# Offshore Wind Farms

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People have been harnessing the wind for thousands of years, first to propel boats along the water, then for pumping water and grinding food, and now as a source of electricity (Wind Energy Foundation, 2014). Oil shortages in the 1970’s increased interest in alternative energy sources and wind power has become increasingly popular (Wind Energy Foundation, 2014). As onshore wind farms are growing in popularity, offshore wind farms are slowly entering the market for harnessing wind energy due to the push by the commitments laid out in the Kyoto Protocol to decrease carbon dioxide emissions (Esteban, Diez, López, & Negro, 2011). In 2007 wind energy reached 1% of generated electricity in the world for the first time (Esteban, Diez, López, & Negro, 2011). The first offshore wind turbine was set up in Sweden in 1990 (Esteban, Diez, López, & Negro, 2011). Currently offshore wind farms are primarily being built off the coasts of Western European countries (Esteban, Diez, López, & Negro, 2011).

Most wind turbines consist of three aerodynamic rotor blades that turn when wind passes over them creating lift. The turning blades spin the low-speed shaft, located in the gearbox, about 30 to 60 rotations per minute (rpm), which is connected to the high-speed shaft that boosts the rotation speed to about 1000 to 1800 rpm (European Wind Energy Association, 2014). The rapidly spinning shaft drives the generator to produce electric power that goes into the transformer, where it is transformed in to the right voltage for the larger electricity grid (European Wind Energy Association, 2014). Wind turbines generate energy at wind speeds of 9 miles per hour (mph) to 56 mph (European Wind Energy Association, 2014). If the wind reaches a faster speed the wind turbine stops to keep from being damaged (European Wind Energy Association, 2014). Additionally, the larger the radius of the blades the more energy can be produced (European Wind Energy Association, 2014). Offshore wind turbines tend to have bigger blades due to available space. Wind turbines produce more energy near sea levels due to the denser air, which exerts more lift on the rotor (European Wind Energy Association, 2014). Normally the wind blows more consistently at sea level, providing a more reliable amount of energy. Space, denser air, and consistency are a few reasons why it is beneficial to build offshore wind turbines.

Offshore wind farms may produce more energy than onshore wind farms, but building them is more difficult as conventional foundations cannot always be used due to deeper waters or water conditions. The three most common offshore support structures are monopile, tripod, and jacket (Lozano-Minguez, Kolios & Brennan, 2011). Monopile consists of a tubular structure that is driven into the seabed and used for water depths of up to 25 meters (Lozano-Minguez et al., 2011). Tripod is a three-legged structure that is generally used in water depths of 25 to 50 meters (Lozano-Minguez et al., 2011). Then there is the jacket structure, which is four-legged and interconnected with bracings and used in water depths of 25 to 50 meters (Lozano-Minguez et al., 2011). To decide which structure is best for the circumstances depends on the seabed geology and soil, environmental impacts of each structure, how economical it is, and the wave and tidal effects (Lozano-Minguez et al., 2011). The tripod structures seem to be the best option generally, however the monopile is more economical and less harmful to the environment (Lozano-Minguez et al., 2011).

The monopile is what is used in the London Array offshore wind farm in the Thames Estuary, which officially opened in 2013, and is the largest operational wind farm in the world (London Array Consents Manager, 2005). The London Array was originally planned to include 4 phases (shown by the black dashed lines) and is placed between Kent and Essex County, with the cable route (delineated by the parallel red and grey lines) running southwest towards Cleve Hill in North Kent (Figure 1) (London Array Consents Manager 2005). Phase 1 of this project consists of 175 wind turbines that can power half a million UK homes and reduce harmful carbon dioxide emissions by about 900,000 tons a year (London Array Consents Manager, 2005). The project was expected to have multiple phases, but the rest have been halted due to environmental concerns regarding the red-throated diver (London Array Consents Manager, 2005).

