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## Case Studies

### London Array - UK (630MW)

London Array is the world's largest offshore wind farm with a capacity rating of 630MW. It is located nearly 20 km off the Kent coast in the outer Thames Estuary, Great Britain. It was planned as a two-phase project with a total capacity of 1 GW, out of which phase-I of the project comprises 175 wind turbines of the type Siemens SWT-3.6-120 with a rated capacity of 3.6 MW each.

The project is owned by a consortium of four stakeholders, out of which three are world-leading renewable energy companies and the fourth one is a global investor having large institutional fund managers from Canada and North America, the individual shares holding by respective parties are as:

- E.ON (30%)
- Ørsted (25%)
- Masdar (20%)
- La Caisse de dépôt et placement du Québec (25%)

The construction work for the first phase was initiated in the year of 2011 whereas the first wind generator got commissioned in January 2012. Phase I of the project got fully commissioned in mid of 2013 which is presently operated by Ørsted.

Phase II was consented for 370 MW. The consortium behind London Array announced in 2014 that it will not proceed with the development of Phase 2 of the offshore wind farm, pointing out technical challenges, environmental uncertainties and concerns regarding impact on regional avifauna.

The developments were not allowed from 8 to 13 kms offshore in order to minimize the visual impact and to avoid shallow feeding grounds for sea birds.

A number of European suppliers were selected to provide the core components and expertise needed to construct Phase 1 of London Array. These are:

- **Construction and Erection of Wind Turbines:** Siemens Wind Power
- **Transport, logistics and installation of wind turbines:** Per Aarsleff A/S and Bilfinger Berger Ingenieurbau GmbH
- **Design, construction and installation of foundations:** Per Aarsleff A/S and Bilfinger Berger Ingenieurbau GmbH
- **Design and construction of offshore substations:** Future Energy, a joint venture between Fabricom, Lemants and Geosea
- **Installation of offshore and onshore substations' electrical systems:** Siemens Transmission and Distribution Limited
- **Design and construction of onshore substation:** Siemens Transmission and Distribution Limited
- **Production of export cables:** Nexans Norway AS
- **Production of array cables:** JDR Cable Systems
- **Installation of all cables:** Visser & Smit Marine Contracting
- **Supply of vessels:** MPI and A2SEA

#### Project Specifications

- a. **Onshore Substation:** The onshore substation, at Cleave Hill near Graveney, on the north Kent coast connects to the offshore turbines via undersea cables buried in the seabed. Each 1 m length of the export cable weighs over 88 kg. From the substation, electricity is fed directly into the existing 400 kV National Grid transmission network.
- b. **Foundation:** Each wind turbine is placed on foundations consisting of a monopile and a transition piece. The monopiles measure up to 68 m tall and 5.7 m wide, and weigh up to 650 tonnes. A total of 177 monopiles – one for each of the 175 wind turbines and two for offshore substation – were installed for the Phase 1 of the project.
- c. **Wind Turbines:** The turbines for Phase 1 were supplied by Siemens Wind Power and are fitted with Siemen's new 120 m rotor. Each turbine has a hub height of 87 m above sea level.
- d. **Offshore Substation:** London array's Phase 1 wind turbines export electricity at 33 kV. The transformer in the two offshore substations increases this to 150 kV. The two substation topsides are identical and are built on three levels, with an area of around 20m x 20m. Each assembled and fully equipped topside weighs around 1,250 tonnes.

- e. **Array Cables:** The array cables are much shorter than the export cables, measuring 720m to 3,100m long.
- f. **Export Cables:** The cables are laid and buried into the seabed using a plough from a cable installation barge. All four cables are installed in continuous lengths over 50 km. The export cables also hold vital fibre optic wires that are used to communicate remotely with the wind turbines.

The Phase 1 of the project has already set a record for the amount of electricity produced by an offshore wind farm in a single calendar month. It has been observed that during the winter winds i.e. from October 2013 to March 2014, the machines had produced 1.5 TWh of clean energy. The strong performance of the turbines were able to touch the peak generation at 630.9 MW capacity which was more than the installed rated capacity. The passing year witnessed generation crossing the 5 TWh mark which is equivalent to the annual consumption of 1.2 million UK households. Correspondingly, it has prevented 2.15 million tonnes of carbon dioxide to release to the atmosphere.

### **Greater Gabbard Offshore Windfarm - UK (504MW)**

The Greater Gabbard Offshore Wind Project is located 25km off the coast of Suffolk in the North Sea, adjacent to two sand banks: the Inner Gabbard and The Galloper. It is a joint project with RWE npower renewables (50%), a UK subsidiary of RWE Innogy, and Scottish and Southern Energy (50%). The project construction started in September 2009 and was commissioned in September 2012. The Greater Gabbard Offshore Windfarm spreads over an area of 147 sq. km and is situated 26 km away from the shore at about 24-34m water depth.

