

**The Wind Index Story - or: The Challenge of Determining 100%**

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**1. Introduction**

For the determination of the long-term energy yield, the available wind energy data from short-term periods have to be converted to long-term periods by suitable methods and data. In Germany the so-called IWET wind indices [1] are usually used for this purpose.

DEWI published results of critical investigations of the IWET wind index ([2], [3]). These investigations lead to the result that several properties of the IWET wind index (called energy index in the following) are causing non-realistic results, if the index is applied in a simple way (as it is mostly done). In the beginning of 2004 the IWET energy indices have been improved. The new energy indices lead to more realistic results, but still detailed correlations and modifications are necessary. One critical aspect is the determination of the correct 100%-level.

**2. Considered Data**

DEWI evaluated Reanalysis data to investigate the long-term trend of the wind speeds. One focus was the comparison of these data to the IWET energy indices.

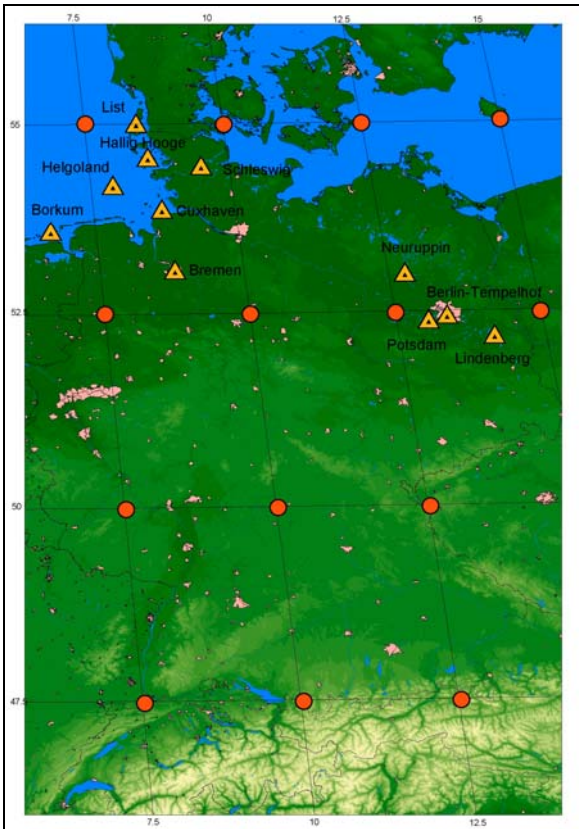


Figure 1: Considered Reanalysis grid points and meteorological stations.

The Reanalysis Data provided from the NCAR/NCEP Global Reanalysis Project [4] for 850 hPa ("geostrophic Wind"), for 925 hPa, for 1000 hPa and for the surface wind data for the grid points shown in Figure 1 have been evaluated. Also, Reanalysis wind data for 10 m height above ground (forecasts, data based on a different grid) have been considered. These data are available for the period from 1948 up to now.

As shown in Figure 2, Reanalysis data that have been recalculated to an energy index show very often a good correlation to energy yields and energy indices. Experience shows that there exists no general rule, which of the data sets of the nearest grid points correlates best.

Furthermore, some data sets of the Reanalysis 2 project, available for 1979 - 2003 (also NCEP / NCAR) (Figure 5) and data of several long-term stations from DWD have been considered.

**3. Comparison of the 100%-level of long-term data**

The following conclusion can be drawn based on 10-years averages for the 1950s - 1990s (Figure 3):

- For the Reanalysis pressure level data, a slight increasing trend of the wind speeds for middle and northern Germany can be found.
- For the Reanalysis surface data, no general trend has been found. The trends differ considerably from grid point to grid point.
- Despite similar (good) correlation, long-term results differ (often by 10% in energy yield) for the different data sets.
- Due to the Reanalysis wind data, the 1990s differed to the long-term average by -2% – +8% (mean +4%, std. dev. 2.5%).
- For the last 10 years (1994 – 2003), the average is +1.5% (std. dev. 2.0%) compared to the long-term average of the Reanalysis data.
- Applying the Reanalysis data as reference leads to the conclusion that energy yields based on the IWET index values (1989 - 2002 = 100%) are 6% higher than the long-term average.
- The meteorological station data support these results for the German Bight, but show bigger variation. For the stations around Berlin, the 1990s or the last 10 years represent almost the long-term average.
- There was no clear evidence of long-term cycles or patterns.