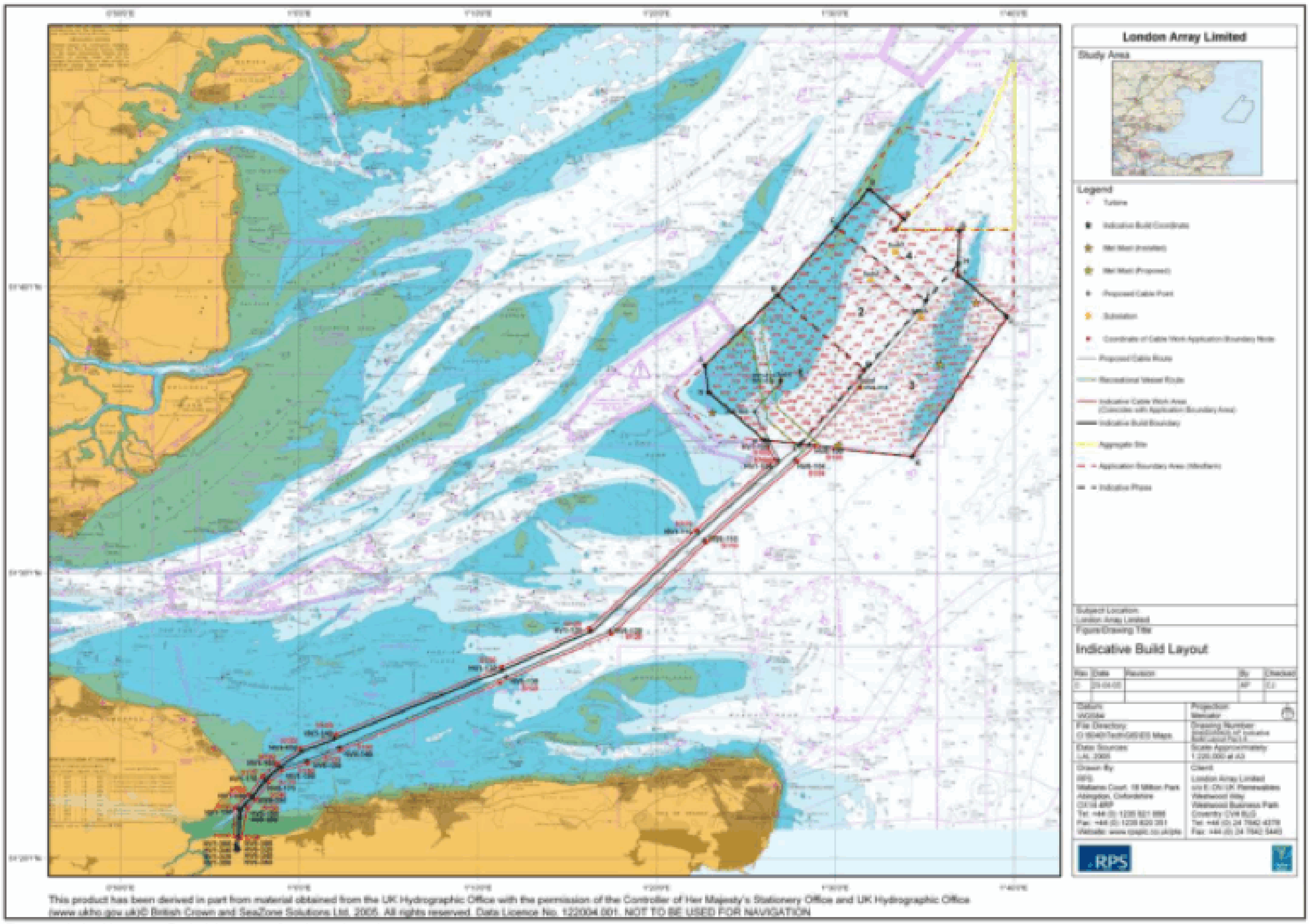


Figure 1. Indicative Build Layout for London Array.

**Figure 1**: The planned layout of the London Array. The location within the London Estuary of the proposed wind farm is shown along with the layout of the four phases, each planned wind turbine, and the cable route (London Array Consents Manager, 2005).

