ENERGY YIELD PREDICTION
AN OFFSHORE GUIDE
LESSONS LEARNED AT SEA

In this, the second in our guide series, we draw on our experience analysing offshore wind farms and wind data for research, tender, acquisition and operation. Our goal is the unbiased estimation of energy yield, with the lowest feasible uncertainty.

Here are some highlights of our recent involvement offshore:

**Tender: Borssele I & II (700 MW) offshore wind resource and energy yield assessment**

Using an innovative ensemble approach to predicting site wind speed that considered a host of data sources, Prevailing was able to predict the resource of a Dutch offshore wind farm with a lower uncertainty than could have been achieved through sole reliance on site measurements.

**Acquisitions: Investment due diligence**

Yield review and analysis of offshore projects to support valuation by institutional investors during competitive divestment processes.

**Analysis: Offshore wind map validation dataset**

Analysis of approximately 45 years of offshore met mast wind measurements, to provide a series of validation points for the Met Office offshore wind map for the UK Crown Estate.

**Research: Variation in turbulence intensity around the British Isles - findings presented at Wind Europe, Hamburg 2016**

One area where remote sensing devices do not replicate traditional cup anemometry is the measurement of turbulence intensity. A study of 8 masts in the North and Irish Seas provide some rules of thumb for turbulence intensity to expect at offshore sites, and so extend the usability of floating remote sensing devices. In collaboration with Mainstream Renewable Power.
Unprecedented offshore growth

The acceleration in offshore wind installations in recent years has been extraordinary. Sometimes the scale can be hard to comprehend. At the time of writing this guide, Europe now has 11 GW operating and 20 GW consented, the US is targeting 86 GW by 2050, and China has constructed a Gigawatt to date.

Little tolerance for over-predicted pre-construction yield

Meanwhile, as the market matures, reverse auctions and lower tariffs are putting real pressure on costs and margins. Sometimes this has been gradual and sometimes seismic, as seen during the Borssele auction. The need to re-cycle capital by introducing debt and equity means increased scrutiny and leaves no space for the inaccurate or over-predicted pre-construction yield assessments that have dented confidence in the onshore market.

Yield assessments - an inconvenient truth

But how difficult can it be out at sea where it is flat? Here’s a hard truth: many yield assessments for offshore wind farms are done using short or biased data sets, plagued with equipment failures. And that’s before the all-too-common use of poorly validated wake models, ambitious availability assumptions and new turbine models with little or no track record.

This uncomfortable reality is often what underpins investment decisions worth billions.

So with these facts in mind, how can project valuation risks be mitigated? Read on to learn more about the key components of accurate offshore assessment.
IT’S ALL IN THE WIND

**Wind measurements – the single biggest failing**

If there is a single point of failure in an offshore yield assessment, it is the use of inaccurate wind measurements. The cost and difficulty of recording wind data out at sea can be huge, particularly during the cost-sensitive development phase. This often means data sets are short and degraded by equipment failures. Even when the systems have worked perfectly, offshore mast structures bias the anemometer readings due to their size.

Floating LiDAR devices are becoming increasingly common, but have their own complications, such as data coverage, power supply issues, movement compensation and validation against measurements.

**Multiple data sources for lower uncertainty**

Despite the health warnings, it is rarely necessary to rely on a single data source. There are now numerous data sets publicly available. Used alongside mesoscale wind maps, they can provide a lower uncertainty estimate than any single mast.

At Prevailing, we use Gauss-Markov methods to estimate lowest uncertainty wind speed estimates. This enables us to reduce uncertainty below that from any single source, whether on-site or not. We recently took this approach on a project with two month’s LiDAR data, supporting the measurements with six additional data sets.
TIME TO WAKE UP

Offshore wake effects can be significant

The wake of a wind turbine – the ‘hole in the wind’ behind the spinning rotor – gets broken down by the turbulence in the air. Offshore, turbulence levels are much lower due to the smooth surface of the sea. The result is that turbine wakes can propagate much further than they do in an onshore environment. They can impact the next row of turbines even when the spacing between them is high. Similarly, neighbouring projects can also have large effects on one another, even at distances of 10 km and more.

Despite the fact that this is not news, wake modelling offshore is still considered difficult and uncertain. A range of models exist, commonly providing diverse estimates for the same project.

