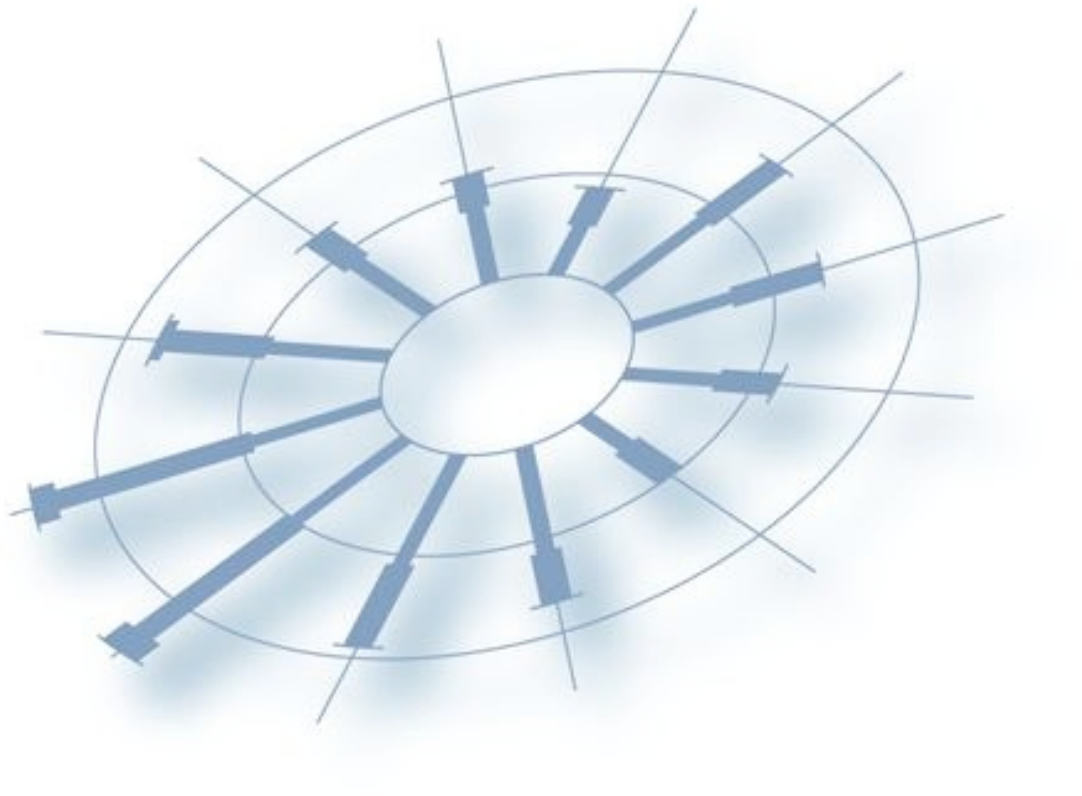
A E O L I S F O R E C A S T I N G S E R V I C E S



# WIND FARM ENERGY ASSESSMENT - FEASIBILITY STUDY

Kees van Vliet

September 2007

Koningslaan 112 3583GV Utrecht The Netherlands • telephone: +31 302515602 • fax: +31 302515697 • www.aeolis.nl

# Wind Assessments

The economic feasibility of a wind farm depends on the wind power output. Aeolis Forecasting Services performs wind assessments to calculate the expected annual farm production for the period of operational operation. This calculation is based on the following three facts:

**Wind climate estimation**

Historical time-series of wind measurements at any location are transformed into a local wind climate. The time-series of wind observations are inspected and corrected and cleaned for local effects. If there is no representative wind station available in the vicinity of the potential site there are two possible solutions. The first is to start a measurement campaign at the site for a certain period. This approach is expensive and requires at least a year. The second is to estimate the wind climate with the use of weather forecasting models.

**Wind power potential**

The total energy contents for a certain wind climate can be calculated with physical relations. With a power curve of a certain wind turbine the annual power production for the turbine in question can be calculated.

**Wind farm production**

The wind turbines in a wind farm introduce turbulence and wake effects that reduces the actual production of the wind farm. Wake losses for each turbine are calculated and the total annual energy production for the wind farm is estimated.