Before any construction could commence at this location an environmental impact assessment had to be performed to confirm this site as suitable. Their findings were that physical damage would only occur during the construction phase with the burying of the cables and putting in the foundations (London Array Consents Manager, 2005). Any worry of scour – erosion of the seabed surface – was not expected, if the cables were buried at a sufficient depth (London Array Consents Manager, 2005). Then any environmental impacts on organisms in the surrounding area were studied. The birds most at risk were found to be the red-throated divers (London Array Consents Manager, 2005). It was found that 1/3 of the red-throated diver's UK population over winters in the Thames Estuary, which is a much greater number than previously thought (London Array Consents Manager, 2005). Therefore, during peak diver period, mid-November to mid-March, construction was halted (London Array Consents Manager, 2005). Now they are worried that if they continue expanding the wind farm as planned it might cause more displacement of these birds, so further studies are under way (London Array Consents Manager, 2005).

Wind farms offer high risk for birds as they are at danger of collisions with wind turbines. There is also the fear that the wind turbines might displace populations or cause birds to avoid the farm altogether to avoid perceived risk (Drewitt & Langston, 2006). Collision risk is higher with larger wind turbines and faster rotor speeds, which are more common in offshore turbines (Drewitt & Langston, 2006). Displacement of birds from the surrounding area due to visual intrusion or noise of wind farms can lead to substantial habitat loss (Drewitt & Langston, 2006). Birds may also change their migration or local flyways to avoid the wind farm, which can increase energy expenditure and might disrupt linkages between feeding, roosting, and breading areas (Drewitt & Langston, 2006). There is not yet much information on the possible avoidance movements of bird species that are usually of concern in offshore wind farm locations (Drewitt & Langston, 2006).

Besides conducting studies on birds, the possible environmental effects of offshore wind farms on the marine ecology, fish, and marine mammals are also being investigated (London Array Consents Manager, 2005). In the London Array, the cable route was changed to avoid damaging eelgrass and mussel beds (London Array Consents Manager, 2005). Other than that, the only disturbance to the marine ecology would be during construction (London Array Consents Manager, 2005). Construction would also affect the fish and marine mammals due to the noise levels (London Array Consents Manager, 2005). In the Thames Estuary there is a diverse number of species, including ten species of sharks and rays and 100 bony fish (London Array Consents Manager, 2005). However, it is thought that post-construction there will be long-term benefits to the fish and marine mammals, as the fish will aggregate around the foundations, acting as artificial reefs, while fishing in the area decreases, which will increase the amount of prey for larger fish or marine mammals (London Array Consents Manager, 2005).

These studies were conducted before the construction of the London Array, as legislation required. However, for many wind farms post-construction investigations are not common, so the long-term impacts are not completely known (Fox, Desholm, Kahlert, Christensen & Krag, 2006). Knowing the long-term impacts of offshore wind farms is key for future development and creation of wind farms. A study done by Wilson and Elliot in 2009 found that wind farms might actually compensate for habitat loss by creating habitats in their support structures and acting as a refuge for a number of species, specifically fish, since their hearing is not as sensitive. However, for marine mammals it may give them less of an area to live in as the noise of just a small wind turbine is greater than ambient noise when 100 meters from the turbine (Thomsen, Lüdemann, Kafemann, & Piper, 2006). This is demonstrated in Figure 2, which shows the pressure levels of a wind turbine in operation at 27 mph from 100 meters away is greater than the ambient noise, as well as the audiograms of both porpoises and seals (Thomsen et al., 2006). Bigger turbines, which are planned for most offshore wind farms, are much noisier than the one used in Figure 2, and could negatively affect marine mammals, such as harbor seals or porpoises (Thomsen et al., 2006).