A combined wake model, with CFD, to understand uncertainty

Our preferred method at Prevailing is to compile an ensemble model from three different underlying wake calculation codes, drawing on both the most validated models and the latest CFD-based technology. This reduces reliance on any one model and the resulting spread is a good indication of uncertainty.
The challenges of maintaining equipment in the marine environment are well known. Overall project availability and losses are dependent on the design and reliability of key components and systems and on the intended operation and maintenance strategy. Project specifics such as the proposed turbine technology, electrical system and grid connection need to be assessed alongside access considerations such as vessel availability, proximity to port, and metocean metrics.

Experience of nearby operating projects and information obtained through discussion with prototype turbine manufacturers are critical to determining realistic project availability.

Unlike onshore, the meteorological environment offshore – mainly shear, veer and turbulence – is relatively consistent. In the onshore environment, variation in these conditions can cause large turbine performance variations but for offshore this is rarely the case, at least across a given region. The real challenge comes with verification of each new generation of turbine. Often machines, such as the new MHI Vestas V164-8.0 MW, are prototype tested onshore, where conditions and performance differ. See our recent presentations at the AWEA and EWEA conferences on the effects of conditions on performance.
Isn’t it always windy offshore? Why do I need a detailed assessment?

Yes, fair point, wind speeds are usually higher and more consistent offshore than on, so in many ways the wind resource is better suited to energy production. However there is still variation in the wind speed at different sites. The windiest North Sea offshore wind farm is approximately 10% windier at 100m than the lowest wind speed site, which translates to a 15% difference in energy production – enough to make or break a project.

How good are floating LiDARs?

Due to the significant cost of offshore met masts, developers are looking to new technologies to keep costs in check. Floating and scanning remote sensing devices offer one of the main ways to reduce the costs of offshore wind measurement campaigns in comparison to a freestanding offshore met mast.

There are widely accepted development and validation pathways for these devices. However, a number of other key parameters from cup anemometers are not as well validated, most notably turbulence intensity used to calculate turbine fatigue loading and hence lifespan. Prevailing has analysed a multitude of offshore wind measurements and is excellently equipped to maximise the value of available offshore wind measurements.

Aren’t wake effects really big offshore?

They certainly can be, with the big turbines packed into a regular array and the low turbulence making wind speeds recover more slowly there is the potential for large energy losses, as was the case for much of the first generation of offshore wind farms. However, with less constraint upon space than onshore, there is potential to mitigate this. There are also several experimental methods for reducing wake effects, such as non-symmetrical layouts, yaw wake bending and reduced running.

Offshore wind farms are currently planned on a scale never before seen, with turbines a generation larger than those currently in service. The models used to predict turbine-on-turbine wake losses are therefore further and further from their validation cases. The underlying physics defining these models is still largely valid but it is ever more important to capture the range of conditions experienced at offshore sites.

We address this problem by running 3 independent models across a range of atmospheric conditions and then weighting the results by the applicability of the model and the occurrence of the conditions. This approach diminishes the impact of any given model’s limitations and allows us to incorporate the correct atmospheric conditions at the site.

Are there any other things that affect energy production?

It’s harder to get to an offshore wind farm when it goes wrong. From an energy assessment perspective, this manifests itself as an increase in wind farm availability loss and an increase in uncertainty. Offshore wind farm operators are looking to more advanced O&M strategies to keep their projects operating; these include helicopter landing pads on turbines to allow quick access and dedicated offshore service vehicles that provide living quarters for continuously on-site teams of engineers at large far-shore sites.

Turbines can be bigger offshore. The lack of noise and other human interaction constraints, combined with the high cost of support structures, means offshore turbines have bigger rotors. Most wind farms currently in development are looking to use 6-8MW technology, with pipeline projects considering 10+MW machines. These turbines have a larger sweep than the wingspan of an Airbus A380 and now represent the cutting edge of large aerofoil design. This leap forward in technology, combined with short operating track records makes predicting availability, and consequently energy yield, a real challenge.
ABOUT PREVAILING

Informing smart wind farm decisions

Prevailing offers financial-grade analysis and engineering services for onshore and offshore wind farms of all sizes, at all lifecycle stages. Clients worldwide rely on us to provide accurate and timely information which they use to inform and de-risk their investment, development and operational decisions.

Rapid response industry best practice

With many years’ experience, we are acknowledged for highly accurate energy yield analysis, applying broader know-how during provision of routine services and responding flexibly to individual client and project needs. As a result, we frequently identify risks and impacts that would otherwise have been missed and deliver them, with context, much faster than many of our competitors.