Wind resource assessment and siting - a wider perspective

Landberg, Lars; Mortensen, Niels Gylling; Lundtang Petersen, Erik

Published in:
The world directory of renewable energy suppliers and services 1995

Publication date:
1995

Document Version
Publisher's PDF, also known as Version of record

ARTICLE

Wind resource assessment and siting – a wider perspective

LARS LANDBERG, NIELS G. MORTENSEN AND ERIK L. PETERSEN

This article aims to provide a broad overview of wind resource assessment and siting around the world. For convenience, the world has been divided into a number of regions according to their wind climate. The characteristics of these regions are described in some detail and so is the ability of state-of-the-art models to predict the wind resources. Where possible, examples of wind resource estimation studies are also given. (The views and information presented in this article are biased towards what we ourselves have been working with.)

The wind resource of a site is the expected mean wind climate – or the power production of a wind turbine located at that site – over the next 10–20 years. If one is interested in the wind resources at one or more sites, like the locations of wind turbines in a wind farm, at least two things are needed: high-quality nearby wind measurements (preferably on-site) and a micro-siting model which can estimate the spatial distribution of the wind resource over the entire area. Using only measurements from a nearby mast (e.g. at a meteorological station) will cause the local effects on the flow around that mast to be 'transported' to the site in question; this procedure will obviously result in erroneous results. If, for example, the meteorological mast is located near a building – which will reduce the wind speed of the flow coming from that direction – this reduction is almost certainly not found at the site. It can therefore be seen that models have to be used in order to obtain correct estimates of the wind resource at any site.

Basically, two modelling approaches exist: models based on statistical relations between the two sites and models based on the physical laws governing the wind flow. An example of the first kind of model is the measure-correlate-predict (MCP) method which correlates two sets of measurements – one taken at the site of interest and one taken at a station with a long wind speed and direction record. An example of the physical approach is the WAsP model,[1] though numerous other models exist as well.

THE ARCTIC

As wind turbine technology matures, the potential for wind power generation in more marginal areas of the earth – including the Arctic and sub-Arctic – has been recognized. The exploitation of wind power in these regions has been scarce until now, but this may well be changing. The barriers for widespread application of wind energy in the Arctic were recently identified[2] and comprise both technological, economic, social and institutional issues. However, many of these barriers are not unique to the Arctic – or even particularly severe here.

One important barrier, though, is the lack of adequate knowledge of the wind resources in candidate regions. Apart from the northern parts of Sweden and Finland, little seems to have been done with respect to a systematic mapping of Arctic and sub-Arctic wind resources. Moreover, it is not clear to what extent the methods developed for wind resource estimation and siting in the temperate climates will apply to these regions.

In general, the density of meteorological stations in the Arctic is low; however, this may not be a problem since measurements are often taken in or close to the settlements where the power is needed. More importantly, the quality of the wind measurements is often not known and neither is the applicability of current wind resource estimation methods. Snow, ice and subzero temperatures not only make it difficult to make reliable wind measurements, they also change the roughness of the terrain considerably from season to season. Furthermore, the cooling of the lower layers of the atmosphere leads to local wind flows of a limited extent. Consequently, it is often very difficult to extrapolate the measured wind climate over more than a few kilometres.

Recent investigations in Greenland suggest that wind power generation may be a viable alternative or supplement to more traditional ways of generating electricity. They also show that the increased costs of constructing and maintaining wind turbines in the Arctic may be at least partially offset by the generally higher costs of electricity generation in these areas.

TEMPERATE PLAINS AND THE WESTERLIES

The temperate plains are characterised by large-scale low-pressure systems moving over the areas. These systems give rise to powerful storms and – because of the regularity of these systems – a steady wind climate. In wind energy terms this means that the potential and the reliability of predictions of the production can be expected

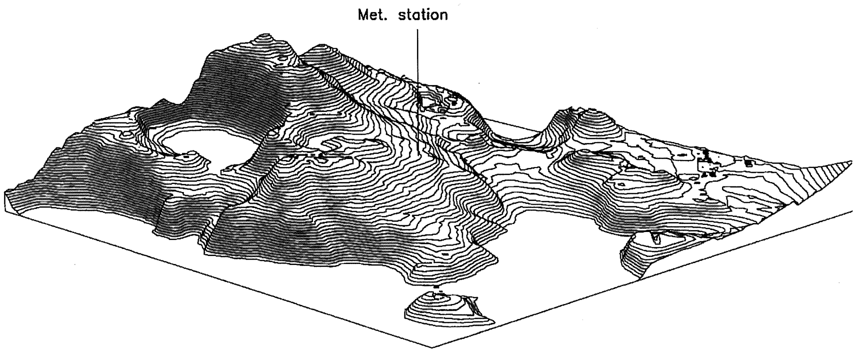

Figure 1. Wind power generation in Greenland and other Arctic settings may benefit from the terrain-induced speed-up of the wind and also the occurrence of smooth terrain surfaces, like water, snow and ice

to be high. Another characteristic of at least the European and American parts is that these are also the areas with the highest growth in the installed capacity of renewables, but also with the highest production of CO_2 and with the most intense competition from other sources of energy (coal, gas, nuclear etc.).