Some of these results are illustrated in Figure 3 and Figure 4.

#### 4. Uncertainties of long-term correction

The differences in the different data sets show that the prediction of the average wind climate is connected with a relevant uncertainty, which has to be taken into account for the energy yield evaluation.

As described in [3], the uncertainty of long-term correction is composed of the following components:

1. the statistical uncertainty of correlation, expressed by incomplete mapping of the data
2. the uncertainty of the correction or correlation procedure (possibly, this may coincide with (1)).
3. the uncertainty whether the long-term period of wind or energy yield data considered is free of inconsistencies and errors
4. the variation of the long-term average of several years as opposed to longer periods (e.g. 30 years' average).
5. additionally and irrespective of (4) the uncertainty whether the future wind resource (e.g. for the next ten or twenty years) corresponds to the period examined in the past.

Items (1), (4) and (5) can be determined from the long-term data examined, or from experience values. Annual wind data, for example, often vary in a range of 4% to 7% of the average wind speed; this applies to many data evaluated world-wide. In case of strong local influences on the wind resource, the data may also scatter differently. One expects generally that the degree of uncertainty is reduced with increasing duration of the periods considered.

Regarding the future wind climate (point no. 5) climate changes due to the man-made greenhouse effect might have severe influences on the wind climate as shown as example in [6]. This subject should be investigated in the future.

With regard to uncertainty features of the wind climate, which are not considered in the correlation (2) and inconsistencies in the data (3) there are hardly any analysis methods that are generally applicable. However, the uncertainties should not be neglected and their influence at least estimated. A realistic analysis of the uncertainties of long-term correction is the pre-requisite for reducing it by suitable means (e.g. by examining other long-term data or by extensive correlation procedures).

Experience shows that almost no measurement is completely consistent over long-term periods. The Reanalysis data base on different filtered input data. Still, general changes in the way these data have been measured and reported, influence its trend. Figure 5

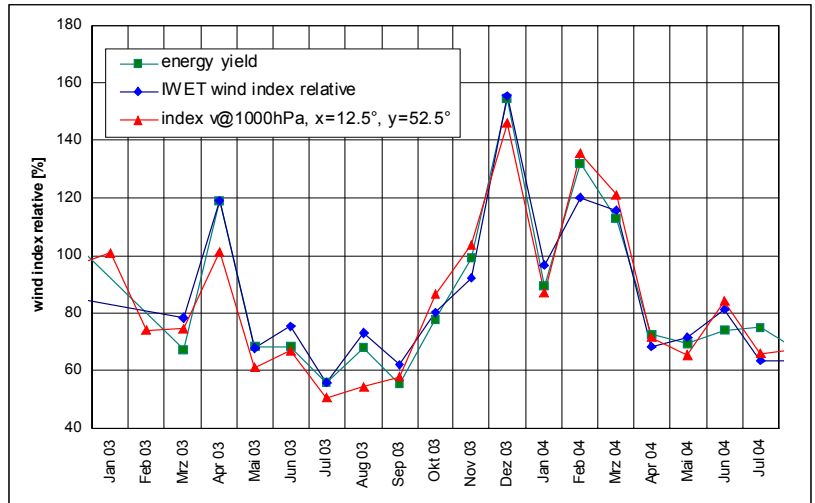


Figure 2: Time series of energy indices and energy yields of a wind turbine of the same region.

