Sander + Partner GmbH

Wind Atlas Poland

Wind & Energy
Resource Assessment

Created for
Our Customer

May 09, 2008

SANDER + PARTNER GmbH
Neuhausweg 37
3097 Liebefeld
Switzerland

Tel: +41-31-961 2565
Fax: +41-31-961 2566
info@sander-partner.ch
www.sander-partner.ch

We strongly advise that measurements be carried out at the site of the wind park.

SANDER + PARTNER GmbH is a fully employee-owned company and operates independently of any third parties.

Executive Summary

Latitude:	**54.940 N**
Longitude:	**15.539 E**
Hub height:	**120 m**
Wind speed at hub height:	**8.5 m/s 19.01 mph**
Wind turbine:	**GE 1.5 se (1500 kW)**
Annual capacity factor:	**44.3%**
Annual power production:	**5831 MWh**

Wind speed and power production are evaluated using the wind data of a period of 10 years, and show the mean values for the period 1/1/1998 to 12/31/2007.

The wind and power assessment use the most recent wind data available for the specific site.

This report shows the probabilities and risks of wind power production at the selected site, which are obtained using historical wind data that cover at least the time span of the life cycle of a wind turbine.

The wind data have been derived from a “regional reanalysis” by way of a leading weather model. As a result, wind speed and power production represent the average values of an area measuring 5 km x 5 km.

Contents

The Wind Resource

The wind resource is estimated using more than 10 years of wind data — the period 1/1/1998 to 12/31/2007.

The wind data used are delivered with this report.

The source of the wind data is a regional reanalysis that has a resolution of 5 km x 5 km. As a result, the wind data should be considered to represent the average conditions within an area measuring 5 km x 5 km. Any local meteorological influences from the very narrow vicinity of the site have been omitted in this regional reanalysis.

Wind speed and wind power production should be regarded as a first estimate. To more accurately reflect the site's local meteorological influences, the wind data of the Wind Atlas Poland need to be corrected, which is done by carrying out measurements at the site of the wind turbines. This method of correction is called MCP (measure – correlate – predict).

The Wind Atlas Poland provides the latest wind data available at the time of writing, and thereby guarantees that the correlation can be calculated between the wind data and the local measurements for the longest possible temporal overlap.

