

## UK onshore wind capacity factors 1998-2004

### Background

In recent years there has been considerable interest in the performance of wind schemes; this article presents a definitive account of an analysis of the capacity factors for UK wind farms between 1998 and 2004 in relation to annual average wind speed. The capacity factors calculated were based on actual metered generation data for the UK and for different regions where possible. This involved analysing RESTATS data from the Non Fossil Fuel Obligation (NFFO) Orders for England and Wales and for Northern Ireland (NI-NFFO), and Scottish Renewable Obligation (SRO) Orders (the term "NFFO Orders" is used to refer to these instruments collectively) together with additional data from the Renewables Obligation Certificates (ROCs) databases, incorporating additional metered output<sup>1</sup> (AMO) data where necessary. RESTATS, the UK's renewable energy statistics database, is a project that has been running since 1989 and over this period has become the primary source of accurate, up-to-date statistics of UK renewable energy sources.

### Capacity Factor and Load Factor

DTI publishes in Table 7.4 of the Digest of United Kingdom Energy Statistics the aggregate load factor for on-shore wind farms calculated in the same way as for load factors of other generating technologies ie:

$$\text{Load Factor} = \frac{\text{Electricity generated during the period [kWh]}}{(\text{Installed capacity at beginning of the period} + \text{Installed capacity at end of period [kW]}) \times 0.5 \times \text{number of hours in the period [h]}}$$

However, because installed capacities have been growing rapidly as onshore wind generation expands, the average installed capacity calculated in the denominator of the formula above may understate or overstate the true average capacity available during a calendar year according to whether the new capacity began to generate early or late in the calendar year.

DTI therefore commissioned Future Energy Solutions to calculate *capacity factors*. The definition of a capacity factor is essentially similar to that for a load factor in that it is the energy produced during a given period divided by the energy that would have been produced had the wind farm been running continually and at maximum output, ie

$$\text{Capacity Factor} = \frac{\text{Electricity generated during the period [kWh]}}{\text{Installed capacity}^2 \text{ [kW]} \times \text{number of hours in the period}^3 \text{ [h]}}$$

But only those wind farms operating throughout the period and with an unchanged configuration are included in the calculation. Hence the following rule-base was used to collate and analyse the data and produce capacity factors:

- Data were only included where a wind farm operated for a complete calendar year. This is because the use of part-year generation would make the calculated capacity factor lower than is actually the case. For example, if a new wind farm started operating in May 2003 it would only be included in the analysis in the calendar year of 2004.
- For a re-powered wind farm, data were only included where a wind farm operated in the same configuration for a complete calendar year.
- Only aggregated figures can be released publicly under the confidentiality requirements of 'National Statistics'. Therefore, where there were only 1 or 2 wind farms in operation within a particular region, data for these regions were excluded; eg the South East is not reported. These regional capacity factors were calculated using the total capacity and generation within each region.

<sup>1</sup> Additional metered output is that generated over and above that contracted under a NFFO contract

<sup>2</sup> Where the installed capacity is the name plate rated power of the wind farm

<sup>3</sup> Where the period is calendar years

- The UK capacity factor was calculated using the total capacity and generation within the UK (including data for regions that could not be reported at a regional level).
- As this study was looking at commercial scale wind power and not small/micro generation, turbines under 100 kW were excluded. For the purposes of this study any single turbine above 100 kW is considered as 1 wind farm.
- The generation figures include any additional metered output (AMO) where it occurred.

As a result of the above approach, it was only possible to analyse data for the UK in terms of the following areas:

#### England

*East of England and Lincolnshire*

*South West*

*North East*

*North West*

*Yorkshire and the Humber*

#### Scotland

**Wales**

**Northern Ireland**

## Results

Table 1 shows the regional capacity factors, expressed as a decimal, with ‘.’ indicating where there were insufficient data to publish the regional capacity factor.

**Table 1: Regional capacity factors**

	1998	1999	2000	2001	2002	2003	2004	Average 1998-2004
East of England	0.23	..	..	..	..	0.23	0.26	<b>0.24</b>
North East	..	..	..	..	0.23	0.19	0.22	<b>0.21</b>
North West	0.30	0.29	0.27	0.23	0.27	0.24	0.26	<b>0.27</b>
Yorkshire and The Humber	0.32	..	..	..	..	0.28	0.27	<b>0.29</b>
South West	0.30	..	..	..	..	0.24	0.24	<b>0.26</b>
England	0.30	0.28	0.27	0.23	0.27	0.24	0.25	<b>0.26</b>
Northern Ireland	0.40	0.39	0.37	0.32	0.35	0.34	0.36	<b>0.36</b>
Scotland	0.34	0.29	0.29	0.27	0.29	0.28	0.34	<b>0.30</b>
Wales	0.29	0.29	0.26	0.23	0.26	0.25	0.26	<b>0.26</b>
<b>UK average</b>	<b>0.31</b>	<b>0.31</b>	<b>0.29</b>	<b>0.26</b>	<b>0.28</b>	<b>0.26</b>	<b>0.29</b>	<b>0.29</b>
<b>UK aggregate load factor</b>	<b>0.31</b>	<b>0.28</b>	<b>0.28</b>	<b>0.26</b>	<b>0.30</b>	<b>0.24</b>	<b>0.27</b>	<b>0.28</b>