The European Wind Atlas methodology was developed with these areas in mind. The method is used to estimate the expected production at a given site using wind data from up to 100km away. Since, generally speaking, the meteorological network is very dense in these areas, the wind energy potential at virtually any location can be calculated. Furthermore, numerous studies have shown that the method gives very reliable results for these regions. This is fortunate since recently problems with obtaining planning permission have arisen, meaning that accurate siting methods must be used to meet the investor's as well as the planning authorities' wishes and demands.

As a consequence of the above it is possible to estimate the expected wind power potential at almost any location, using either nearby measurements or data from the European Wind Atlas (see also map on page 186).

In Canada, a wind atlas similar to the European is being developed and, because of the geographical likeness of the two regions, the method is expected to work well here, too. Before the European Wind Atlas was established, the Batelle Laboratories constructed a map of worldwide wind resources.[3] Although this study provides a good first guess, also of the European resources, it lacks resolution over the land areas.

In USA proper, the 'wind rush, in California gave a new start to wind energy worldwide. The Californian terrain is dominated by local effects, such as sea-breeze flows, making the potential very hard to predict. A second 'wind rush' in the USA is now taking place in the very windy central states. These areas are in many ways quite similar to the European landscapes, promising much higher reliability in the wind resource estimates.

The European Wind Atlas methodology has also been used in New Zealand, but due to lack of data no firm conclusions can be drawn as of now. Australia has also seen some applications of the methodology and there is extensive experience in using the method with good agreement found in different parts of the country.

In conclusion, there is no doubt that very reliable estimates of the long-term wind energy potential can be obtained in most of the temperate regions – where the terrain is not too complex.

DESERTS AND SEMI-ARID AREAS

From a wind energy point of view these regions have a number of advantages: the 'pressure' on the land is often very low, access is easy, and construction work relatively simple. Also, the surface roughness tends to be low and uniform, so siting can be done primarily with optimization of the power production – or minimization of cost – in mind. Such areas could provide space for large-scale utilization of wind energy, provided they are favoured by a healthy wind climate and located not to far from places where power is in demand.

Unfortunately, like in other sparsely populated regions, the meteorological network is very coarse and the wind climate is therefore not known in great detail at present. The physics of the flows in these dry regions of high solar insolation and little vegetation are also quite different from, for example, the temperate regions – where most of the models and techniques for wind resource estimation and siting were developed and tested. However, studies carried out in, for instance, Algeria, Libya, Egypt, Israel, Syria and Jordan should lead to a better understanding of the limits of contemporary models in these regions.

THE TROPICS

The tropical regions are dominated by seasonal wind systems, like the monsoon and the trade winds. In many areas the measuring network is dense and dates back many years, providing long records, very useful for wind energy purposes. These regions are also characterized by a high demand for power, with many people still without electricity. A very high growth rate of the population is also found in these areas, resulting in even higher demand for electricity in the near future. Therefore, an increasing interest in all kinds of energy, including wind energy, exists.

Because of the aforementioned dense network quite reliable estimates of the expected wind resource can be given for many tropical areas, the task being made slightly difficult by the local thermally driven wind systems found in some areas.

Studies along the lines laid out in the European Wind Atlas have been carried out in many places. A couple of examples are in Somalia and India, which are both dominated by monsoon type flows. Here regional studies have been carried out, and the Wind Atlas method has been verified by comparing the predicted production of wind farms to actual production. India also has a very comprehensive database of meteorological measurements.

On the Cape Verde Islands a wind atlas has also been compiled and again the method has been verified, with good results using actual output from wind farms.

OPEN SEA

The open sea is in general characterised by a very high wind potential, but a detailed and reliable map of these resources is very hard to produce because of the very sparse measuring network. An overview of the offshore resources is given in the map published by the Batelle Laboratories in the USA.[3]

There are two sources of information available for estimating the resource: measurements from small islands, which are few and far between, and the so-called COADS database. COADS is short for the Comprehensive Ocean-Atmosphere Data Set and is a result of a continuing cooperation between several American institutions.[4] The data set contains measurements of the wind speed and direction as reported from ships crossing the oceans. This gives a huge, albeit in some areas sparse, data set covering most of the oceans. The data set has been compared to coastal measurements in some areas and the overall agreement seems to be good.

Other sources of information are available for certain limited offshore areas, e.g. the wind atlas for the North Sea.[5] Also, a study covering the Baltic Sea is in progress and a wind atlas will be produced within the next year.

COASTAL AREAS

Land sites close to the coastline have always been in demand for wind power generation, because of the generally high wind resource compared to (flat) inland sites in the same wind regime. This demand, as well as many other interests in the coastal land area, have led to a decrease in the availability of such sites, and near-coastal offshore sites have therefore become more attractive. Taking 'near-coastal offshore' to mean the offshore area where the influence of the land on the wind flow is still present, this zone is of the order of 10km wide.

Several conflicting constraints must be taken into account in the siting of offshore wind turbines. Evidently, the cost of construction, grid connection and maintenance transport will increase with increasing distance from the coastline – but so will the available wind resource.