Wind Speed

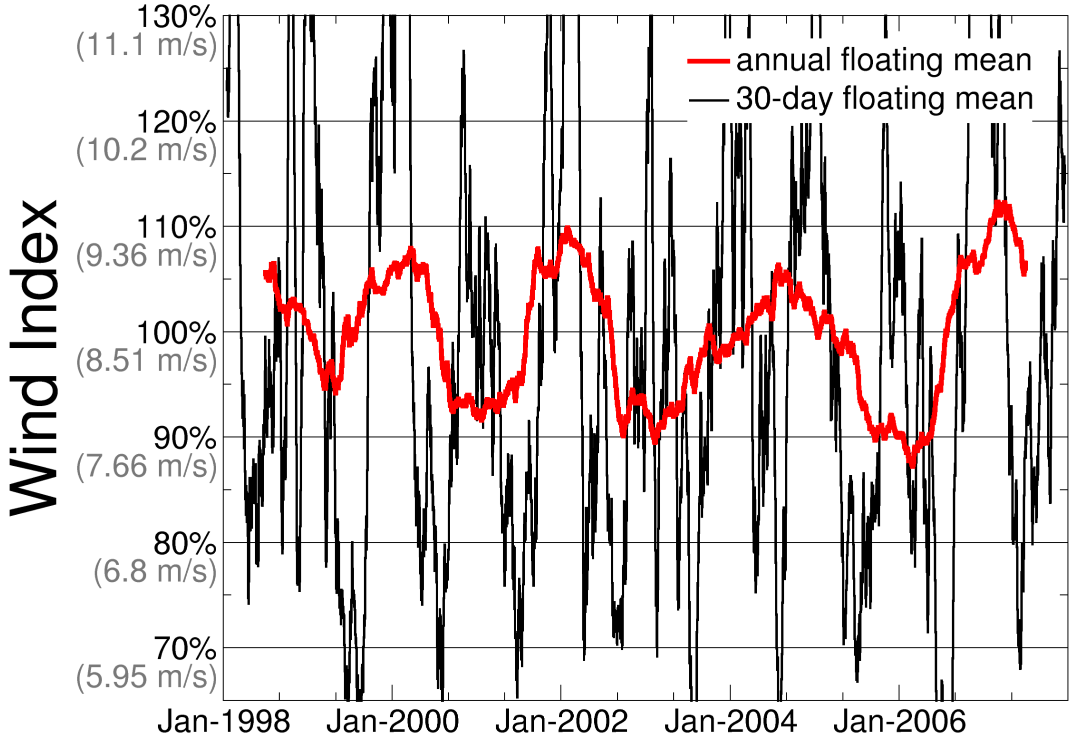

Figure 1: The wind index and wind speed over the past 10 years: the black line shows a floating mean over 30 days (monthly means), the red line shows a floating mean over 365 days (annual means).

Financial risks arise from changing wind speeds. Wind speeds can vary on a daily, monthly and even interannual basis. To determine the level of risk, a wind index is used, which is based on the wind data of the past 10 years.

Interannual variations constitute the major cash-flow risks during the life cycle of a wind park.

SANDER + PARTNER GmbH

Wind Distribution

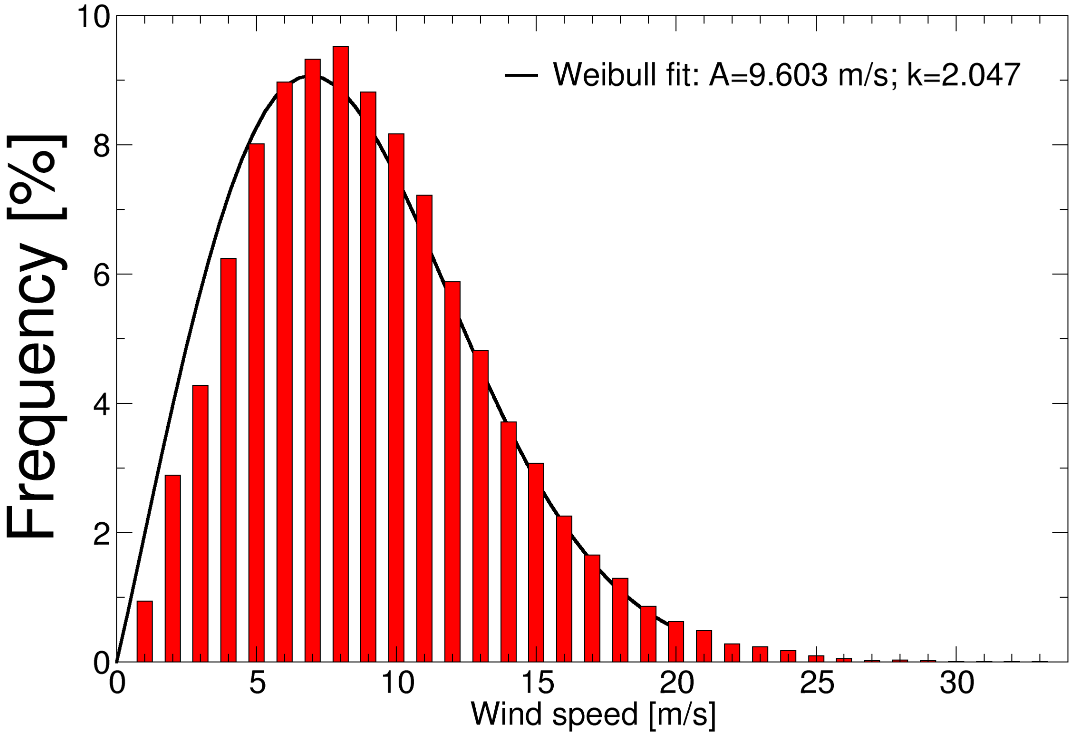

Figure 2: Wind speed distribution: the red bars show the actual wind data in bins of 1 m/s. The black line indicates a fitted Weibull distribution. The Weibull parameters are given in the top right-hand corner.

The Weibull distribution is often used to estimate power estimation. The figure shows whether the actual data are well represented by the Weibull distribution. Large errors in power estimation may occur when the fit does not represent the wind data well.

A large Weibull value of the scale parameter A does not imply high power production. Power production must be considered using both the scale parameter A and the shape parameter k.

