXX billion, translating into an average annual investment of around USDXX billion by 2030.
- Over the next decade, the key markets for OSW-related transmission investment will be the US, the UK, Germany, China, the Netherlands and Taiwan.
- Together, these markets will account for over 60% of the total expected investment in OSW-related transmission sector between 2020 and 2030.

Investment requirement by 2030, USD billion

	2019	2020-2030	Average annual capex, 2020-2030
Global OSW industry	XXX	XXX	XXX
Global OSW transmission	XXX	XXX	XXX

Source: Global Transmission Research

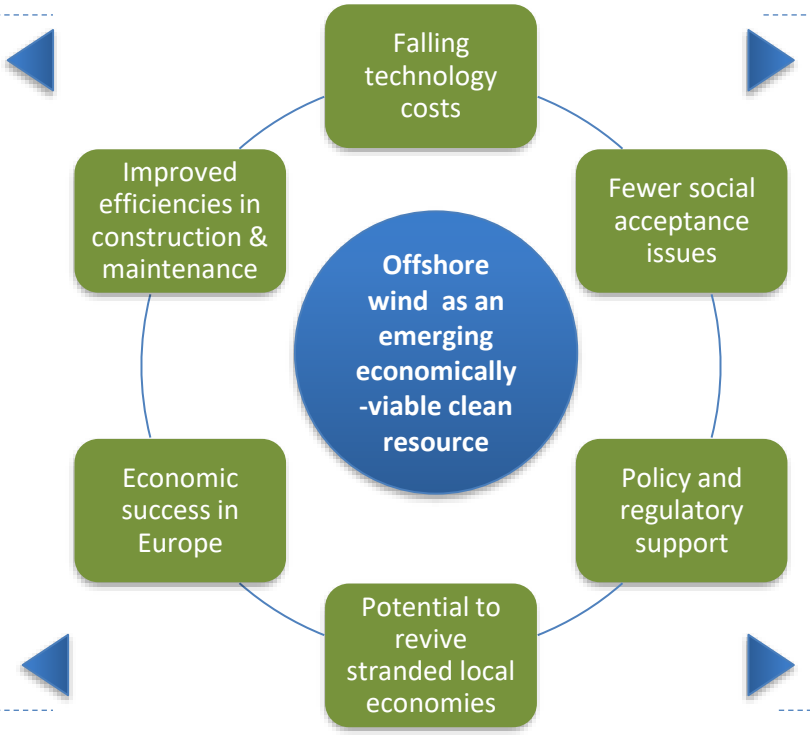
Key growth drivers

- Offshore wiind is surging ahead and is fast becoming a key component of the clean energy policies and agenda of governments around the world. While offshore wind accounts for only a fraction (<0.5%) of the world's electricity supply today, according to the International Energy Agency (IEA), it has the potential to generate more than 18 times the current global electricity demand over the next two decades and become a USD1 trilion industry by 2040.

Falling technology costs, demonstrated efficiencies in installation and maintenance, and, recent economic success in Europe is spurring offshore wind's global growth.

Offshore wind's potential role in creating jobs and boosting the local economy makes it one of the most promising investment avenues in the energy industry.

Operations and supply chain synergies with the oil and gas industry create new business opportunities for financially-stressed oil and gas players.



Significant improvements in capacity and availability factors have made offshore wind a reliable and secure RE resource.

Relatively fewer social acceptance issues compared with other sources of power generation (including onshore wind now in many developed economies), makes offshore wind highly attractive as a clean energy option.

Given offshore wind's vast exploitable potential, politicians are putting their weight behind offshore wind and regulators are drafting supportive legislation in many countries.

- Several emerging economies with strong offshore wind resources are also now keenly exploring this opportunity. These trends are perhaps one of the reasons for the World Bank and the International Finance Corporation (IFC) to launch a new programme to fast-track the adoption of offshore wind in some emerging economies. Through this programme, these two institutes aim to help emerging economies assess their offshore wind potential and provide technical assistance to develop a pipeline of projects that are ready for investment.