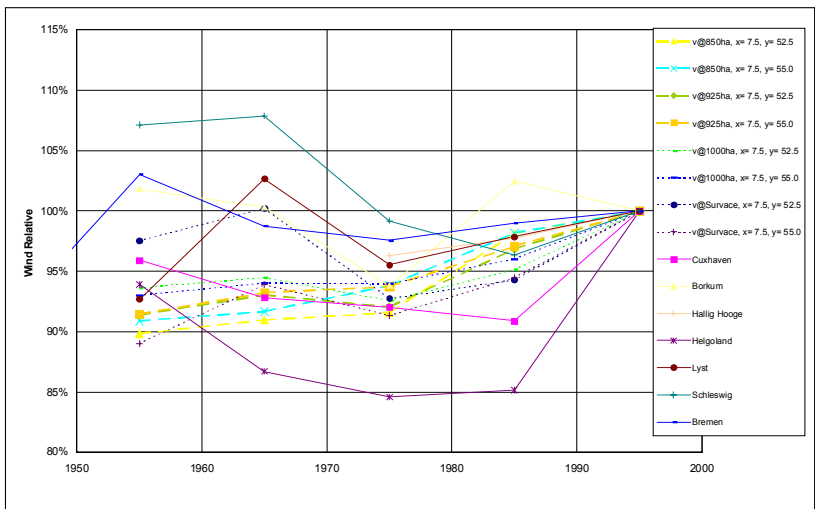


Figure 3: Relative wind speeds (10-years-averages) near the North Sea (1990-99 = 100%).

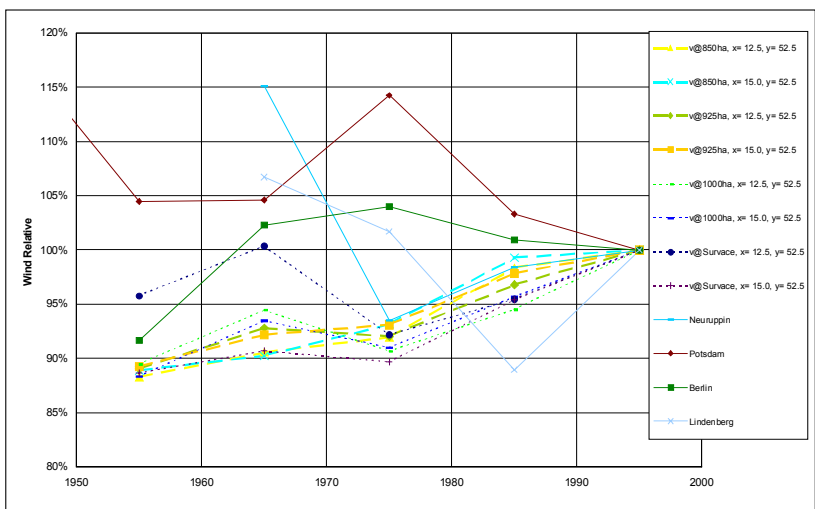


Figure 4: Relative wind speeds (10-years-averages) near Berlin (1990-99 = 100%).

shows relative deviations of data of the NCEP Reanalysis and the NCEP Reanalysis 2 data.

The differences depending on the data set confirm the presumption that these data cannot be expected as being free of errors.

**5. Choosing the long-term period**

The following investigations have been performed in order to find out possible shortcomings and uncertainties to the chosen reference period for long-term correction.

The calculation bases on the yearly means of all Reanalysis data sets described above for Germany for the period 1948 – 2003 as well as some meteorological station data (different measurement periods; since 1900). For the investigation all data have been recalculated to energy indices to make them comparable to energy yields.

For each of the data-sets the future energy index during the next 10 or 20 years has been predicted based on the assumption that it is the same as the wind of the most recent past periods with varying lengths. For example, the past period was 1954 – 1983 (30 years) and the future period 1984 – 1993 (10 years).

This procedure reflects the usual assumption for long-term correction without the error induced by imperfect correlation of different data sets. This procedure has been followed for all possible combinations and afterwards these predicted energy index data have been compared to the actual ones.

Figure 6 and Figure 7 show some results of these investigations for the prediction of the wind of the next ten years. The next ten years are an interesting period in respect of financing of wind farms.