The Wind Rose

Wind Rose

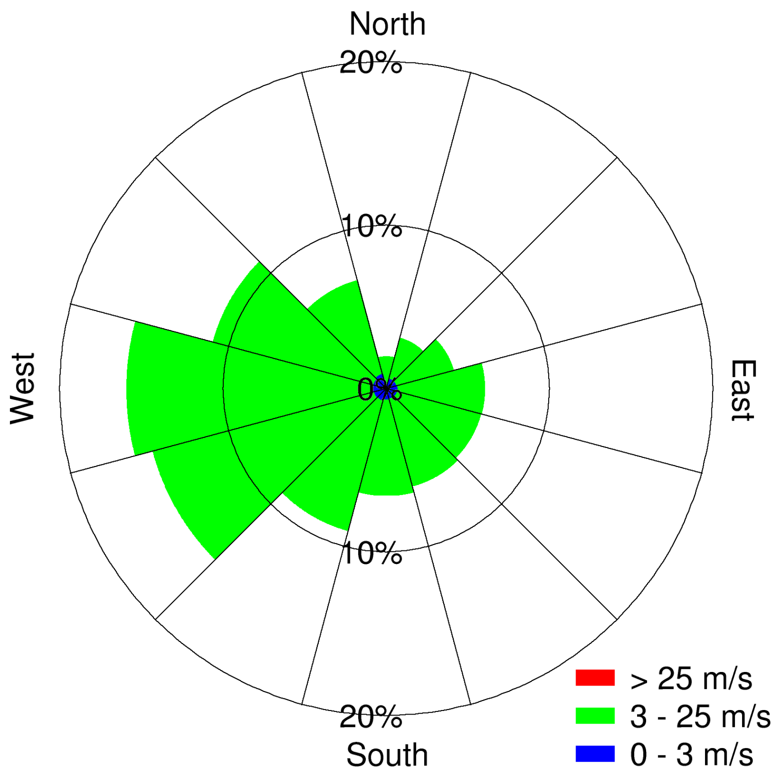

Figure 3: The wind rose: the blue area indicates a wind speed of less than 3 m/s, the green area a wind speed in the range of 3 m/s to 25 m/s, and the red area a wind speed of more than 25 m/s. For most types of wind turbines, only wind speeds in the green area will produce any power.

The wind rose shows the major wind directions at the site of interest. The production of wind energy takes place during winds in the green area. The blue area indicates low wind speeds that are not used by large wind turbines. The red area shows the wind speeds at which most turbines must be stopped to prevent damage from occurring.

The wind rose is based on 10-year wind data, and represents the overall wind conditions of the wider area. Local topography can change the wind substantially.

Power Assessment

Power assessment was undertaken using a single wind turbine of type GE 1.5 se (1500 kW).

Power production is evaluated at a hub height of 120 m.

The conversion of wind speed into power production is based on the power curve of this turbine. Any losses incurred during the conversion of wind energy into electrical voltage have not been considered here.

A note from the wind turbine's manufacturer: Please, check the availability of the wind turbine for your local market.

The power assessment figures are shown as the capacity factor.

The capacity factor expresses the power production relative to the nominal power of the wind turbine. To estimate the annual mean power production in MWh, multiply the capacity factor by the nominal power of the wind turbine and by the number of hours per year.

For example: the annual capacity factor is 35%. The annual power production of a wind turbine with nominal power production of 1.5 MW is than calculated as 0.35 x 1.5 x 8,760 = 4,599 MWh.

