CHAPTER 1 : Background to the POWER project

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1.1 The importance of offshore wind energy in Europe

The countries of the European Union (EU) are faced with the challenge of meeting the energy needs of Europe's industries and of its population in general. At the same time the global community is becoming increasingly aware of the need to consider the strain that human activities are placing on the planet. In particular, there is widespread concern that modern societies' broad reliance on carbon-based energy sources within a so-called "carbon economy" is leading to significant changes in the composition of the atmosphere, which in turn is believed will be responsible for large scale and long-term changes to global climate. The international response has been to draw up the UN Framework Convention on Climate Change (UNFCCC) – an international agreement which sets out the overall policy framework for addressing the climate change issue. The Kyoto Protocol to UNFCCC set out for the first time a binding commitment for developed nations – including the member states of the EU - to achieve reductions in emissions of carbon dioxide and other greenhouse gases. Furthermore, climate scientists point out that the Kyoto reductions should be seen as only the first step in a longer-term effort to reduce greenhouse gas emissions by the 60% or more that will be required to restore and sustain the balance within the planet's atmosphere.

In this setting, renewable energy technologies are set to play a central role in assisting EU member state governments achieve their national carbon dioxide reduction targets (both now and in the future), whilst continuing to meet the demand for energy.

Compared to other regions, Europe is blessed with an extensive wind energy resource which has the potential to provide for a significant component of the its future energy needs. By the mid-1990s land-based wind energy developments were firmly established on a commercial basis in several EU countries. However, increasing pressure on land use has led to a move to develop wind power offshore; Denmark, Sweden, the Netherlands, the UK, Eire and France have either already started to develop offshore wind energy installations, or have plans to do so in the near future and other EU member states, such as Belgium, are currently considering developments of this kind.

It has become apparent that rapid exploitation of the offshore wind energy is an important part of Europe's overall energy strategy. Development is currently handicapped by significant knowledge gaps, including a scarcity of good quality information on the extent, characteristics and distribution of the offshore wind energy resource. Clearly these issues must be addressed before Europe's offshore wind energy resource can be exploited fully.

1.2 The demand for information on offshore wind energy resources

Information on offshore wind energy resources is sought by several end user groups ranging from policy-makers and planners at regional (e.g. EU), national (e.g. EU member state) and local (e.g. local government/district authority or equivalent) scales to the fledgling offshore wind industry who are seeking to develop offshore wind energy on a commercial basis. Knowledge of the overall extent and distribution of the offshore wind resource is required to:

- Identify the most appropriate and economically attractive regions/areas for offshore wind energy development.
- Develop regional/national/local energy strategies that are in accordance with current and future regulation and other initiatives such as the Kyoto Protocol, Agenda 21 etc..
- Plan investment in new technologies, suitable infrastructure etc. in areas where offshore wind energy developments are expected to go ahead.
- Provide underpinning knowledge when developing any future trading scheme of "green" electricity, carbon credits, investment in technology transfer projects etc.

In addition, offshore wind farm developers have a series of specific data needs and require accurate, detailed and long-term characteristics of the local wind regime and wave conditions to:

- Select the most favourable site(s) for an offshore wind farm within the broadly attractive regions already identified.

- Assess and/or infer many of the fundamental environmental design parameters for the wind turbines and support structures at the chosen site.

- Provide evidence of the technical and commercial viability of a proposed project (required when seeking support (e.g. financing, planning permission etc.) for a new development. The local wind regime not only controls the amount of energy that is harvested at the site, but also influences directly the operation and maintenance regime of the turbine(s). Together, these factors largely determine the initial capital and maintenance costs of the development as well as its revenue potential.

- Predict suitable windows of opportunity for construction, installation, maintenance and repair operations.

- Identify the optimum operation, maintenance and repair regime for the offshore wind development.

It is clear that various categories of end user need an accurate knowledge of the offshore wind regime. Furthermore these user groups need this information at a range of levels of detail and geographical scale.

1.3 Estimating offshore wind energy resources in European waters

After years of study, meteorologists now have a relatively good understanding of the wind regime over the land, as well as a toolbox of wind models and data manipulation techniques that can be used to estimate the wind resource in particular sites. There have also been numerous studies to assess onshore wind energy resources ranging from specific data gathering campaigns followed by detailed analysis of the local wind regime at sites selected for wind energy developments to broad-brush assessments of the extent and distribution of the onshore wind energy resource throughout Europe and, at a higher resolution, in several EU member states.

By contrast, the phenomena that influence offshore winds are not well understood at the present time and measured wind data at offshore locations are spatially and temporally sparse and of variable quality. This scarcity of information means there is little on which to base offshore wind models and, unfortunately, it is believed that many of the data manipulation techniques used onshore cannot be extended to offshore sites. There have, however, already been a few basic assessments of the offshore wind resources in EU waters, which have demonstrated that the offshore wind resource is very large, particularly in the waters of northern Europe. However, without detailed knowledge of the characteristics and distribution of the resource the offshore wind industry is unable to answer questions on the economics of offshore wind energy because of the uncertainties that still exist.