## Method used by Aeolis

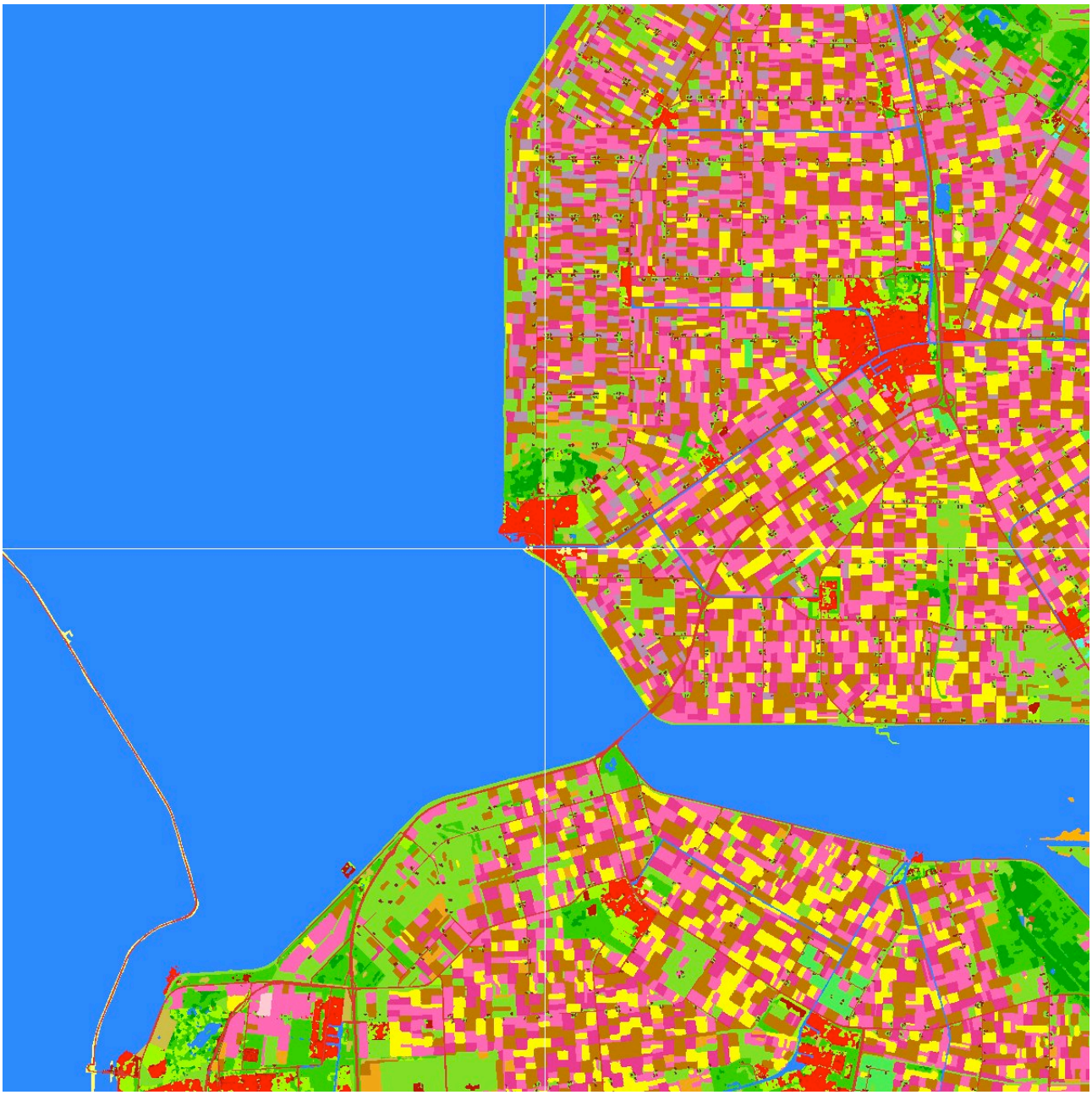
For such an assessment study we use WASP (www.wasp.dk). With this program the analyses can be performed and a great advantage of this tool is the transparent modular approach that is used. This modular approach makes it possible to add extra knowledge and adjust certain steps in the process.

There are three main factors that have a significant influence on these assessment studies (wind climate and wind farm production) that are all related to the terrain.

- Obstacles have a major impact on the wind (flow of air). It is very important to have detailed information about all objects in the vicinity of the wind measurement site and potential wind farm site.