The Capacity Factor

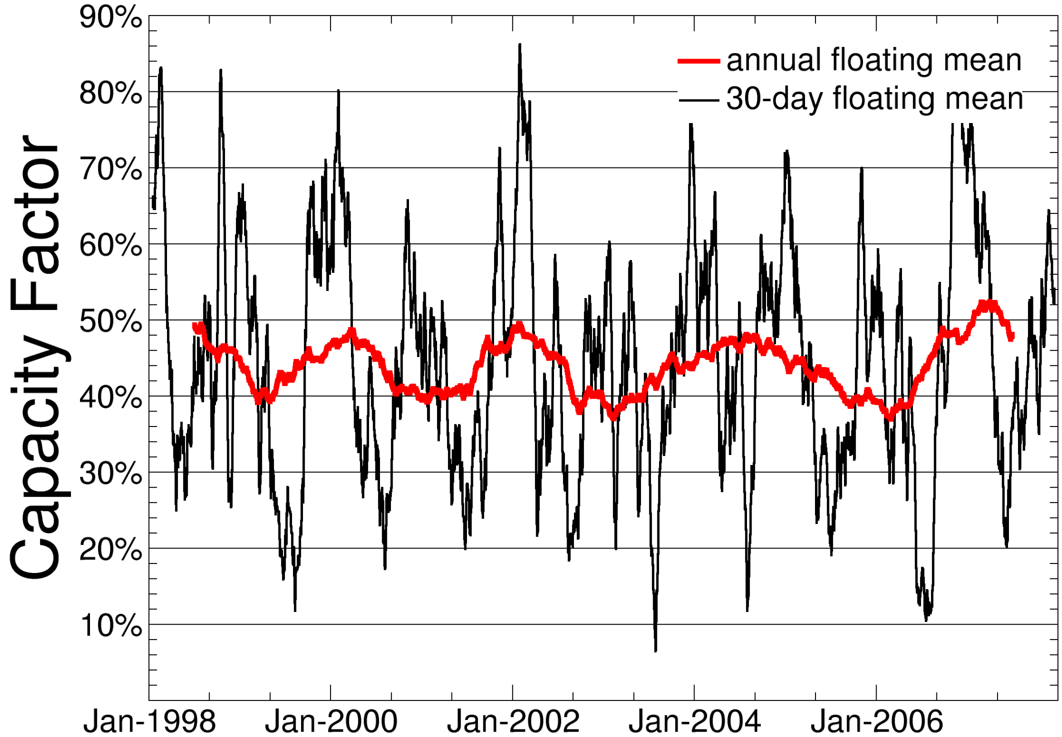

Figure 4: The capacity factor during the past 10 years for a GE 1.5 se (1500 kW) wind turbine: the black line shows 30-day floating mean values, the red line shows the annual floating mean capacity.

The course of the capacity factor, shown in figure 4, is a key factor in estimating cash flow during the life cycle of a wind turbine.

Financial planning should consider the interannual variations of the capacity factor and therewith the probabilities and risks of fluctuating cash flows.

Professional portfolio management uses the history of returns and risks in order to optimize the selection of different sites and the size of wind farms.

Probabilities and risks are estimated using wind data that cover a period that is at least equivalent to the life cycle of a wind turbine.

Seasonal Variability

Wind speed and power production vary over time. In the course of a year, seasonal cycles may arise; this seasonal variability is useful for planning maintenance or other technical services.

Rigorous cash-flow planning requires a deeper knowledge of the variations that can occur during the lifetime of a wind turbine. Seasonal variability is not a robust indicator and should not be used for cash-flow planning. When planning cash flows, the complete history of the wind park's power production needs to be taken into account.