All results refer to the relative difference of the predicted wind speed in comparison to the reported wind speed. Figure 6 shows

1. the averages of all *absolute* values of the deviations caused by this assumption for periods of the past of 10 years (the averages of all values would diminish; that is why the absolute value of the deviations has been used)
2. the standard deviation of the deviations described in (1)
3. the standard deviation of the mean energy index in comparison to the mean energy index

The results show different values for each of the data sources; e.g. the absolute deviations differ from two to six percent.

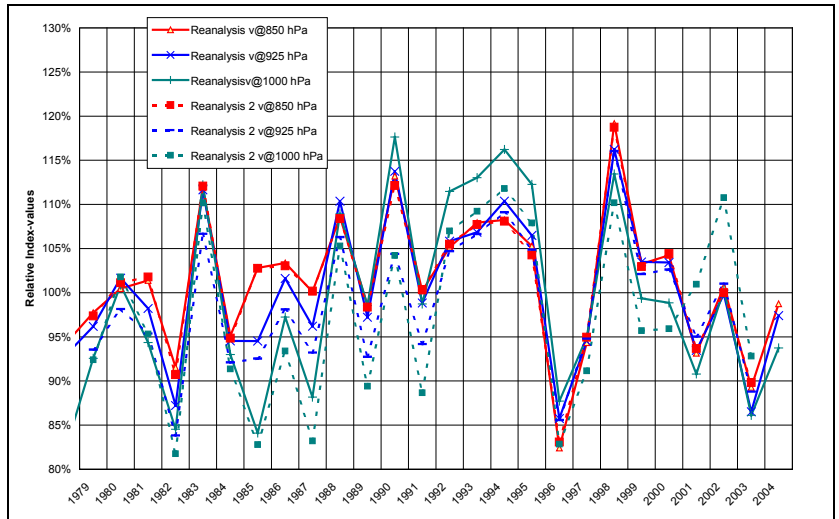


Figure 5: Yearly energy index values for different data sets. Comparison of data from the NCEP reanalysis 2 project with data from the reanalysis project.

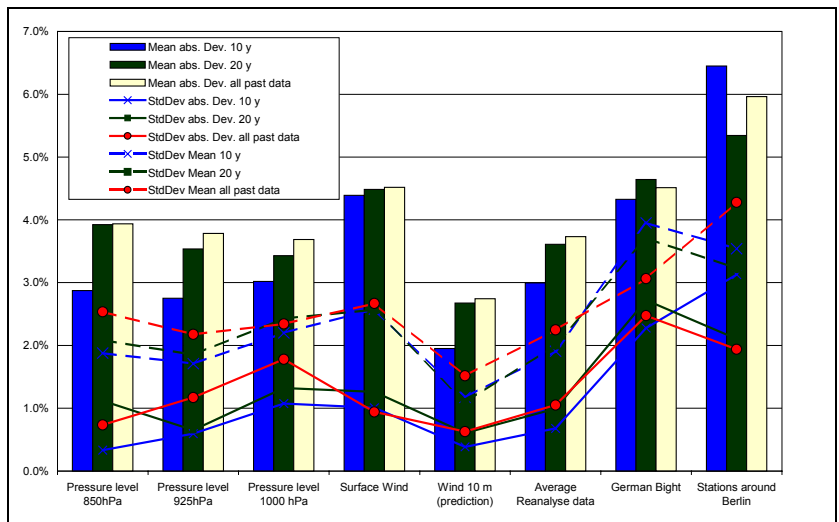


Figure 6: Relative absolute deviation, standard deviation of absolute deviation, standard deviation of the mean energy index of the prediction of a future period of 10 years depending on the length of the past period.