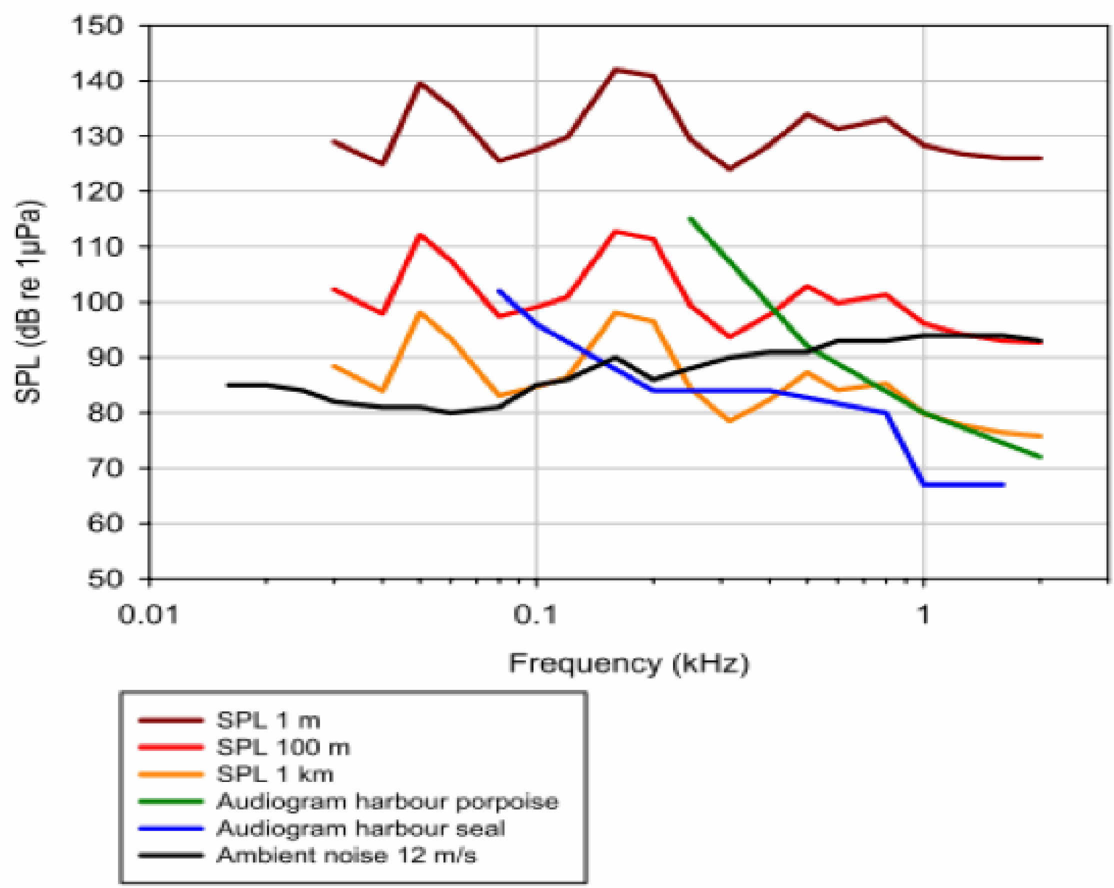


**Figure 2**: Sound pressure levels of offshore wind farm in operation at different distances from the source compared to the audiogram of harbor porpoises, harbor seals, and ambient noise. Measured by sound pressure level (SPL) given in decibels (dB) at the different frequency levels measured in kilohertz (kHz). At 100-meter distance, turbine noise would be

audible to both harbor porpoises and harbor seals (Thomsen et al., 2006)

The long-term environmental effects are still unknown and further techniques need to be developed to learn more. However, as countries, particularly European countries, are running out of landmass, they are turning to the water to build their wind farms and harness energy as it avoids land disputes, and noise and visual impact for humans is greatly reduced (Henderson, Morgan, Smith, Sørensen, Barthelmie, & Boesmans, 2003). So far they have had lots of success even though the technology is still in its early stages (Breton & Moe, 2009). Denmark and the UK have been the leaders in offshore wind farms, but as the demand for more renewable energy grows other European countries, such as Germany, Netherlands, Belgium, France, and Spain, are working on plans for offshore wind farms (Breton & Moe, 2009). North America is just in the planning stage concerning offshore wind energy, but the potential is enormous (Breton & Moe, 2009). As the technology improves and the demand for alternative energy sources keeps growing, offshore wind farms will grow in number around the world.

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