Targets and mandates for offshore (3/5)

	Germany	Japan	Netherlands
Targets	XX GW by 2030	XX GW by 2030	XX GW by 2023 and XX GW by 2030
Key government initiatives	Offshore Wind Act ; Draft Climate Action Law and Climate Action Program 2030; Zero-subsidy auctions	Offshore Wind Legislation; Port and Harbour Law	Offshore Wind Energy Act; Zero-subsidy auctions
Offshore transmission investment needs	USDXXX billion	USDXXX billion	USDXXX billion
Key market drivers	Achieve EU Cimate Action Plan targets; Huge potential; Enabling state policies	Greater emphasis on new energy technologies Easing government policies	Achieve EU Climate Action Plan targets; Clear and stable policy structure

OSW export cables – top markets by 2030

Top markets for export cable, 2020-2030

Country	Expected OSW Capacity, 2020-2030	Installed export cable length (km), 2019	Estimated addition in export cable length (km), 2020-2030	CAGR (%), 2019-2030	Remarks
XXXXX	XX GW	XX	XXX	XX%	The top six markets for OSW export cables account for close to 84% of the export cable installations by 2030.
XXXXX	XX GW	XX	XXX	XX%	
XXXXX	XX GW	XX	XXX	XX%	Among these, the US and Taiwan are two new entrants with aggressive OSW capacity targets.
XXXXX	XX GW	XX	XXX	XX%	
XXXXX	XX GW	XX	XXX	XX%	This analysis is based on the OSW projects expected to be completed by 2030. Any delays in clearances or approvals for these will impact the growth of the export cable installations.
XXXXX	XX GW	XX	XXX	XX%	
Rest of the world	XX GW	XX	XXX	XX%	

Note: This analysis s based on the OSW projects tracked in the countries covered in this report.
Source: Global Transmission Research

Independent offshore wind transmission – competitive solicitation

- Experience in independent offshore wind transmission through competitive solicitation is limited.
- Massachusetts, US is in the process of evaluating the independent transmission route through competitive solicitations.
- New Jersey amended its laws in January 2020 to add the definition of an open-access offshore wind transmission facility and qualified offshore wind projects. This allows the New Jersey Board of Public Utilities (NJBPU) to conduct competitive solicitations for offshore wind transmission to be conducted independently of OSW solicitations.
- In New York, the New York State Energy Research and Development Authority (NYSERDA) is analysing issues related to transmission options for the upcoming second OSW solicitation. Various stakeholders have been pitching for an open-access offshore wind transmission system in the state to maximise benefit given its ambitious offshore wind target.

Competitive solicitation in Massachusetts

DOER evaluates competitive solicitation route

- 2018 law allows the Massachusetts Department of Energy Resources (DOER) to require EDCs to solicit and procure proposals for independent offshore wind transmission.
- This may take place before the OSW solicitation in 2022
- In early 2020, DOER, in association with Massachusetts Clean Energy Centre (MassCEC), started gathering industry feedback to investigate possible structures of paired solicitations of independent offshore wind transmission followed by OSW generation.

Progress so far

- Round 1 wind solicitation under 2016 law required bidders to submit two separate bids – generator lead line (GLL) bid and expandable transmission network (ETN) bid (to create an open-access offshore network).
- Round 2 solicitation required two bids viz. GLL bid and GLL bid with commitment agreement (for voluntary access agreement with third-party developers)
- Both rounds followed Section 83C of the 2016 law to Promote Energy Diversity 2016 (which required the electricity distribution companies (EDCs) to procure 1.6GW offshore wind by June 2027)

Projects

- Selected Vineyard wind project in Round 1 included GLL only
- Selected Mayflower wind project in Round 2 includes a commitment agreement
- Possible independent offshore transmission solicitation structures under discussion

Offshore transmission solutions (5/5)

HVAC vs HVDC

HVAC

Pros

- Well proven technology
- Cost
- Dynamic rating application
- No need for converter station
- Small/Medium footprint onshore and offshore

Cons

- Limitations in very long length. However, proper compensation schemes will increase lengths possible
- Limitation in current carrying capacity

HVDC

Pros

- Reduced losses on very long distance compared to AC transmission
- Possibility to connect HVAC-networks with different characteristics