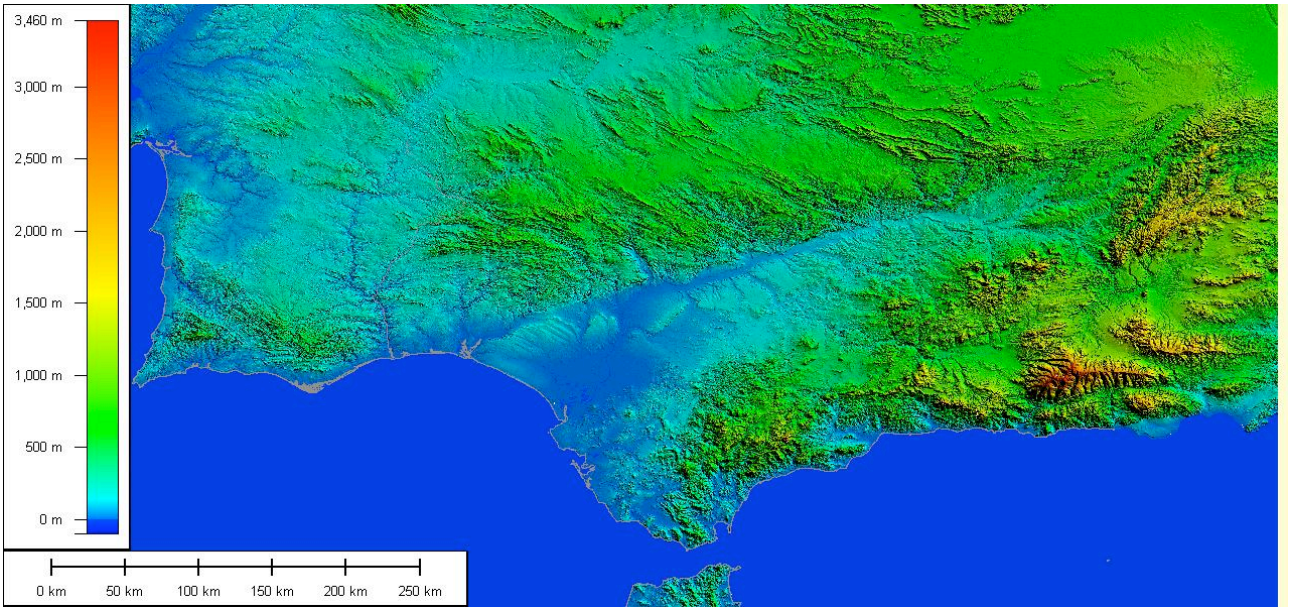
- Roughness. This is a classification related to the type of vegetation and soil. The classification used is the roughness length ($z_0$). Where bare soil and water have the lowest values

($z_0$ = 0m) an the values increase for more vegetated areas, for example $z_0$ =0.03m for grass and for areas with trees and buildings $z_0$ = 0.10m and $z_0$ = 0.40m for urban areas.



Land use in the province of Flevoland (mostly agriculture) starting point for the roughness classification.

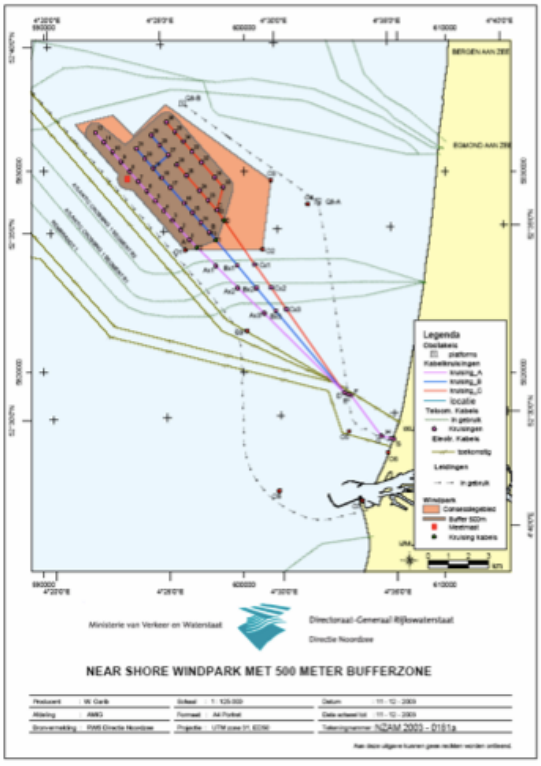
- Orography. Hills, cliffs and valleys have a strong influence on the wind. The wind accelerates near the summit or crest and decelerates near the foot and in the valleys. For assessment studies in the Netherlands the effects of orography are negligible. However for certain areas on the Iberian peninsula for example the effects of orography are dominant.




Orography on the South west part of the Iberian peninsula.

# Offshore Windpark Egmond aan Zee

The first operational offshore wind farm in The Netherlands is located about 15 km off-shore from Egmond aan Zee. The knowledge and experience gained from this project will be used for the future development of wind energy as a source of renewable energy. The Ministry of Economic Affairs has also clearly designated the farm as a demonstration pro-ject. The farm comprises 36 wind turbines, each with a capacity of 3 MW. Together they supply enough renewable electricity for more than 100,000 households.




Offshore windpark Egmond aan Zee on the Dutch North Sea coast.