Wind Speed

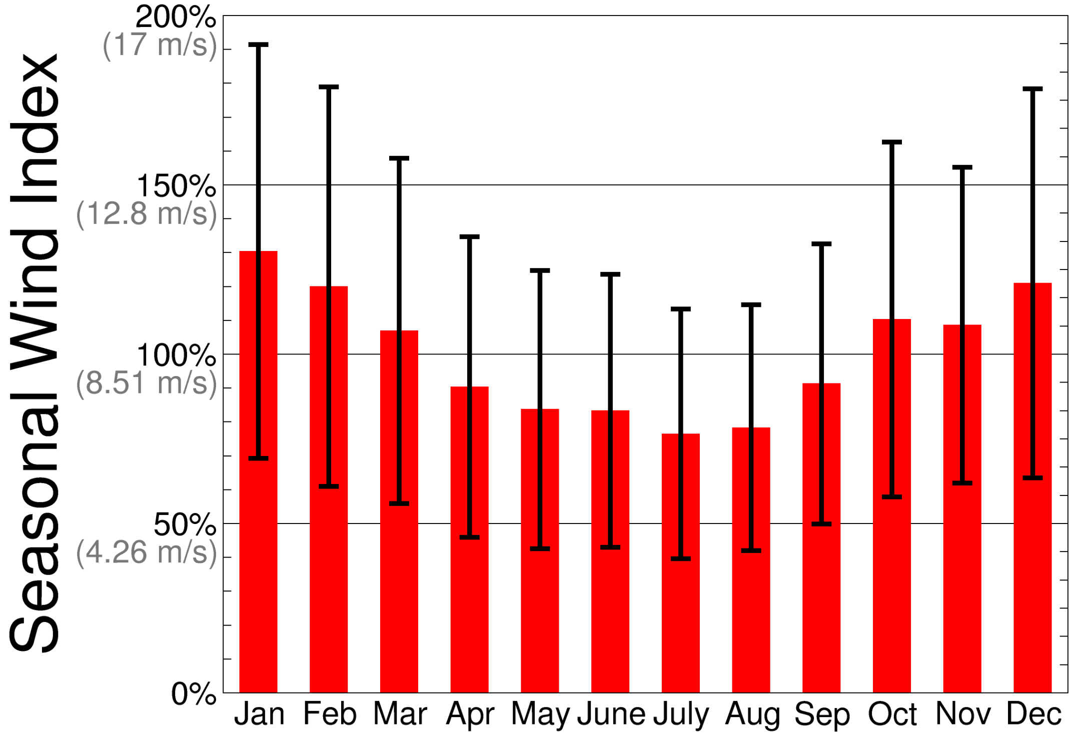

Figure 5: The seasonal wind speed variability: wind speed is given as an index and in absolute numbers. Seasonal variability can be large, as shown by the vertical error bars indicating one standard variation. The seasonal wind index is based on the wind data of the previous 10 years.

The seasonal wind speed variability or the corresponding wind index are useful for planning maintenance. The error bars for each month can become very large due to the interannual variability of the wind speed. Therefore, seasonal variability is not a robust indicator.

Power Production

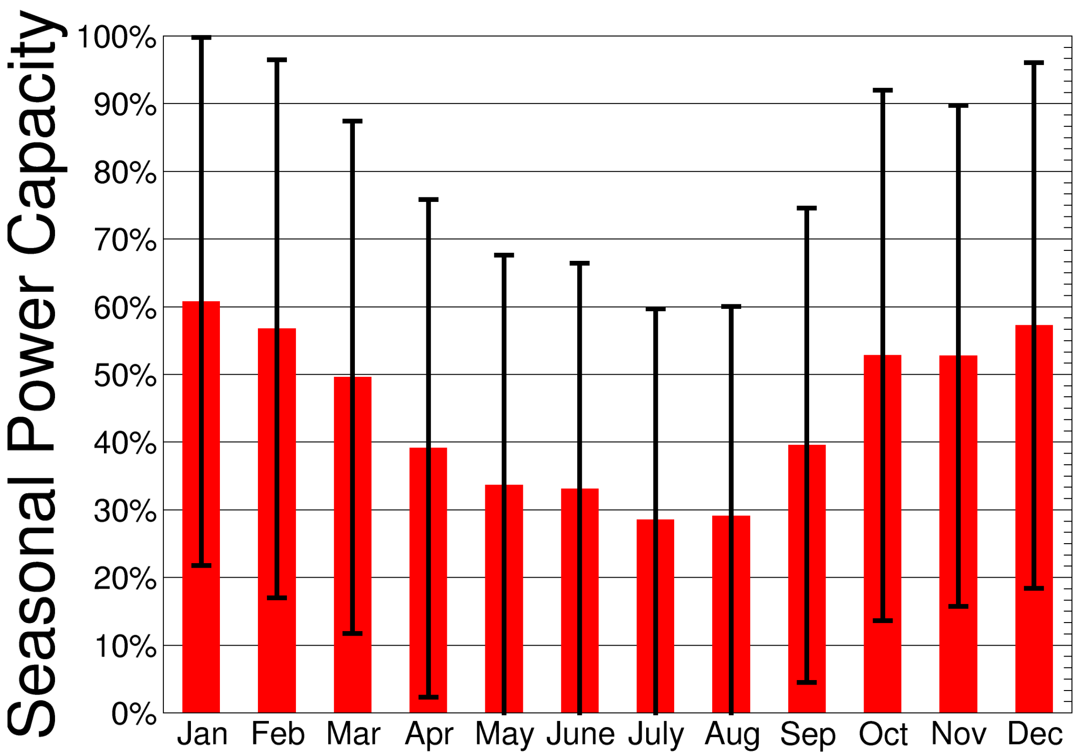

Figure 6: The seasonal variability of the capacity factor: the red bars indicate the mean power capacity during the past 10 years, the black vertical lines correspond to one standard deviation of the capacity factor. The standard deviation shows the range of the monthly capacity factor, where 68% of the variation occurred during the past 10 years.