Cons

- Large footprint for Converters (Onshore and Offshore)
- Limited operational experience (in XLPE)
- Converter losses
- High O&M
- High cost

Applications/Trends

- 90% of the realised OWF grid connection projects in Europe are based on HVAC technology
- HVAC cable distance is being increased by enhancing reactive power compensation at both ends of the cable and at the cable mid-point (dynamic compensation system on an isolated platform)
- Power ratings of HVAC links is being increased from 132 kV to 220 kV, due to new XLPE cables
- Example: DONG's 600 MW Hornsea project 1 in UK is being built on HVAC over 150 km at 220 kV.

Applications/Trends

- OWFs in the German North Sea are using HVDC grid connection by clusters. The large size of OWF (900 MW) and distance to shore (> 150 km), HVDC was chosen over HVAC cables
- Further, most of the new projects in the UK (East Anglia, Dogger Bank, Hornsea) will also be linked via HVDC grid connection. In this case, as well, rated power (1,200 MW) and the distance to shore (> 130 km) was the deciding factor for choosing HVDC over HVAC.

Source: Presentations made by Nexans and GE at Global Transmission's conferences on Offshore Wind Transmission in USA in 2018

XXXXXXX

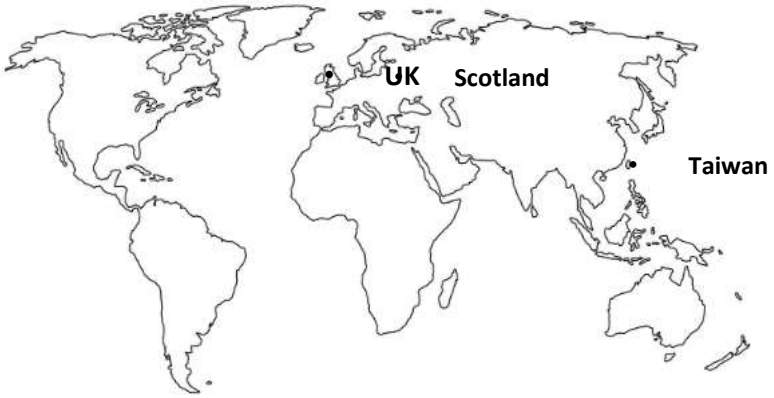
Key information	
Headquarters	Littleport, United Kingdom
Description	XXXXXX is a leading subsea cable supplier to the offshore wind industry. The company manufactures power cables, umbilical systems, and other accessories, as well as provide installation, maintenance, and field support services.
Manufacturing facilities	United Kingdom United States

In 2017, XXX **was acquired by Polish cable giant Tele-Fonika Kable (TFKable).** Both companies have a long history of collaboration, with TFKable being JDR's important business partner providing power copper cores for its cable and umbilical systems.

In 2018, XXXXX **won the contract for the world's biggest offshore wind farm** project-Hornsea Project Two, in the UK. The contract involves 66 kV, 100 km of inter-array cables and will come in operation by 2022.

In 2019, XXXXX **signed a memorandum of understanding (MoU)** with Taiwan's Ta Ya Group, an electric wire and land cable manufacturer, to collaborate on localisation opportunities in Taiwan.

Key Markets



Recent contracts		
Year	**Project**	**Details**
2019	Changhua Phase-I OWF Project (Taiwan)	65 km of inter-array and export cable
2018	Formosa 1 Phase 2 OWF Project (120 MW) (Taiwan)	13 km export cable; 21 km inter-array cable and 16 km of land cable
2017	714 MW East Anglia One offshore wind project (UK)	155 km, 66 kV inter array

Key planned or proposed OSW transmission projects (9/16)