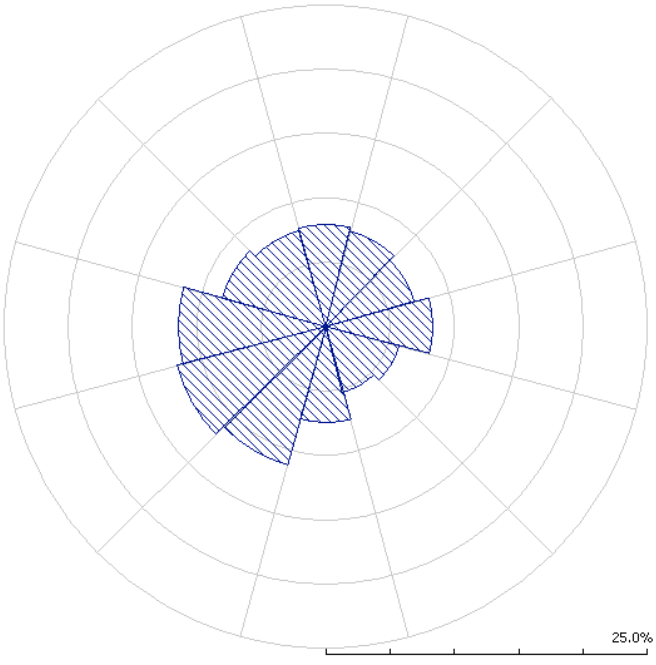
The layout of the farm is visualized on the picture on the previous page. The V90-3MW turbines are manufactured by Vestas (www.vestas.com) and have a hub-height of 70 meters.

The wind assessment study for this site reduces to the construction of a local wind climate and the calculation of losses due to wake-effects in the wind farm. In this study we will use the results of the Texel LS as published in the European Wind Atlas[1] as a first estimate off the local wind climate.

### A summary taken from the European Wind Atlas

Sector frequencies for roughness length 0.00 m

| i | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [°] | 0 | 30 | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 |
| f [%] | 7.9 | 7.6 | 7.2 | 8.3 | 5.9 | 5.3 | 7.4 | 11.1 | 11.9 | 11.4 | 8.3 | 7.7 |




Wind rose for a roughness length of 0.00 m

### Calculation of the annual output

1 European Wind Atlas, Copyright 1989 by Risoe National Laboratory ISBN 87-550-1482-8

| Turbine | Gross AEP[MWh] | Net AEP[MWh] | Efficiency[%] |
|---|---|---|---|
| Turbine site 1 | 10689 | 10417 | 97.45 |
| Turbine site 2 | 10695 | 10335 | 96.63 |
| Turbine site 3 | 10703 | 10316 | 96.39 |
| Turbine site 4 | 10711 | 10321 | 96.36 |
| Turbine site 5 | 10717 | 10317 | 96.27 |
| Turbine site 6 | 10723 | 10317 | 96.21 |
| Turbine site 7 | 10729 | 10338 | 96.35 |
| Turbine site 8 | 10734 | 10364 | 96.55 |
| Turbine site 9 | 10738 | 10412 | 96.96 |
| Turbine site 10 | 10743 | 10472 | 97.48 |
| Turbine site 11 | 10747 | 10525 | 97.94 |
| Turbine site 12 | 10752 | 10626 | 98.83 |
| Turbine site 13 | 10673 | 10367 | 97.14 |
| Turbine site 14 | 10680 | 10228 | 95.76 |
| Turbine site 15 | 10689 | 10176 | 95.20 |
| Turbine site 16 | 10698 | 10188 | 95.23 |
| Turbine site 17 | 10709 | 10146 | 94.74 |
| Turbine site 18 | 10714 | 10117 | 94.43 |
| Turbine site 19 | 10721 | 10140 | 94.58 |
| Turbine site 20 | 10727 | 10177 | 94.87 |
| Turbine site 21 | 10733 | 10296 | 95.93 |
| Turbine site 22 | 10668 | 10268 | 96.25 |
| Turbine site 23 | 10678 | 10173 | 95.28 |
| Turbine site 24 | 10687 | 10178 | 95.24 |
| Turbine site 25 | 10698 | 10149 | 94.86 |
| Turbine site 26 | 10707 | 10114 | 94.46 |
| Turbine site 27 | 10714 | 10129 | 94.53 |
| Turbine site 28 | 10720 | 10174 | 94.90 |
| Turbine site 29 | 10726 | 10310 | 96.13 |
| Turbine site 30 | 10667 | 10298 | 96.54 |
| Turbine site 31 | 10675 | 10274 | 96.25 |
| Turbine site 32 | 10689 | 10270 | 96.08 |
| Turbine site 33 | 10698 | 10246 | 95.78 |
| Turbine site 34 | 10706 | 10258 | 95.82 |
| Turbine site 35 | 10711 | 10303 | 96.19 |
| Turbine site 36 | 10717 | 10426 | 97.28 |
| **Wind farm** | **385486** | **370164** | **96.03** |

The losses due to wake-effects in the wind farm depends on the location of the turbine in the wind farm. The turbine situated on the north west edge (site 12) has the smallest loss (1.2%) while the turbines more in the center of the wind farm have losses just exceeding 5%. The total loss for the wind farm is about 4%.