Power production during the life cycle of a wind turbine is highly sensitive to the interannual variability of the wind. Large error bars indicate that long-term variability can lead to highly fluctuating cash flows from year to year.

Extreme Wind Speeds

Extreme wind speeds can seriously damage wind turbines by causing extreme loading. Extreme wind speeds are characterized as a wind speed that returns once every 50 years.

Evaluating extreme wind speeds is sensitive to the method used for the evaluation. We use a procedure called “peak over threshold” to determine the extreme wind speeds that have the probability of returning once every 50 years. The results can provide a first estimate of extreme wind speeds.

Please bear in mind that the wind data used for the evaluation represent the average values of a medium-size perimeter. No adjustment of the wind speed to local meteorological conditions has been made.

Extreme wind speeds represent meteorological events that last for a minimum of ten minutes. By contrast, gusts or extreme loads last for only three seconds. This report includes a conversion of extreme wind speeds to gusts.

Fifty-Year Wind Speeds

Extreme Winds

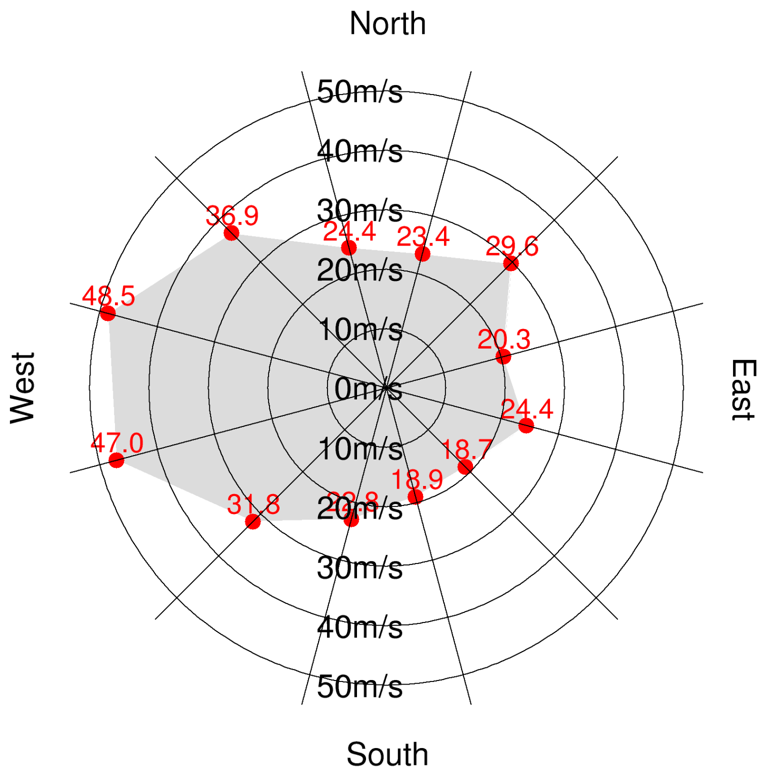

Figure 7: An estimate of wind speeds that have the probability of occurring once every 50 years: the red dots and numbers indicate the extreme wind speeds for each wind sector of the wind rose. The wind speed is given in meters per second (m/s).

Extreme wind speeds represent events that last for a minimum of ten minutes.

To determine the speed of local gusts, the local land cover (surface roughness) must also be taken into consideration: multiply the numbers shown in the wind rose of extreme wind speeds with the appropriate gust factor given in the table on the next page.

Local Wind Gusts

Local gusts are determined using the wind rose of extreme wind speeds. The values given in the wind rose need to be adjusted according to the local land cover.

The resulting wind speed provides a good estimate of three-second gusts as required by IEC 61400.

Land cover	Gust factor
Water	1.40
Rock, sand, wetland	1.45
Grassland	1.50
Field	1.50
Deciduous forest	1.65
Mixed forest	1.70
Coniferous forest	1.75
Built-up areas	1.85

Table 1: Gust factors for different kinds of land cover.

