SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 1:
Sustainable production and consumption patterns

FINAL REPORT

IMPROVED PREDICTION OF WIND POWER IN BELGIUM

CP/54

Alexis Dutrieux – ATM PRO
Andy Delcloo – RMI
Christian Tricot – RMI
Guy Schayes – UCL
Jean-Pascal van Yperseele - UCL
Philippe Marbaix – UCL
Karen Van de Vel – VITO
Koen De Ridder – VITO
Patrick Hoebeke – 3E NV
Pierre Antoine Mali – 3E NV
Yves Cabooter – 3E NV
Luc Dewilde –3E NV

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Rue de la Science 8
Wetenschapsstraat 8
B-1000 Brussels
Belgium
Tel: +32 (0)2 238 34 11 – Fax: +32 (0)2 230 59 12
http://www.belspo.be

Contact person:
Mrs Anne Fierens
Secretariat: +32 (0)2 238 37 61

Summary

In the planning and engineering phases of wind energy projects, there is a need for high quality statistical data of meteorological parameters and for validated methods to make extrapolations from measured data to specific wind turbine sites.

The objective of the project is to improve the basis for the accurate prediction the power that could be generated by wind energy plants in Belgium. The project focussed on the quality of the meteorological data and the description of the different meteorological stations in terms of surroundings and set up of the measurement and analysis of the different models and tools for extrapolation from observation sites to specific sites of interest.

Reference stations

In the framework of the qualification of the meteorological stations for wind energy applications in Belgium, a review has been made of the existing stations. The set mainly consists of stations operated by the Meteo Wing (military aviation) and Belgocontrol (civil aviation). These stations have long time series of synoptic data. In addition, to be as complete as possible, the automatic weather stations (AWS) of RMI are reviewed.

In total 28 stations have been visited, 7 from Belgocontrol, 9 from Meteo Wing and 12 Automatic Weather Stations of RMI. For all stations the relevant information needed for accurate precisions have been given.

Emphasis has been given on the time period 1985 – 2004. Based on the observations we can already conclude that most of the stations are well located in the landscape. We can also exclude Brasschaat because some very important criteria are not respected

Roughness

In order to calculate the effects of topography on the wind it is necessary to describe systematically the characteristics of the topography. These are:

- The influence of the terrain surface, referred to as the roughness of the terrain.
- The influence of the orography such as hills, cliffs, mountains, escarpments,
- The influence of obstacles in the close neighbourhood of the envisaged site.

The roughness of a particular surface area is determined by the size and distribution of the roughness elements in that area. For land surfaces these are typically vegetation, built-up areas and the soil surface.

The roughness characterisation has been done based on the CORINE Landover. The objective of the pan-European project CORINE Land Cover (CLC) is the provision of a unique and comparable data set of land cover for Europe. It is part of the European Union programme CORINE (Co-ordination of Information on the Environment). The mapping of the land cover and land use was performed on the basis of satellite remote sensing images. The interpretation has been complemented with analysis of exogenous data (topographic maps, aerial photography,). The scale of this data basis is 1:100 000 and is well adapted to a regional mapping.

The CLC database is particularly well suited for the definition of terrain roughness because this depends on the actual land use based on remote sensing (and not on an assigned land use).

For wind energy resource calculations, it is advised to take into account the roughness of the region for up to 20 km from the site of interest (cfr. WAsP, WindPro). Therefore, at the country borders, information of the roughness of the neighbouring countries is necessary. In addition to the Corine database zoning maps and topographic maps are used as well.

The CORINE Land Cover database is used as the main input. These are checked with the regional zoning maps and in case of confusion, the topographic maps are consulted.

The Corine database, the database of the regional zoning maps and the topographic maps are imported in a GIS application like ArcView. A number of manipulations and specific adaptations have to be executed:

- Transformation of full polygons into hollow polygons
- Refinement of the CORINE classification: adjustment to the categories continuous and non-continuous urban terrain
- Single code definition of overlapping areas.
- Definition of the corresponding roughness length based on the Corine and/or zoning map codes.

In this way, the roughness database for Belgium has been created. The result is a database in shape format that can be imported in a GIS application like ArcView. In total 10 Roughness maps have been produced for the different provinces.