Together these limitations represent a severe handicap to commercial exploitation of the resource. To illustrate the difficulties currently faced by offshore wind energy developers it is, perhaps, useful to compare methods currently available to assess the detailed wind energy resource onshore and offshore sites.

At onshore locations it is common practice to first consult a wind atlas to get an initial indication of the resource in the locality. It is then straightforward and inexpensive to erect one or more meteorological masts at the selected site, and to gather numerous data parameters for a period of several months, if not years. Typically these masts (and their foundations) have a standard design and are relatively cheap to install. Furthermore at onshore there are few difficulties in supplying the power demands of the instruments and it is easy to visit the site frequently to recover the data gathered (which therefore does not need to be stored for long periods) and for maintenance and repair purposes.

To produce a long-term estimate of the wind speeds for the onshore site, the short-term measurements from the mast are correlated with those from a nearby meteorological station where reliable long-term data is available. Fortunately there is an extensive system of well-established meteorological stations throughout Europe where long-term and historical data suitable for this purpose is available.

By contrast, very few offshore wind atlases have been produced to date and even these are largely based on extrapolation and interpolation of onshore data. In addition, offshore meteorological masts are expensive and difficult to install and very costly also to operate – particularly for prolonged periods. The offshore environment is notoriously harsh and in these areas structures such as meteorological masts and their instruments are subject to severe loading and high rates of corrosion. Typically each offshore meteorological mast and its foundation must be specifically designed to cope with the wind, wave, ice, current and seabed ground conditions at the site. Furthermore, in these conditions it is not straightforward to ensure an adequate power supply at the mast or to make regular visits to maintain and repair the instruments mounted on them and to retrieve the data gathered. Consequently, offshore meteorological masts have been erected in only a very small number of locations and the data gathered have an extremely high commercial value and as such are not always in general circulation.

Finally, in the almost total absence of reliable long-term measured offshore wind data developers are forced to correlate short-term offshore mast measurements with long-term data from a nearby onshore site. These sites are often a considerable distance apart and, in any case, the correlation may not be appropriate due to the differing on-and offshore climatologies.

It is easy to see why there is considerable interest in establishing an accurate knowledge of the wind regime in offshore waters.

1.4 POWER project objectives

The Predicting Offshore Wind Energy Resources (POWER) project was an ambitious attempt to improve the understanding of the nature and distribution of Europe’s offshore wind resource. In particular the project team set out to improve upon previous estimates of the European offshore wind energy resource, to consider a number of additional factors that could affect its exploitation on a commercial basis and to present the information in straightforward, yet useful format.

The project had the following specific objectives:

1. To develop and document a combined three-model methodology for the estimate of wind power offshore applied to EU waters which gives more accurate estimates of the offshore resource (where suitable observed data exists) than current estimates, in particular, the European Wind Atlas, the Germanischer Lloyd/Garrad Hassan study (JOUR 0072) and Young and Holland’s Atlas of the Oceans: Wind and Wave Climate.

2. To produce two detailed data sets of SODAR measurements of on-to-off- and off-to-on-shore winds on the east coast of England and on the Dutch coast.

3. To produce a data product that will allow an end user:

    a) To find out the long term wind power resource at a given offshore location in European Union waters.

    b) To assess the expected inter-annual and seasonal variability at that site.

    c) To deduce the expected wind speed distribution at the location of interest.

    d) To investigate whether the area of interest is unsuitable for offshore wind farm siting due to excessive wind/wave loading and extreme gust events.

4. To make and document a case-study at prospective offshore wind farms site(s) in order to validate the data product at site(s) where observed data exists.

The project was organised into a set of 12 discrete work packages, each tackling a specific task within the overall work programme. However, during the course of the project it became increasingly apparent that the work packages were not arranged in the most logical manner for reporting purposes. Therefore in this report the POWER project team’s work and findings are not presented within a framework of work packages, but instead have been regrouped and reordered to guide the reader through the project more logically.

1.5 Structure of this report

The reports starts (in Chapter 2) by describing the basic POWER methodology; it then describes (in Chapter 3) how the geostrophic winds were calculated using pressure data using an interpolation method, and the checks carried out to test the accuracy of the resulting wind fields; Chapter 4 describes the use of the WaSP package to transform the geostrophic winds to a range of turbine hub heights; Chapter 5 introduces the Coastal Discontinuity Model (CDM) and its application, before comparing the WaSP and CDM wind fields, and the modelled and measured offshore wind profiles; Chapter 6 describes the SODAR measurements made in the Netherlands and in the UK, reviews the usefulness of the SODAR instrument , and then compares the on-shore and off-shore winds; Chapter 7 examines the variability of offshore winds : long-term trends, diurnal cycles and gusts; Chapter 8 describes wind/wave modelling carried out and the results obtained; Chapter 9 reports on the confidence limits calculated for monthly mean offshore wind speeds – these were calculated on a regional basis; Chapter 10 describes the comparison of the POWER wind field with measured data in the Netherlands, in Denmark, in the Mediterranean, and with those obtained by an earlier EU study. Finally, Chapter 11 describes the POWER Tool, a simple graphical user interface, which allows the user to display in graphical and tabular form the POWER results for a specified grid point.

Appendix 1 of the report lists the publications issued during the study.