LONG-TERM WIND SPEED TRENDS IN GERMANY

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Summary

The long-term average energy predictions for German wind farms often appear high compared to the achieved production even for long operational periods.

The BDB Wind Indices [1] are often employed in Germany as reference data sources and are, generally, very helpful, as they usually correlate very well with wind and production data. However, the long-term energy production as indicated with the original BDB 100% level is subject to ongoing concern.

Updated results of investigation carried out by GL GH on wind speed trends in Northern Europe earlier [2, 3] accompagnied by some investigation on the BDB Index level are shown here. As part of this work it has been tried to validate the BDB Index data against NCEP reanalysis data; however these seem to show disagreement in the trend for the last years. Also, it has been found that the 2009/10 winter season was subject to exceptionally low winds.

1. Windiness Indices

Wind farm investors are exposed to risk associated with annual wind speed trends. There are risks both with how robustly the historical wind speed has been established and also how future winds may vary from historical winds.

The windiness index system has become a widely used tool within the wind energy industry, being used for operational wind farms to understand monthly production and as a reference when estimating future long-term production. These windiness indices are only available for the past 15 to 20 years (Danish Index: 30 years). In order to investigate the past trend in wind speeds over several decades, alternative data sources need to be investigated. Conclusions have been drawn relating to the wind speed trends in northern Europe over the past 40 years which is shown in more detail in [2, 3]. Updated results of [2, 3] are shown here.

The data of windiness indices in northwestern Europe are shown in Figure 1. To allow comparison, the indices have been normalised by dividing the index anomalies for each annual value by the long-term standard deviation.

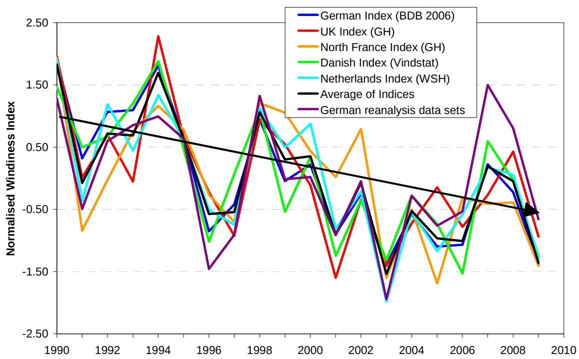

Figure 1 Windiness Indices in northwestern Europe

From the data plotted in Figure 1 for the period 1990 to 2009, it would be easy to conclude that annual mean wind speeds are dropping, as indicated with the arrow. A consequence for future wind energy projections would be that we should ramp down future expectations of wind speed and energy yield.

In order to investigate the past trend in wind speed we need consistent data going back several decades, covering the period before the start of the windiness indices.

Obvious sources of data are wind measurements. However, due to changes to measurement equipment, location or procedure at a measurement, it is common that consistent data extend back no more than 15 to 20 years and usually less. Due to the short period of development, turbine production data are not available for a period of over 20 years.

NCEP reanalysis data [4] are widely used as a reference data source in the wind industry and are available since 1948. The reanalysis data are based on a global meteorological model which is kept consistent over time, however, the data, which are fed into it, are not consistent. Therefore, GL GH considers these data are only suitable to be used as additional verification data source, especially over longer periods. Nevertheless, the reanalysis data were used for some investigations reported below.

As pressure differences are the main driving force for wind speeds on a wider scale, pressure or related data are considered as an alternative data source to establish the long-term trend of wind speeds. Due to the simple, slow changing nature of pressure and the simple instruments used to measure these, pressure measurements as such are likely to be more consistent than wind measurements. These data sets are available from the beginning of the 20th century but as it is considered that the certainty of the data increases with time, care should be taken when considering the weight to be put on the earlier years of the data.

Based on pressure measurements, the following proxies based on pressure data have been considered as longer term reference: The Großwetterlagen (GWL), the Jenkinson Lamb (JL) data sets, which are both based on synoptic charts of weather types, and the North Atlantic Oscillation (NAO) index, defined as the difference in normalised pressure between the Azores and Iceland. Description of these data sets can be found in [2, 3].

For the purpose of this investigation, these data have been considered from 1965 onwards and compared to the indices.

In Figure 2, the three proxies for wind speed described above are plotted alongside the average of the five windiness indices (UK, North France, Denmark, Germany and the Netherlands) for the period 1990 to 2009, again normalized as described before.