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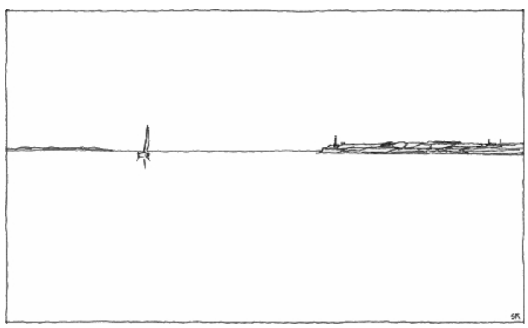
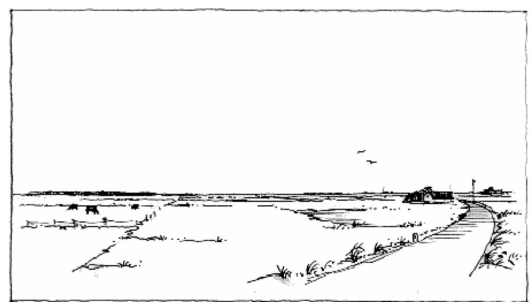
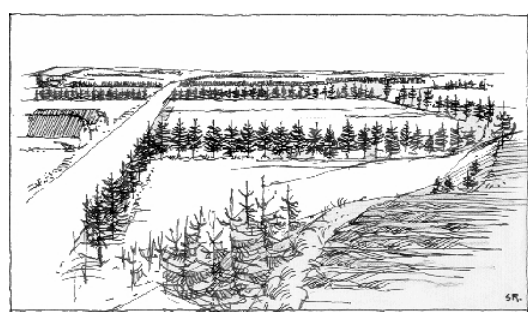


Example of terrain corresponding to roughness class 0: water areas. This class comprises the sea, fjords, and lakes. The roughness length is z0 = 0.0002 m. However, the roughness must be specified as 0.0 m in WAsP.



Example of terrain corresponding to roughness class 1: open areas with few windbreaks. The terrain appears to be very open and is flat or gently undulating. Single farms and stands of trees and bushes can be found. The roughness length is z0 = 0.03 m.



Example of terrain corresponding to roughness class 2: farm land with windbreaks, the mean separation of which exceeds 1000 m, and some scattered built-up areas. The terrain is characterised by large open areas between the many windbreaks, giving the landscape an open appearance. The terrain may be flat or undulating. There are many trees and buildings. The roughness length is z0 = 0.10 m.

Example of terrain corresponding to roughness class 3: urban districts, forests, and farmland with many windbreaks. The farmland is characterised by the many closely spaced windbreaks, the average separation being a few hundred metres. Forest and urban areas also belong to this class. The roughness length is z0 = 0.40 m.

Figure 1 Illustration of roughness classes and roughness lengths

It is difficult to reduce the uncertainty for a regional mapping without physical visits to the site. For a particular site to be evaluated, the on-site terrain observations could allow to refine the roughness values and to reduce the uncertainties due to modelling. It should be noted that fault ranges of a factor 2 on the roughness lengths changes the estimated wind speed with about 15%.

Orography

Orographic elements such as hills, cliffs, escarpments and ridges have an important influence on the wind. Near the summit or crest of these features the wind will accelerate while near the foot and in valleys it will decelerate.

Height contours or lines with constant elevation for Belgium are available on the topographic maps. However, these topographic maps are in raster format and their information cannot be extracted for detailed analysis. Therefore, digital orographic data of Belgium has been consulted. Different sources have been used:

DTED and DataForWind datasets have the highest horizontal resolution and therefore result in the highest accuracy for the terrain modelling of sites.

The digital terrain model from NGI (National Geographic Institute of Belgium) has been created by scanning, vectorisation and identification of the height contour lines on the topographic maps on the scale of 1:50 000. The height value is determined in reference to the Belgian zero level.

The DTED-Lambert model has a vertical accuracy of 3.8 m in lower Belgium, 7.8 m in mid Belgium and 10.2 m in high Belgium. The reliability of the data is 90%.

DataForWind are proposing to professionals of the wind industry an easy access to relevant geo-information for on-shore wind farms. In the website http://www.dataforwind.com/, you will access to relief information available world-wide.

DataForWind is part of the EO-Windfarm project aiming at proposing in a One-Stop-Shop information for wind farm management and development.

The Orography Service allows an easy download of orographic information. The orography information is available for the entire landmass of the Earth between 60° N and 57° S with a statial resolution of 3 arc sec (± 90 m). The orography information can be extracted either in geographic co-ordinates and in UTM co-ordinates.

Modelling

Five different models for the prediction of the surface wind climate are investigated. These models can be divided into mesoscale and micro scale models, or the combination of the two. The high-resolution mesoscale models simulate the regional wind characteristics like flow in presence of large hills and valleys (up to a typical resolution of 1 km). These sophisticated 3 dimensional models are necessary to obtain reliable wind simulations especially in complex terrain. The micro scale models calculate the effects of orography, roughness conditions and obstacles on a high-resolution mesh.