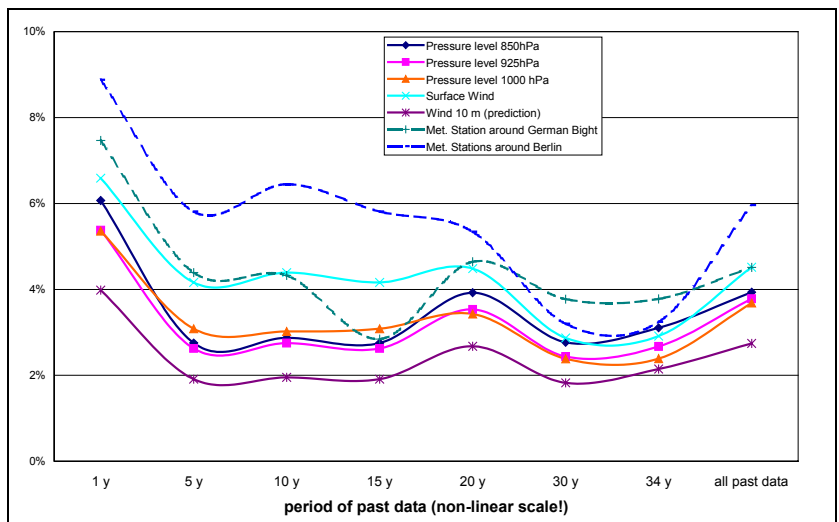


Figure 7: Relative absolute Deviation of the prediction of a future period of 10 years depending on the length of the past period.

The latter high value is true for meteorological data and supposedly heavily influenced by inconsistent data.

Figure 6 describes that using very long reference periods is not always advantageous and might lead to higher errors than using shorter periods.

The different standard deviations do not change significantly with the length of the reference period.

Figure 7 shows, as expected, that a very short reference period (only 1 year) might lead to large deviations. Also, the usage of all past data (for at least ten years of data) is not the best solution, but this is not unambiguous for the data. Most data sets show an increased deviation for a reference period of 20 years, but one can question whether this is significant.

All other reference periods from 5 to 34 years of reference data lead to similar conclusions.

For the prediction of the wind of the next 20 years (not shown here), the results are similar, but even less unambiguous. In this case a reference period of 20 years is a good choice.

### 6. 100%-level of the IWET-Indices

The IWET-Indices base on WTG data. Especially in the periods the IWET reports also values for these indices where no or only a few wind turbine data have been reported in the related region. Comparison to data of neighbour-region shows that these data-sets have to be treated with care [3]. That is why DEWI usually neglects IWET-Index values, if the index-value bases on no or only a few data wind turbine data of the region [2].

Period	Reanalysis 10 m	Reanalysis v@850 hPa	Reanalysis v@925 hPa	Reanalysis v@1000 hPa	Reanalysis surface wind
R <sup>2</sup> to IWET-index	91%	87%	90%	89%	92%
<b>Oct 94 - Sep 04</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>
Jan 89 - Dec 02	104	105	104	105	105
Jan 84 - Dec 03	102	103	102	102	102
Jan 74 - Dec 03	100	101	101	100	101
Jan 48 - Dec 03	96	96	96	96	101

Table 1: Comparison of the 100%-level of several indexed Reanalysis data in comparison to ten years of an IWET index

To analyse the question, if the 100%-level of this period is correct, Table 1 shows as example the comparison of the 100%-level of several Reanalysis data sets in comparison to 10 years of an IWET-Index. These levels have been determined by linear regression.

For this example, the level of the original scaling period of the IWET-Indices (1989 – 2002) is slightly too high.

The comparison to 20 or 30 years lead to the conclusion that the last 10 years show wind speeds, which are lower than average, while the data since 1948 do not give a clear picture. Most of the regarded data

lead to the conclusion that the last ten years showed higher wind speeds than the average. The difference to the other periods and between the different data-sets is relative high. Considering also that the consistency of these data to the shorter periods cannot be assured, the best guess is to neglect the longest reference data period.

### 7. Conclusions

The prediction of the average wind climate of the future is connected with a relevant uncertainty, which has to be taken into account for the energy yield evaluation.

The determination of wind conditions that are actually valid for long-term averages is difficult. Meteorologists generally base their long-term average data on climate time series of 30 years.

As long-term reference data should be checked against other independent data sources, which are not always available, a reference data period of 30 years cannot be recommended in general.

Experience shows that the application of very long reference periods for long-term correlation is not always advantageous, and might lead to higher errors. When in doubt, shorter periods are better suited if there is the danger of inconsistencies in the long-term data and there exists no possibility to verify the long-term data.

### 8. References

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