This wind farm comprises of 140 Siemens wind turbines, make: SWT-3.6-107, totaling to 504 MW installed capacity and an annual estimated production of 1,749 GWh per year. The estimated capacity factor of this wind farm is 40%. Each wind turbine is 131 m high and the hub height is 77.5 meter above sea level. They are installed on 140 steel monopiles, weighing 300 tonnes each, which are driven 30m into seabed. Greater Gabbard will contribute 20% of the UK's renewable target by 2020 and 60% by 2050.

The new Galloper wind farm, being developed beside the Great Gabbard project site, under the state's extension programme by the Crown Estate, is to increase the existing capacity of the round one and two wind farms (<http://fes.nationalgrid.com/media/1324/davidfloodround3windfarms.pdf>) by 2GW.

### **Gode Wind Farm - Germany (582 MW)**

Gode Wind 1, 2 and 3 are offshore wind projects that are developed by Ørsted. Located at a distance of 45 km off the shores and around 33km from the islands Juist and north-west of Norderney in the German sector of North Sea, this is Germany's biggest offshore wind farm. While Gode Wind 1 and 2 are operational, Gode Wind 3 is being developed.

The first foundation was successfully installed on 14 April, 2015, at the Gode Wind Offshore Wind Farm with the first turbine being installed in August 2015. The combined capacity of the three projects would be up to 900 MW. Gode Wind 1 has a capacity of 332 MW, Gode Wind 2 has a capacity of 252 MW and Gode Wind 3 will have a capacity of 316 MW. The wind farms comprise of 97 direct drive Siemens SWT-6.0-154 wind turbines generating up to 582 MW. Each turbine installation comprises of a monopile. The 67 m long monopiles, with a diameter of 7.5 m and weighing 939 tonnes, are the largest and heaviest monopiles which have ever been installed in the German part of the North Sea.

Source: Power-Technology.com

### **Anholt Offshore Windfarm - Denmark (400MW)**

Anholt offshore wind farm project is a Danish offshore wind farm in the Kattegat Sea. Located between Djursland and Island of Anholt, this wind farm is situated at water depths of about 15 to 19 meters. Construction works began in January 2012 and the project was commissioned in September 2013. It is the third largest offshore wind farm in the world and the largest in Denmark at 400 MW capacity. It caters to 4% of the total electricity consumption in Denmark, which is equivalent to consumption of 400,000 households in Denmark, using carbon dioxide free power.

DONG Energy (50%), Pension Danmark (30%) and PKA (20%) jointly own the wind farm. The majority shareholder DONG Energy operates the wind farm. The Danish transmission system operator, Energinet.dk, was responsible for construction of the offshore substation and establishing the export cable connection with the shore and to the main high-voltage power grid on land. A 25km-long export cable was laid to connect the wind farm to the national grid at Trige.

The total project site area is 144 sq. km, out of which actual area occupied by the wind farm is 88 sq. km. The windfarm is located about 15 km away from the shore and is approximately 15 km long and 5km wide with 111 Siemens wind turbines of 3.6 MW. The total height of each wind turbine is 141.6m and rotor diameter is 120m. Each unit weighs 450 tonnes and the cut-in and cut-out wind speeds of the turbine are 4m/s and 25m/s respectively.

Source: [http://assets.dongenergy.com/DONGEnergyDocuments/com/Business%20Activities/Wind%20Power/Anholt%20Offshore%20Wind%20Farm%20\(EN\).pdf](http://assets.dongenergy.com/DONGEnergyDocuments/com/Business%20Activities/Wind%20Power/Anholt%20Offshore%20Wind%20Farm%20(EN).pdf)

## **BARD Offshore 1 Wind Farm - Germany (400MW)**

BARD Offshore 1 (BO1) wind farm is located around 100 km north-west of Borkum Island in the North Sea. The project area covers approximately 60 sq. km and has a water depth of about 40 to 44 meters. The project is owned by SudWestStrom Windpark (70%) and KNK Ocean Breeze (30%). The wind farm was developed by BARD Engineering and construction started in April 2010. Bard Offshore 1 windfarm was commissioned in August 2013. The wind farm has total capacity of 400 MW and annual production figures amount to 1.6 TWh. BO1 supplies green energy to approximately 400,000 households in Germany.

Bard Offshore 1 consists of 80 Bard 5.0 wind turbines of 122m rotor diameter and a hub height of 90 m. The foundation of each turbine weighs 239 tonnes and is a tri-pile structure consisting of three pylons and one transition piece. Each pylon weighs 72 tonnes and the ancillary structure weighs 23 tonnes. BO1 has installed 80 tripod foundation structures which weigh 80 tonnes, consisting of three pylons and one transition piece that are specially engineered for far offshore installations.

Electricity generated from BARD Offshore I will first be transmitted to the Borwin I (Alpha) Offshore platform and then to Diele substation onshore, 75km off the coast. The AC transformer at the Borwin I (Alpha) Offshore platform will convert the power into high-voltage direct current (HVDC), before transmitting it to the German power grid through a 200 km cable line. The substation further feeds it to the 380kV German national grid.