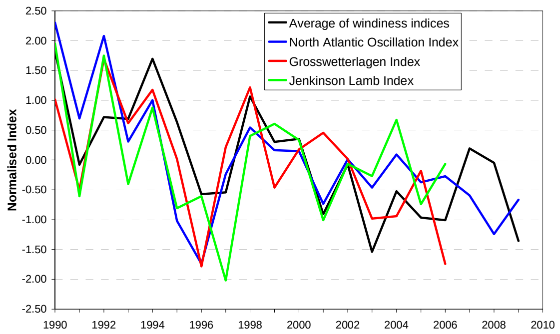

Figure 2 Wind speed proxies and average of windiness indices

Correlations of the proxies and the average of the windiness indices indicate an average coefficient of determination, R^2 value, of 0.45. It is clear that, although the correlation quality is not high, on the whole the proxies follow the same trend as the windiness indices and it is considered that the correlations are strong enough to justify the qualitative but not quantitative use of these proxies.

Figure 3 provide valuable information on the trend in wind speed prior to the start of the windiness indices discussed in Section 1. Figure 3 shows also an Index made up of reanalysis data, which is further described below. It is clear that the recent downward trend does not exist prior to about 1990. This suggests that the recent downward trend in mean annual wind speed seen in the indices may represent a return to the longer-term mean, and therefore it would be illogical to conclude that this downward trend in wind speed will continue for the next 15 to 20 years.

It is also implied from the proxies for wind speed discussed here that the period centred on the early 1990s experienced unusually high wind speeds. The data in Figure 3 show that this period, while having higher wind speeds than the period since the mid 1990s also appears to have had higher wind speeds than the previous 20 to 30 years. In fact, inspection of these data sets prior to 1965 indicates that this period was one of the windiest periods, if not the windiest period since the beginning of the century.

If it were possible to obtain a source of reference wind speed data that were consistent for the past 40 years, it is considered that the inclusion of this period of higher windiness would have little effect on the average for the reference data. However, due to consistency considerations such a long consistent period is not typically available. Long-term references used in energy production assessments can usually not be considered consistent over such long periods, and as such, are likely to include an unrepresentative proportion of data from this windy period. Where this is the case it is considered that care is needed in the selection of the most appropriate long-term period to use.

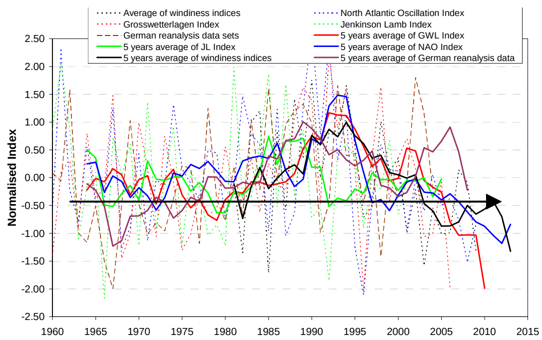

Figure 3 NAO, GWL, JL and Reanalysis Indices

2. Production data trends in Germany

The accurate forecasting of the future level of wind speeds and energy production in Germany has been a topic of discussion for a long time; see for example [5, 6, 7]. The underlying difficulties are however still unresolved or disregarded. As shown in [8], the predicted future energy production of operating turbines varies by up to 30 %, only due to the assumed long-term average of wind potential.

A special area of concern is the long-term wind potential assumed with the usage of the BDB Wind Indices [1] applied as standard in Germany. The BDB (BeteiberDatenBank) Indices are also known as IWET or Keiler/Häuser-Indices. Some facts about these are:

- BDB Index data are produced from production data of turbines grouped in 25 regions of Germany.
- These are production indices, not wind indices.
- They have undergone several revisions (1999, 2003, 2006). The current version is denoted BDB 2006. The last change was thought to mitigate concerns about the 100 % level.

Figure 4 shows the averages of the index levels for some example regions for various periods. Table 1 shows average BDB Index values for the periods 2000 to 2009 for some example regions.

The following conclusion can be drawn:

- The year 2009 showed very low energy production.
- The relative trend of the regions differs significantly.

- The average level of energy production according to the indices was considerably below 100 % for almost all periods shown. Only if data from approximately 1990 to 2009 were considered, the approximate level of 100% could be reached.
- The last 10 years would in general be considered as period being representative of the long term, thus a realistic period to describe the average of wind speeds and energy production. However, the average BDB Index level for the period 2000 to 2009 is certainly below the average with 91.5 %.