Table 1: Planned or proposed OSW transmission projects

Project	Country	Transmission developer	Capacity (MW)	Export cable length (km)	Technology	Expected completion
Grussian Floating OWF	France	RTE	XXX	XXX	33 kV, AC	2020-21
Offshore Wind Production Connection – Courseulles-sur-mer	France	RTE	XXX	XXX	225 kV, AC	By 2025
Offshore Wind Production Connection –Fécamp	France	RTE	XXX	XXX	225 kV, AC	By 2025
Offshore Wind Production Connection – Tréport	France	RTE	XXX	XXX	225 kV, AC	By 2025
Offshore Wind Production Connection – Saint-Nazaire	France	RTE	XXX	XXX	225 kV, AC	By 2025
Offshore Wind Production Connection – Iles D'Yeu et de Noirmoutier	France	RTE	XXX	XXX	225 kV, AC	By 2025
Offshore Wind Production Connection – Dunkirk	France	RTE	XXX	XXX	225 kV, AC	2026
NOR-6-3 (BorWin4)#	Germany	TenneT	XXX	XXX	HVDC cluster connection	2029
NOR-10-1 OWF#	Germany	TenneT	XXX	XXX	HVDC cluster connection	2030
NOR-1-1 OWF	Germany	TenneT	XXX	XXX	HVDC cluster connection	2024
NOR-11-1 OWF#	Germany	TenneT	XXX	XXX	HVDC cluster connection	After 2030
NOR-11-2 OWF#	Germany	TenneT	XXX	XXX	HVDC cluster connection	After 2030
NOR-12-1 OWF#	Germany	TenneT	XXX	XXX	HVDC cluster connection	After 2030
NOR-12-2 OWF	Germany	TenneT	XXX	XXX	HVDC cluster connection	NA

Continued…

Note:#–The projects have been approved by Benetza in the Bestätigung des Netzentwicklungsplans (NEP) Strom für das Zieljahr 2030, published in December 2019.

Recent policy and regulatory developments

Draft Climate Action Law and Climate Action Program 2030

- A draft Climate Action Law and Climate Action Programme 2030 was released in Q3 2019, stipulating 55% emissions cut goal for 2030 and outlining sectoral targets; increasing the share of renewables in total consumption to 65% by 2030; phasing out of coal-fired generation by 2038 (through a separate law); revising expansion target for offshore wind from 15 GW to 20 GW by 2030; removing support cap for solar PV currently at 52 GW capacity. Germany also plans to gradually reduce the country's trademark renewables surcharge and other policy related components of power price such as grid fees to lower electricity prices.

Renewable Energy Sources Act (EEG) 2017

- The EEG 2017, which marked the new stage of Energiewende, adopted the auction system for new renewable energy projects. It set the target of generating 35% of supply from RES by 2020, 40-45% by 2025 and 55-60% by 2035 and 80% by 2050. The interim targets were limited from previous levels due to slow progress in grid expansion.
- Starting from 2017, funding rates for RES are determined through a competitive auction procedure in which the plant operators submit bids for funding. Each year 5% of newly installed renewable capacity will be opened up to installations from other EU member states. For instance, Germany and Denmark for the first time held cross-border auctions in Europe open to bidders with installations in either country in the second half of 2016.
- The target for installed capacity for offshore wind is to reach 6.5 GW by 2020 and 15 GW by 2030. It may, however, be noted that the 2020 targets were surpassed in 2019 with the country achieving 7.5 GW of installed offshore wind capacity and there are plans to expand 2030 targets to 20 GW as mentioned above.

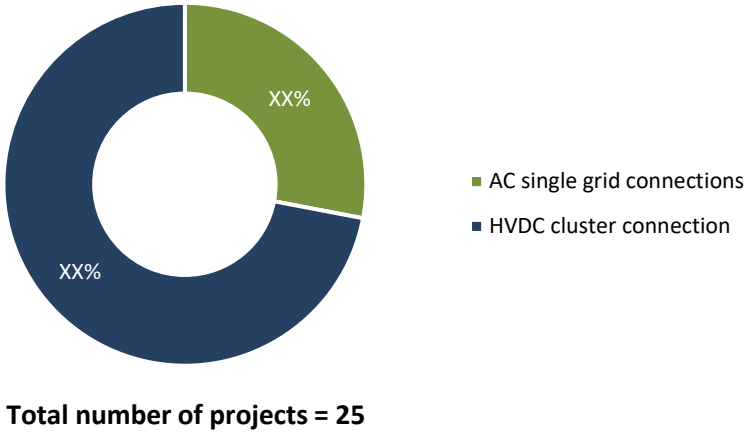
Offshore Wind Act (Wind-auf-See-Gesetz or WindSeeG) 2017