Regional average capacity factors are only reported where the region contained 3 or more operational wind farms. The figure for England includes data from all English wind farms regardless of how many operational wind farms were in each English region. Likewise the UK yearly average figure includes all the operational wind farms regardless of how many operational wind farms were in each area.

Table 2 shows the number of wind farms in each region. In some cases a wind farm may have two NFFO contracts awarded, where this is the case, and NFFO data are used in the analysis, this is presented as two separate wind farms.

## Discussion

Historically, the RESTATS dataset relied heavily on data from NFFO contracted projects. As such, the expiry of NFFO 1 and 2 contracts in 1998 meant that generation data after this date were no longer available for 24 wind farms. Fortunately, since the introduction of the Renewable Obligation in 2002, NFFO data are now not the only source of generation figures. These former NFFO1 and 2 wind farms are still operational and now claim ROCs and so the 2003 figures (the first full year of the Renewables Obligation) include these sites (as do the 2004 figures).

**Table 2: The number of wind farms in each region used in the analysis**

	1998	1999	2000	2001	2002	2003	2004
East of England	3	-	1	2	2	3	8
North East	2	1	1	2	4	5	5
North West	7	4	10	11	11	15	14*
Yorkshire and the Humber	5	-	-	-	1	5**	5
South West	7	1	1	1	2	8	9
South East	-	-	-	-	-	-	2
England	24	6	13	16	20	36	43
Northern Ireland	6	6	8	8	8	8	8
Scotland	6	6	7	11	14	20	26
Wales	13	7	7	8	9	21	20***
United Kingdom	49	25	35	43	51	85	97

\* Haverigg wind farm was repowered 2004

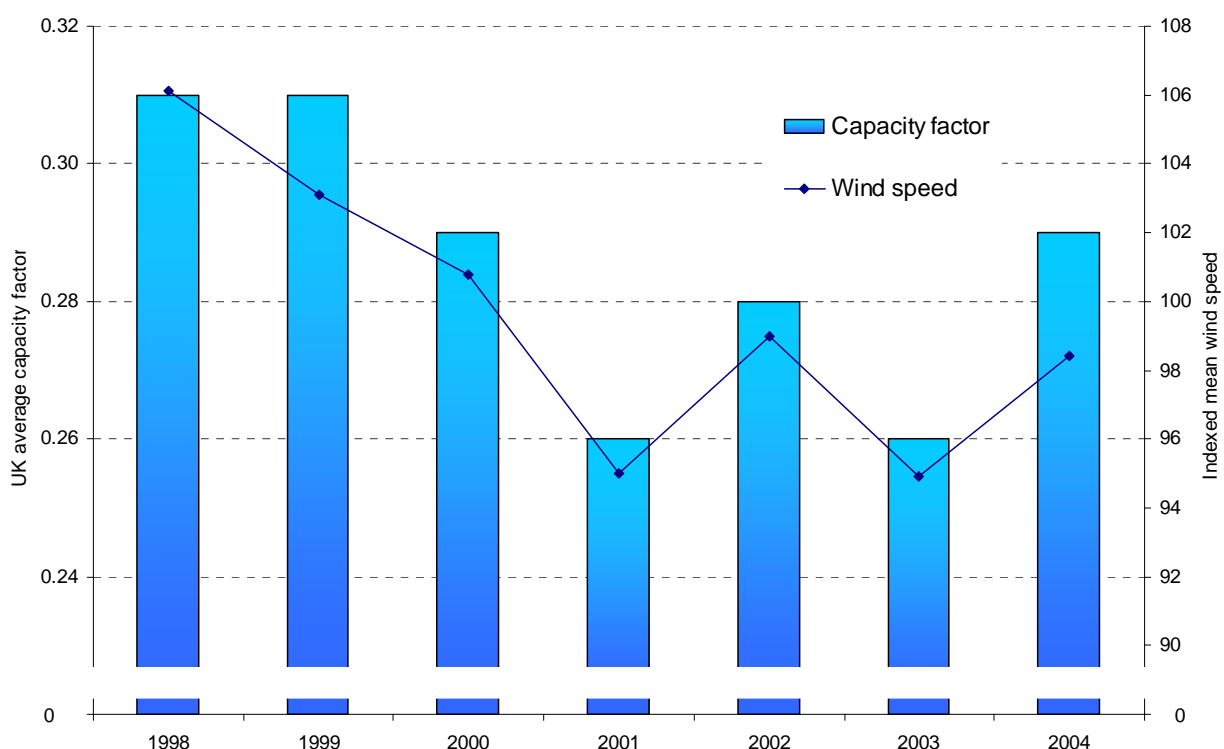
\*\* Chelker Reservoir wind farm was a NFFO 1 project and only ROCs accredited in 2004 therefore is not included in this analysis although it is still operating.

