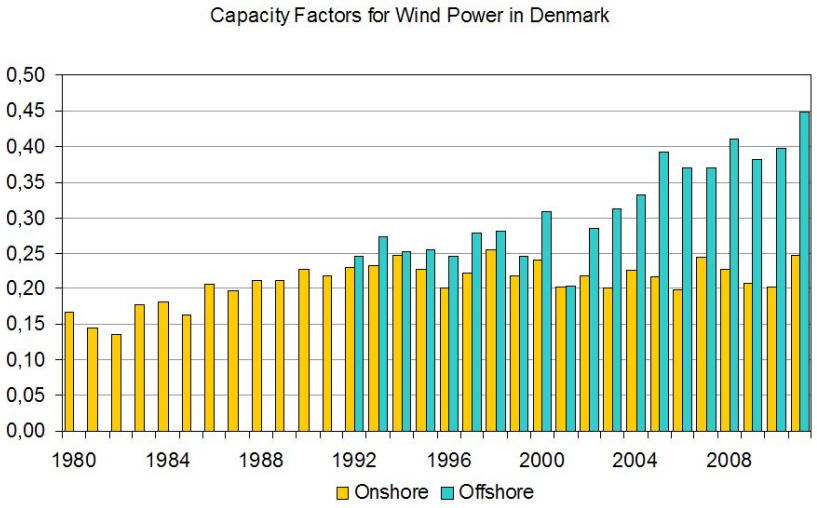
Capacity Factor Degradation for Danish Wind Turbines

Summary

It has been suggested that the capacity factor for a wind turbine declines up to 2% per year[1] due to wear and tear. Based on data from the Danish Energy Agency[2] 3,215 existing onshore wind turbines installed between 1992 and 2001 have been analysed. Each year of installation has been analysed separately. Slightly declining capacity factors was found for nine of the ten samples of wind turbines. The reason could be either declining wind or reduced performance for old wind turbines. Therefore also wind observations have been analysed. A clear negative trend was found for the years 1996 to 2011. Wind variations seem to be the main reason for the declining wind turbine capacity factors.

Capacity Factors for Danish Wind Turbines 1980-2011

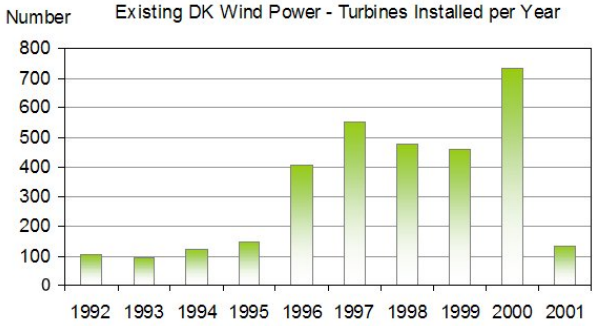
The average capacity factors for each year tell a story about technological improvements and wind variations.

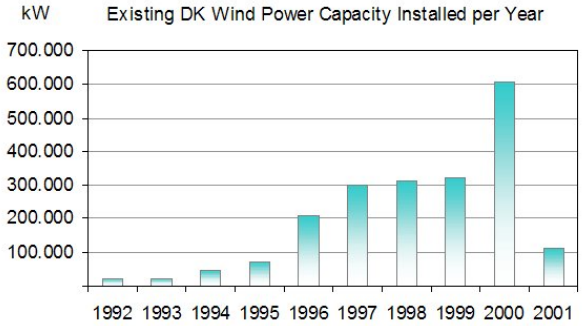


The chart is based on 4,978 existing wind turbines. Turbines being commissioned or decommissioned during a year are excluded. 404 turbines operated offshore in 2011.

The chart does not suggest declining capacity factors. However, the mixture of new and old turbines would not necessarily reveal any capacity factor degradation.

Onshore Wind Turbines with same Year of Installation

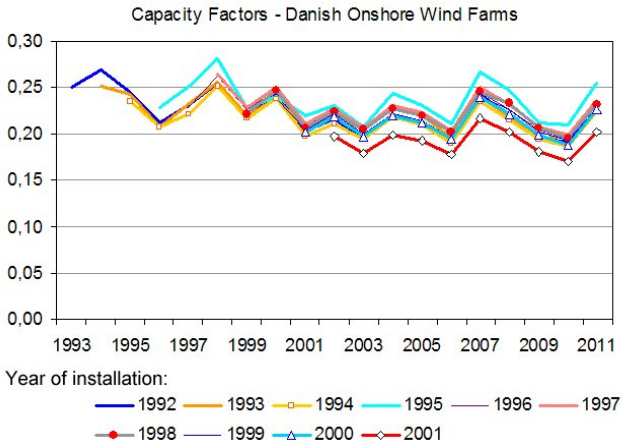




[1] http://windfarmrealities.org/wfr-docs/harrison-viability-ontario.pdf

[2] http://www.ens.dk/en-US/Info/FactsAndFigures/Energy_statistics_and_indicators/OverviewOfTheEnergySector/RegisterOfWindTurbines/Sider/Forside.aspx