BARD Offshore wind farm has generated more than 5 TWh of electricity so far and is the first German offshore windfarm to reach this mark. The wind farm is running stable and is at full capacity.

Source:

<http://www.oceanbreeze.de/en> (<http://www.oceanbreeze.de/en>)

<https://www.power-technology.com/projects/bard-offshore-i-north-sea-german/> (<https://www.power-technology.com/projects/bard-offshore-i-north-sea-german/>)

## **Hywind Scotland Pilot Park- UK (30 MW)**

The Hywind Project is a joint venture between Statoil (75 %) and Masdar (25 %), and is the first floating offshore wind farm project in the world. Located about 25 kilometers off the coast of North-East Scotland and in the depth range of 96m -110m in the North sea, the HYWIND-II, comprises of 5 Siemens SWT 6.0-154 wind turbines (6MW). The height of each wind turbine is 178m and rotor diameter is 154m. The tower head mass of each wind turbine is 360 tonnes and the cut-in and cut-out wind speeds of the turbine are 3-5m/s and 25m/s respectively. Although offshore wind farms have been developed since the 1990s, this project aims to open doors for offshore wind farm project development in deep sea conditions. Hywind can be used for water depths up to 800 meters which is way more than the usual offshore wind projects. This project also comes with various other advantages mainly minimizing visual impacts, plummeting offshore wind prices etc.

Tom Delay, CEO, 'The Carbon Trust' said, "A decade ago Beatrice Offshore Wind Demonstrator in the Moray Firth was the world's first deep-water project with fixed foundations. Today marks another crucial milestone in the development for offshore wind, and again it is happening in Scotland – the world's first commercial floating wind project."

HYWIND II project is expected to provide clean energy to over 20,000 homes and will see a reduction of about 94,000 tonnes of CO2 as compared to fossil fuel energy. The Feed in Tariff is \$ 65/MWh of electricity that is fed into the Scottish Grid. The project even has the provision of battery storage. Each of the Hywind turbines is installed with a battery bank for energy storage. Statoil has installed batteries from one of its own projects – Batwind, which provides battery storage solution for offshore wind. The battery bank can store 1 Megawatt-hour of energy and will assist in smoothening of the grid.

Source: Statoil.com

## **Alpha Ventus - Germany (60 MW)**

Alpha Ventus is Germany's pilot offshore wind farm project. Constructed by a consortium of EWE, E.ON and Vattenfall Europe, the total cost involved in this project is 250 mill.Euros. The project is located at a distance of 56km north of the island of Borkum.

The hub heights of the Senvion 5M and Areva Wind M5000-116 are 117m and 90m, respectively. The cut-in and cut-out wind speeds of the turbine are 3.5-4 m/s and 25m/s respectively.

The construction of Alpha Ventus offshore windfarm started in 2008 and the project was commissioned on 27th of April 2010, kick starting Germany's journey to reach an installed offshore wind capacity of 25,000 MW by 2030.

EWE AG holds 47.5% of the stakes in this joint venture with the rest of the shares split equally between E.ON Climate & Renewables GmbH and Vattenfall Europe Windkraft GmbH (26.25% each). EWE manages the operations of the wind farm whereas TenneT operates the offshore transmission (export cables and onshore substation).

The project achieved impressive operational results with a capacity factor of more than 50 % (4,450 full load hours) in its first operational year. In February 2014 the milestone of total accumulated production of 1 TWh was reached. From 2011 to 2016, the wind farm has produced on average 242.3 GWh yearly, which corresponds to the annual consumption of approximately 69200 households.

Source: <https://www.alpha-ventus.de/english/page/2/> (<https://www.alpha-ventus.de/english/page/2/>)

## **Vindeby Offshore Wind Farm-Denmark (4.95 MW)**

Vindeby offshore wind farm was the first ever offshore wind farm in the world. The project was located off the coast of Denmark, west of Lolland in a depth range of 2 to 4 meters and was commissioned in the year 1991. This project was owned and operated by Orsted A/S formerly known as DONG Energy. The wind farm was spread across 10 square kilometers and was located around 1.8 kilometers from the coast. The project included 11 B35/450 Bonus turbines with each turbine having a capacity of 0.45 MW with a hub height 35 m and a rotor diameter of 35 m. The foundation used for each turbine was gravity based.

Providing clean energy to the Denmark grid, the electricity generated from Vindeby Offshore wind farm could power approximately 3000 homes per year. The project remained and has exceeded the designed life of WTGs till Orsted A/S completed the decommissioning of wind farm in September 2017. The wind farm has produced a total energy of 243 GWh in its lifetime of 25 years.

Leif Winther, Senior Lead Business Developer in DONG Energy, said "And the tale of the world's first offshore wind farm off Vindeby on Lolland will be preserved for posterity with one wind turbine from Vindeby Offshore Wind Farm becoming part of the exhibition at the Danish Museum of Energy in Bjerringbro in Jutland".

Source: [Windpowerengineering.com](http://Windpowerengineering.com)

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