The models that are tested in this project are summarised in the following table:

Table 1 Tested models

Model	Operated by partner	Model scale	Model Reference
ARPS	VITO	Meso	1
TVM	UCL	Meso/micro	2
MAR	UCL	Meso	3
Maestro Wind	UCL/ATM PRO	Meso/micro	4
WAsP	3E	Micro	5

According to different topologies, different sites have been chosen where good quality wind measurements on site are available. The five selected sites are:

A general conclusion that may be drawn is that mesoscale models are useful in the context of wind energy assessment studies, provided that proper attention is given to site-specific characteristics. As an alternative, it should be worth considering the use of a combination of mesoscale models and those semi-empirical models that are traditionally used to do site assessments for wind energy. It would combine the advantages of mesoscale modelling (comprehensive approach, independence of local meteorological data) with those of the site assessment models (advanced accounting for local terrain characteristics, better suited for wind energy yield assessment, users better connected with wind energy industry).

These results show that a potential in using mesoscale models for wind energy exists for sure, but a much longer (in time) and more complete analysis must be performed in order to derive more consistent characteristics.

TVM (as ARPS and MAR) programs are forced by the re-analyses from the European Centre (ECMWF) which delivers data only every 6 hours. This means that meteorological events having variability in time smaller than 6 hours are not represented in the forcing data and thus cannot appear in the results.

The wind speed was generally well simulated, with mean speed errors ranging between 1 and 10% in most cases. Higher error where occurred on specific sites.

For a first set of experiments with MAR in the context of wind energy, and taking into account the limited horizontal scale used (10 km), the results are very satisfying. In some cases, MAR performed as good or better than higher resolution models, while the model resolution probably played a significant role in the inaccurate estimation of wind energy in several other cases. An advantage of this configuration is that it would enable relatively long (months or years) runs over the whole Belgium.

It appears from the study that the location of the observation site is quite crucial when an investigation of the wind potential is performed. Indeed, mast located in or nearby forested area might be influenced by very local effects whose impacts on the wind field might be a function of wind speed, wind direction, forest density, and so on … Extrapolate such data to a wind farm which extends over several km² might result in misleading information on the energy potential of the site.

WAsP is essentially a statistical programme, which deals with long term (Weibull) probability distribution data of wind speed and wind direction. Therefore WasP is not advised to use for short period runs

The impact of the selection of the reference station was examined for the simulation case of Rumes. It was found that the spacing in deviation of mean wind speed, using different reference stations between 30 km and 60 m from the observation site, lies between plus and minus 5%. Nevertheless, the spacing in deviation of mean wind power, proportionally with the third power of wind speed, lies between plus and minus 15%.

Taking into account the user friendly-ness, the price of the software, the short computation times required, one might conclude that WAsP is still an economic, reliable model for the basic micro siting of wind energy projects.

Since power output of a wind turbine is very sensitive to the mean wind speed (proportional to the third power of it), it is clear that e.g. a 5 % bias error on the mean wind speed of the model results (as has been frequently reported in the results) which for meteorological purposes appears to be quite good, but produces a 15 % bias in the power output which is probably for electricity generation an important deviation.

Extreme value analysis

An extreme value analysis of 13 synoptic gust speed series has been performed. After comparison with other more elaborate models, the Gumbel law was finally chosen for its simplicity and robustness. After applying a divisive hierarchical cluster analyse on the maximum wind speed [km/h] results for the Gumbel law for different return periods (years) three clusters could be identified:

Recommendations

A classification of meteo stations has been made according to criteria regarding obstacles. It is advised to use stations that meet class 1 criteria.

In order to verify the quality of the calculations based on reference stations cross correlation's should be performed for the used stations and it also recommended to use the different stations one by one for the site under study.

The roughness maps for the whole of Belgium have been produced including the boundary parts of the neighbouring countries. For a site under study it is crucial to take the roughness maps in the vicinity of 20km around the site.

A third important input parameter for resource assessment is the relief or height contour maps. Different sources are available and the 'dataforwind' site where SRTM data are freely available is giving good results.

The high-resolution mesoscale models simulate the regional wind characteristics like flow in presence of large hills and valleys. For simple terrains the well-known WAsP model is giving good results.

It would be very useful in the future to standardize measuring equipment and measuring systems of meteorological stations and calibrate the instruments on a regular basis.

Although in the framework of the WMO a standard height of 10 m is recommended, some reference data at higher altitude should be envisaged in view of the ever-increasing hub height of wind turbines.