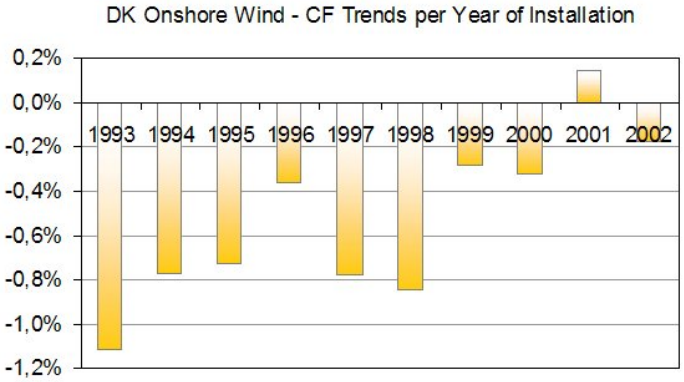
Onshore wind power had a boom in Denmark during the 1990s. 3,215 turbines which still existed at the end of 2011 were installed between 1992 and 2001. Ten samples are defined. All turbines within a sample have the same year of installation. The number of units in each sample is between 97 and 731.



Production data has been collected from the year after the commissioning and up to and including 2011. The samples have observation periods from 10 to 19 years.

The chart with capacity factors for each sample and for each year illustrates the wind power variations from year to year. The reason for differences between the samples is not known.

Linear regression has been used for a calculation of the average slope of each sample.



The chart shows that the slope is negative for 9 of the 10 samples.

The average slope, weighted with the number of turbines, is -0.40%.

Based on installed capacity the weighted average is -0.32%. This is due to larger turbines and more modest slopes for the last years.

Offshore Wind Farms

Only two offshore wind farms were built in Denmark between 1992 and 2001. There has been no degradation for these two parks. The capacity factor slope for a park with ten 500 kW wind turbines was +0.03% for the period 1996 to 2011. For a park with twenty 2 MW wind turbines a +1.00% slope was found for the period 2001 to 2011.

Degradation and Wind Turbine Life Time

Due to the technological development of wind turbines since the beginning of the 1990s we cannot conclude anything about the long term capacity factor degradation. Further observations for a number of years may allow more accurate estimates.

The life time of a wind turbine is often assumed to be 20 years. 0.30% annual degradation over 20 years would give a 6% capacity reduction for the last year. 2% annual degradation as assumed in other papers would give 33% capacity reduction after 20 years.

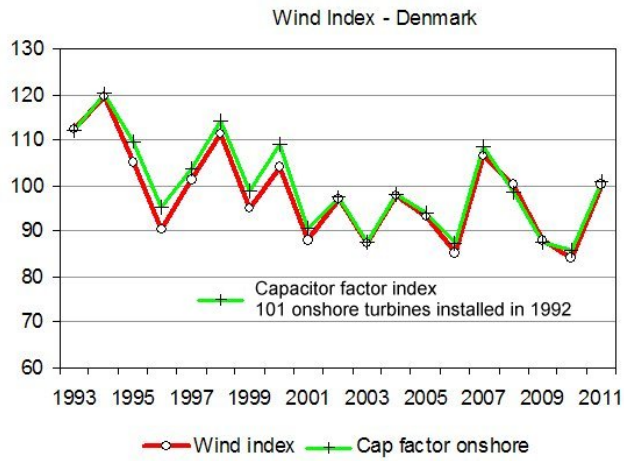
The Danish observations do not support the 2% degradation level.

The Wind (Energy) Index

The Danish wind index[3] might indicate if the reason for the declining capacity factors is falling turbine performance or changing wind conditions.

However, the wind index is based on annual electricity production from selected wind turbines. The index will include both wind variations and possible reduced wind turbine performance.