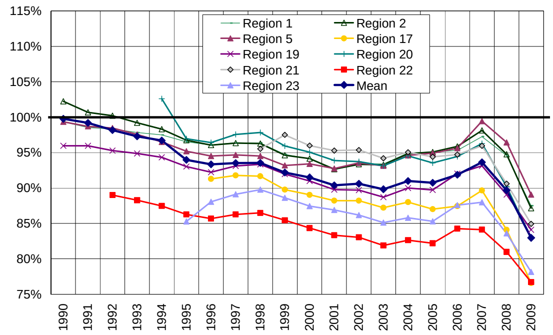

Figure 4 BDB Index 2006 backward averages for example regions (2009 means 2009 only, 1990 means 1990 – 2009, etc)

Region	2000 to 2009 *
1	94.1
8	95.6
21	96.0 (Maximum)
22	84.3 (Minimum)
Mean	**91.5**

* Adjusted for seasonality of incomplete data.

Table 1 Average BDB Index values [%] for the years 2000 to 2009 for example regions

The above low averages of energy production for long-term periods create doubts on whether these can be correct at all.

Based on [3] and [9], figures of 6 % and 12 % appear to be sensible assumptions for inter-annual variability in wind speed and energy respectively at a wind farm site in northwestern Europe.

Sometimes it has been reported that there may be longer term cycles in the wind climate [7, 10, 11] however these reported cycles are weak, sometimes detectable only if summer and winter periods are considered separately or are only evident for some data sets while other data sets show different results. The assumption that there are no cycles in wind climate is reasonable; slight cyclicity would likely not challenge the variability materially.

Assuming the above cited annual variability of 12 % in energy production and general independence of the years, it follows that 10 years period should have a variability of approximately 3.8%. Consequently, the probability that the 10 year periods above had the windiness levels as shown in Table 1 would be as shown in Table 2.

Based on Table 2, the probability that the average original BDB levels are suitable is extremely low or, stated from a technical perspective: The original 100 % level of the BDB Indices leads to an overprediction of energy yields if compared to long-term periods constructed from the last years.

Level [%]	Probability [%]
84.3 (minimum BDB level)	0.002
85.0	0.004
90.0	0.4
91.5 (average BDB level)	1.3
95.0	9.2
96.0 (maximum BDB level)	14.3
100.0	50.0

Table 2 Probability of BDB Index-levels for 10 years periods

Furthermore, in investigating the index consistency, it was noted that neighbouring index regions show significantly differing trends in earlier years, most notably when few turbines were contributing production data into each region. Other regions appear subject to downward trends. Therefore, it is considered that for some index regions the averaging period should eventually be based on shorter periods. GL GH considers that further investigations are required to understand these issues.

3. Comparison with reanalysis data

It has been tried to validate the course of the BDB Index data against reanalysis data [4].

Of the different reanalysis data sets available, GL GH has considered surface data (also denoted Sigma-level) along with data from pressure levels of 850, 925 and 1000 hPa for the period of 1948 to 2009 which are available with a grid spacing of 2.5 degrees latitude and longitude.

Comparisons of an index generated from all grid nodes inside Germany and data sets to the other data sources considered here are shown in Figure 1 and Figure 3. Conclusions from these comparisons and analysis of individual data sets of the reanalysis data for Germany are summarized as follows:

- The reanalysis data sets show a general similar trend to each other apart from the surface data, which trend changes often rapidly from one node to the next, appearing inconsistent in itself.
- In general and for most of the historical data period, no similar levels of high wind speeds compared to the level around 1990 for Germany were observed. The general level during 1950 to 1970 was lower than afterwards, although there are short periods with high wind speeds.
- The early low levels of reanalysis data are likely not comparable to later data due to consistency issues. Regardless, the reanalysis data provide no evidence that the high wind speeds at the beginning of the 1990s are a phenomenon which is likely to appear again.

- The general trend of the reanalysis data fits to the BDB wind indices and the other data sources examined until approximately 2006.
- After approximately 2006 the reanalysis data show higher relative wind speeds than the BDB Index indicates. Since the general course of the BDB Index data is backed up by other data sets, its level is considered more probable than the reanalysis data. Further analyses are required to understand this issue.

Reanalysis data are widely used as long-term reference source in wind industry, especially the surface data sets. It is therefore considered that additional care is required in employing these data.

4. Recent low wind speed period

Germany appears to have experienced a period of particularly low wind speeds in the winter of 2009-10 and throughout the first half of 2010. This observation has been corroborated by data from operational wind farms.