- Germany also introduced the Offshore Wind Act in 2017. Under this, a central model (where projects will be tendered only in areas with pre-examined land development plans) will be followed for projects tendered after 2020 to ensure sychronised expansion of wind energy capacity and offshore connection lines. With this, the BSH became responsible for the development and preliminary investigation of areas for the construction and operation of wind energy projects.
- The central model outlines a tiered planning and tendering process. In the first step, the areas of wind energy are defined spatially and temporally in the Offshore Area Development Plan or Flächenentwicklungsplan (FEP). BSH then pre-examines the defined areas. Thereafter, the areas will be auctioned in a competitive process by the BNetzA whereby the results of the preliminary investigation will be available to the bidders. The successful bidder who is awarded the contract can build the project after going through the approval process. Such developers are entitled to the market premium and may use the connection capacity of the power line.
- BSH published the first FEP in June 2019 which provides specifications for OSW turbines and grid connections for commissioning from year 2026 to at least 2030. Its scope relates to the German exclusive economic zone in the North and Baltic seas.
- Germany plans to hold annual offshore wind auctions of 700-900 MW (not more than 860 MW on an average) under the central model. The offshore developers will be granted a 25-year operation rights period. At the end of this period, the site may be re-auctioned or assigned for a different purpose.

Planned offshore wind generation and transmission capacity

Planned offshore wind capacity (GW)

Planned offshore transmission projects by technology (%)



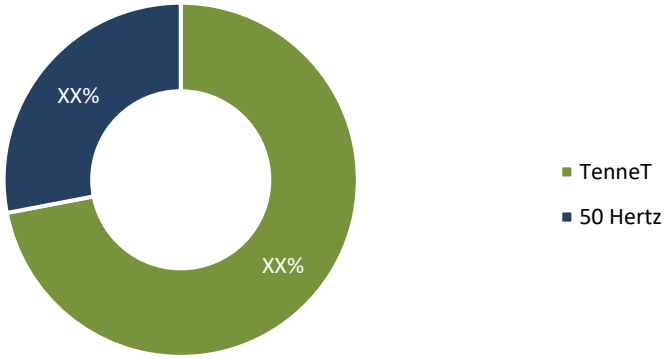
Total number of projects = 25

Expected growth in offshore wind industry

- Germany has officially announced a target of 20 GW of OSW capacity by 2030.
- According to Federal Ministry for Economic Affairs and Energy, Germany has planned to develop about 25 projects by 2030, which are at various stages of tendering.
- According to industry representatives, Germany's long-term OSW plans should include capacity expansion to over 50 GW by 2050.

Source: Federal Ministry for Economic Affairs and Energy Global Transmission Research

Planned offshore transmission projects by TSO (%)



Total number of projects = 25

4.1 Sources and methodology

- Global Transmission Research's industry analysts have utilised various primary and secondary research sources in preparing this report. Extensive secondary research has been conducted by our analysts and research associates. These secondary sources include, but are not limited to, websites of OSW developers; websites of regulators and government agencies; investor presentations; analyst reports; government documents; websites of relevant industry associations; internal and external proprietary databases; news articles; and press reports.

- Primary research includes interviews conducted to gain insights into market trends, and cost and investment analysis. While estimating costs and investment figures, we have also researched the available industry literature and reports.

- These primary and secondary research sources, combined with our industry expertise, have been synthesised into qualitative and quantitative analysis which has been presented in this report. Wherever applicable, all research sources are appropriately cited within this report.

- Please note that this report does not take into account any possible impact of the ongoing COVID-19 situation on the investment analysis. It very likely that the industry will see delays and cost overruns. Therefore, we have taken a longer-term analysis period of 2020-2030.

- Great care has been taken to ensure that all analysis is well supported by facts. Where facts were not available and assumptions were made, we have explained our assumptions and our methods of estimation.