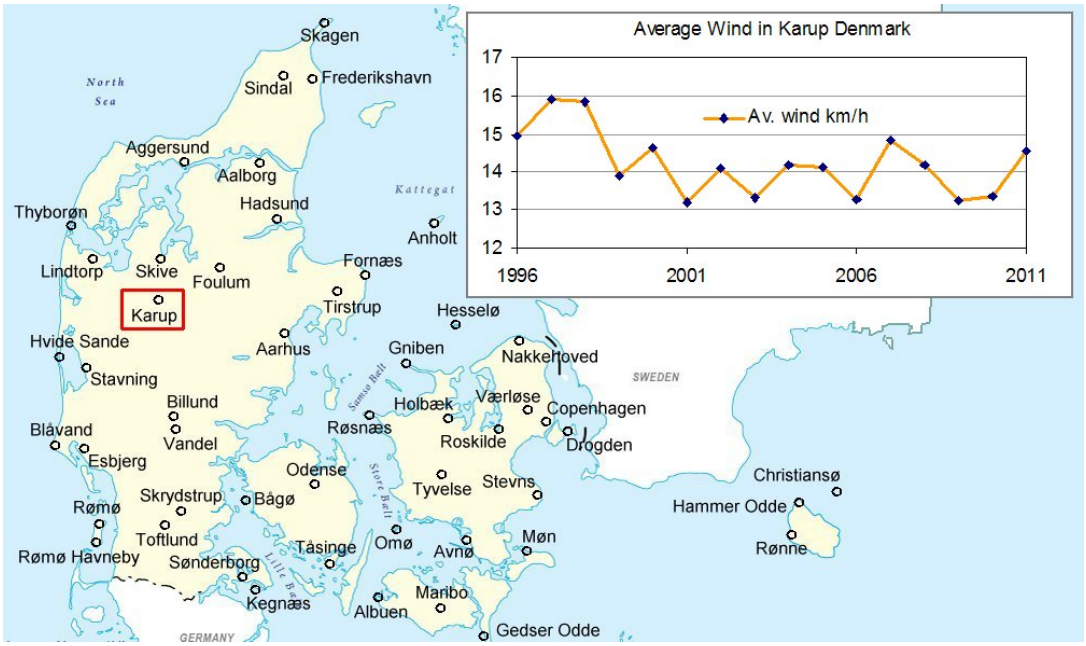
A comparison between the wind index and a capacity factor index for 101 onshore wind turbines installed in 1992 reveals nearly identity between the two indexes. A better term for the wind index would be the *wind energy index*.



Wind observations

Real wind observations could help separating the influence of wind changes from turbine wear and tear.

It is not easy to find relevant wind data. Wayne Gulden has drawn my attention to a site[4] with daily Danish weather observations for a large number of locations since 1 July 1996.

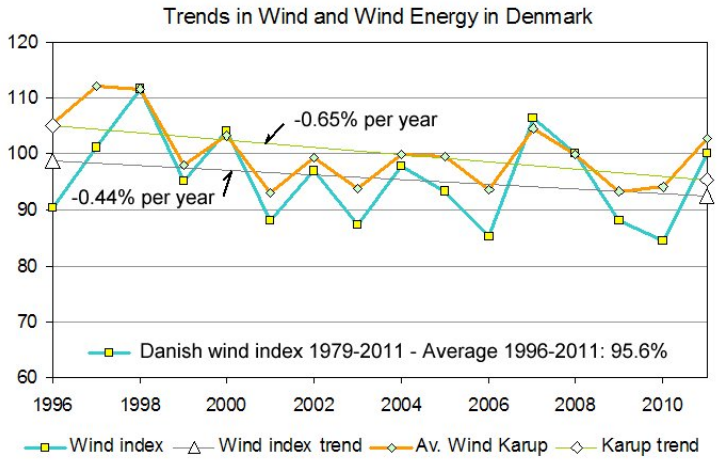


I have arbitrarily selected observations from Karup in Jutland in order to find a wind trend for the years 1996 to 2011.

[3] http://www.vindstat.dk/PDF_sider/Windindex_DK_new_short.pdf
[4] http://www.wunderground.com/

The average wind speed in Karup cannot be used for a calculation of the wind energy production in Denmark. It would take hourly observations from a representative set of Danish locations and a representative wind turbine power curve.

For comparison with the wind (energy) index the wind speed series has been converted into an index series with an average value at 100 for the years 1996 to 2011. A trend line has been found by linear regression.



The most important observation is that both wind and wind energy have negative trends from 1996 to 2011. The average wind in Karup has been falling by -0.65% per year. Another sequence of years would give other results.

The capacity factor trends on page 2 show annual variations from -1.12% to +0.15% with an average of -0.40% or -0.32% depending on method. The corresponding figures for the wind (energy) index are annual variations from -0.99% to +0.28%.

Based on these observations it cannot be excluded that wind variations have caused all the observed variations in wind energy output within the observation period from 1996 to 2011. There is no evidence of reduced wind turbine output due to wear and tear.

On the other hand, nothing can be proven from this limited set of observations data.