For the average BDB Indices since 1991 as originally reported, the first and second quarters of 2010 were each the second lowest with average index values of 91 % and 60 % respectively. Also, the first half year of 2010 was the lowest reported ever, with an average index of 76 %. Additionally, the year 2009 showed the lowest annual average index value since 1991 with 83 %.

This phenomenon coincides with very low values for the NAO Index [12]. Figure 5 shows a comparison of the BDB Indices to the NAO Index. As the NAO is particularly dominant in the winter months of December to March [12], and has much better relation to site data, this review has focused on these winter periods. There is a non-perfect, but clear relationship of both indices visible. The correlation coefficient R^2 is noted to be 0.67 for the winter months, for whole year averages, R^2 is 0.47.

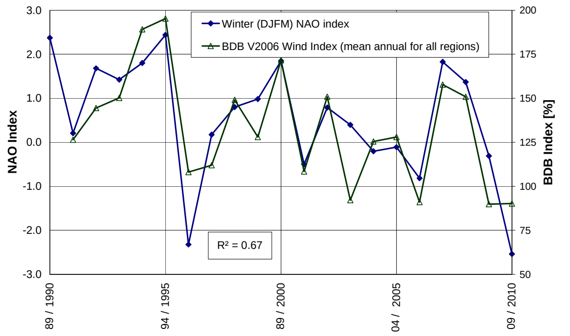

Figure 5 NAO Index compared with average of BDB Index for winter month

The low value NAO index for the winter of 2009-10 is an extreme event. The mean NAO index for December 2009 to March 2010 is the most negative value for the winter months of the year experienced since records of the NAO index began in 1821, shown in Figure 6 for the period since 1930.

As noted above the NAO correlates with the wind index sufficiently to "justify the qualitative but not the quantitative use" of the NAO as a proxy to long-term wind speed trends. Therefore, while the NAO is at its lowest for the most recent winter, this does not necessarily mean this was the lowest wind speed period over the same long-term period.

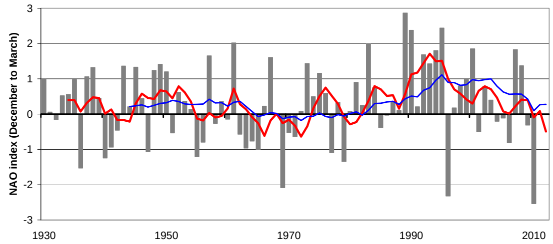

Figure 6 Long-term trend of the NAO during winter

It should be stressed that the recent occurrence of an extremely low winter NAO index is not indicative of a long-term downwards trend in the NAO or winds in general.

In summary, the winter of 2009-10 can reasonably be considered being an extreme low wind speed event in Germany. Although it is possible that this low wind speed period will continue, probabilistically it is considered extremely unlikely.

5. References

1 J Keiler, H Häuser, "BDB-Windindex", www.BtrDB.de.
2 N Atkinson, K Harman, M Lynn, A Schwarz, A Tindal, "Long term wind speed trends in Northwestern Europe", BWEA 28, October 2006.
3 P Thomas, S Cox, A Tindal, Andrew Tindal, "Long term wind speed trends in Northwestern Europe", EWEC 2009.
4 NCEP Reanalysis data provided by the NOAA/NCEP, Boulder, Colorado, USA from their website at www.cdc.noaa.gov.
5 W Winkler, M Strack, Annette Westerhellweg, "Zuverlässige Methoden zur Normierung und Bewertung von Energieerträgen von Windparks", DEWEK, 2002.
6 W Winkler, M Strack, "The Wind Index story – or: The Challenge of Determining 100 %", DEWEK, 2004.
7 A Albers, "Long term variation of wind potential: How long is long enough?", DEWEK, 2004.
8 H Krebs, T Frey, I Wendt, „Ringversuch Langzeitbezug 2008 des BWE-Windgutachterbeirats", 2009.
9 P Raftery, A Tindal, A Garrad, "Understanding the risks of financing windfarms", EWEA Conference, 1997.
10 H Schmid, "Die Entwicklung der Sturmhäufigkeit in der Deutschen Bucht zwischen 1879 und 2000" in DWD: Klimastatusbericht, 2001.
11 B Tinz, "Die Nordatlantische Oszillation und ihr Einfluss auf die europäischen Lufttemperaturen" in DWD: Klimastatusbericht, 2002.
12 University of East Anglia, North Atlantic Oscillation, www.cru.uea.ac.uk/cru/data/nao.htm.