Example: The rose of extreme wind speeds shows 20.0 m/s in a north-easterly direction. The local vegetation at your site is grassland. From the table you can read that the gust factor is 1.50. The three-second gust at the site is therefore estimated to be 20.0 m/s x 1.50 = 30.0 m/s. The wind gust of 30 m/s will return once every 50 years.

Assessment Process

The Wind Atlas Poland is based on what is called a regional reanalysis.

A regional reanalysis uses a weather model to analyse the weather of the past. It requires a number of inputs: high resolution topography to represent the wind flowing across the orography; and maps of the vegetation and soil to address the interaction of the atmosphere with the ground surface or the evaporation and retention of water, etc. Meteorological measurements of surface observations, daily weather balloon records, aircraft reports and satellite observations are also used. These inputs are processed using the weather model, employing the best scientific and physical knowledge available.

To establish the Wind Atlas Poland, a huge amount of meteorological data were analysed with the weather model. Although it might be possible to run the weather model on a Laptop, this would require more than 10 years to finish the calculations. The Wind Atlas Poland incorporates the wind conditions recorded at more than 15,000 locations. Even a simple map showing the mean of 20 years considers more than 1,000,000 points in time, each point having different wind conditions.

However, numerical models do have shortcomings. A weather model will provide wind speeds for the topography represented. The Wind Atlas Poland uses a topography that has a resolution of 5 km, which implies that the influence of hills (or any other undulating topography) that have a base of less than 5 km, on the wind is not represented by the data.

For that reason, the Wind Atlas Poland is intended as a first source of wind data from which long-term correlations with local wind measurements can be determined.

The focus of the Wind Atlas Poland is twofold:

- The Wind Atlas Poland provides an excellent first insight into the wind resource.
- The Wind Atlas Poland supplies long-term (of a period of 10 years) wind data, suitable for carrying out correlations with measurements done at the site.

From Zero to Success

The Wind Atlas Poland marks a first step in the assessment of future wind power production.

The Wind Atlas Poland contributes to the assessment procedure of wind power by providing long-term wind data. However, in order to achieve the highest level of quality, we strongly advise that additional work be undertaken.

As our company specializes in computational meteorology, we recommend that wind measurements be carried out at the actual site and that they are started as soon as possible. Wind measurements should be taken for a minimum of one year, and calibrated instruments should be used.

The multi-year historical wind data of the Wind Atlas Poland should be combined with the measurements carried out at the site in order to create the best possible database for any further evaluations.

The process of combining the two data sets is called MCP (measure – correlate – predict). However, the term “predict” is misleading: like any other form of financial investment, the planning of wind power production depends on historical data.

While the measurements taken at the site record the very local wind conditions with **high precision**, the multi-year data of the Wind Atlas Poland provide **homogeneous**, long-term wind data.

Only by combining high precision with homogeneity does one obtain the ultimate goal: wind data of the highest quality.

Our Services

SANDER + PARTNER GmbH specializes in everything to do with computational meteorology.

- **Historical wind data provision:** we provide historical wind data, based on regional reanalysis. A unique feature is that we deliver a complete picture of the past: ten, 20 and even 30 years of wind data.
- **Wind mapping:** we map wind conditions using historical wind data. A wind map can include the wind conditions of more than 1,000,000 points in time. Wind maps are also available in low resolution (as low as 200 m).
- **Forecasting:** we provide wind and power forecasts, ranging from forecasts for the next few hours to forecasts for the next five days.
- **Wave forecasting:** we forecast wave heights and other offshore risk factors for the offshore industry.
- **Wave hindcasting:** we explore previous offshore wave conditions, a service that is needed by offshore wind farms and other industries.

Project Report

This report was automatically generated. Please send any inquiries to:

Address	SANDER + PARTNER GmbH
Street	Neuhausweg 37
ZIP Code/City	3097 Liebefeld
Country	Switzerland

Project manager	Dr Johannes Sander

Direct contact	Dr Johannes Sander
Telephone	+41-31-961 2565
Fax	+41-31-961 2566
Email	sander@sander-partner.ch

Memberships

Dr Sander is a member of the:

- German Wind Energy Association
- German Meteorological Association
- Swiss Meteorological Association
- Swiss Academy of Science.

SANDER + PARTNER GmbH is registered with the chamber of commerce of the Canton of Bern, Switzerland. The company is a fully employee-owned firm, and operates independently of any third parties.

SANDER + PARTNER GmbH