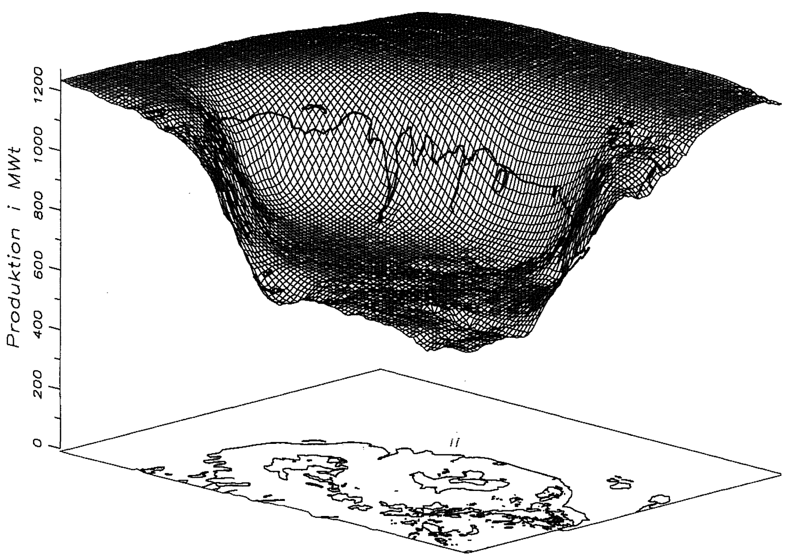

Figure 2. The estimated wind power production in the area of the Vindeby wind farm, Denmark. Here, westerly and south-westerly winds predominate, so the orientation and proximity of the coastline become very important factors in the siting of wind turbines

Costs can be reduced by erecting the turbines closer to the coastline, but here visual impact and interference with other activities may be (too) high. Because the wind resources (and costs) vary considerably over small horizontal distances, there is an increasing demand for accurate offshore wind resource estimates. In particular, this presents a challenge to the physical models, since offshore wind measurements very rarely exist and would be very costly to perform.

The world's first offshore wind farm was constructed in 1990–1 near Vindeby, Denmark (Figure 2). Here, the meteorology of the coastal zone is monitored in great detail from one onshore and two offshore masts. These data will be used to evaluate and further develop models for the prediction of offshore wind climates, leading to improved predictions of the wind power potential of this very promising region.

MOUNTAINS

In mountainous regions the topography enhances the existing wind potential, resulting in very high potentials. However, the exact magnitude of this potential is difficult to assess accurately, because mountainous areas are often very thinly populated and as a consequence have a very sparse wind measuring network. Furthermore, the resources may of course be costly to develop due to the lack of infrastructure.

Because of the very complex nature of the terrain – as well as the fact that the winds are often dominated by local effects, driven by, for example, local differences in the temperature – it is very difficult to model the wind flow. An EU Union) initiative funded under the JOULE Programme is trying to address this problem by combining micro-siting models with models modelling the flow over a larger area, typically hundreds of kilometres. This approach is being tested for Ireland, Northern Portugal, Central Italy and Crete and is indeed showing promising results in these areas.

EDUCATION AND RESEARCH

In this article we have briefly described in wind energy terms most of the areas covering the earth. By examples we have shown that present day state-of-the-art models are indeed able to predict the wind resource in many areas. It has also been indicated that in some areas the potential can still not be satisfactorily estimated. This means that wind energy meteorology today has two main tasks: first, to educate the users on the models currently available – their proper use and known limitations – and, secondly, to conduct research into the fields where knowledge is still missing. Part of this research will be to collect and evaluate the results of the numerous studies that have already been carried out.[6]

ACKNOWLEDGEMENTS

The work by the Risø National Laboratory on wind energy resources has, since 1981, been supported by the Commission of the European Union, Directorate-General for Science, Research and Development.

Lars Landberg, Niels Mortensen and Erik Petersen work in the Department of Meteorology and Wind Energy, Risø National Laboratory, Denmark

REFERENCES

1. Troen I, Petersen EL (1989). European Wind Atlas. Risø National Laboratory, Roskilde, Denmark.
2. Lundsager P, Ahm P., Madsen B, Krogsgaard P (1993). Wind power in arctic regions. An investigation and a seminar. 3–4 June 1993. Risø-I-709(EN), Risø National Laboratory, Roskilde, Denmark.
3. World Meteorological Organization (1981). Meteorological aspects of the utilization of wind as an energy source. WMO Technical Note 175, World Meteorological Organization, Geneva, Switzerland.
4. Diaz HF, Wolter K, Woodruff SD (1992). Proceedings of the International COADS Workshop, Boulder, Colorado, 13–15 January 1992. US Department of Commerce, Boulder, CO, USA.
5. Børresen JA (1987). Wind atlas for the North Sea and the Norwegian Sea. Norwegian University Press and Norwegian Meteorological Institute, Oslo.
6. Petersen EL, Mortensen NG, Landberg L (1994). Wind resource estimation and siting of wind turbines. In: European Directory of Renewable Energy Suppliers and Services 1994. James & James, London.