\*\*\* Llangwryfon wind farm was repowered in 2003/2004

At least 3 operational wind farms are required in each region for capacity factors to be released and post 1998, due to the unavailability of data from NFFO 1 and 2 wind farms, there are a number of years where there is not enough data available for certain regions to be reported.

Where data from only a few wind farms were available, the capacity factor was particularly sensitive to individual wind farm performance. In some regions where this was the case, technical issues on some older wind farms have meant that capacity factors are lower than one would expect for the wind resource. Wind farm/turbine availability varies between wind farms and that affects the capacity factor at both a regional and national level. As this is a real effect, no upward adjustment has been made to the capacity factor figures to compensate for this.

**Chart 1: Wind speed and capacity factor in the UK 1998-2004**

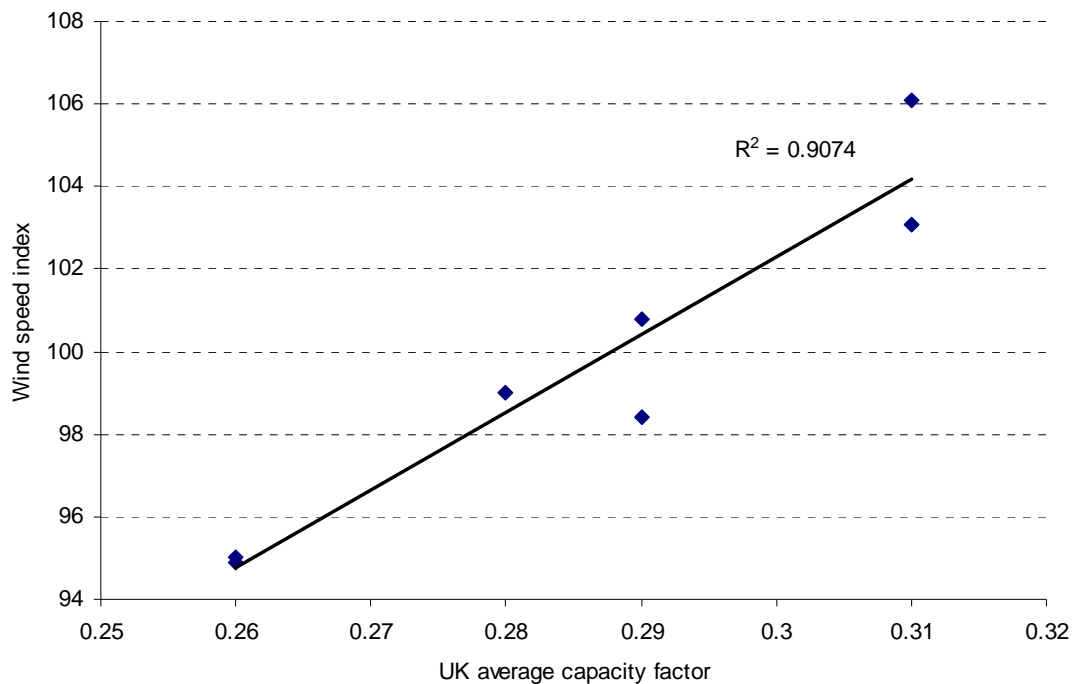


### Correlation with wind speed

Chart 1 shows the annual variation in the UK capacity factor and wind speed. This uses a wind speed index<sup>4</sup> that provides an indication of the mean wind speed relative to that of the long-term average across the UK. This wind speed index is calculated from a sample of 10 meteorological stations that have sufficient data quality in terms of consistency, accuracy and exposure and a long-term, 10-year record. The windiness of any given year is expressed as a percentage relative to the mean where 100 per cent is equal to the 10-year mean wind speed for the years 1995 to 2004.

1998 was the windiest year and 2003 the least windy over the 7-year period from 1998 to 2004. The relationship between wind speed and capacity factor is shown in Chart 2.

**Chart 2: Correlation between capacity factor and indexed UK average wind speed**



There is a strong correlation between UK average capacity factor and UK average wind speed in any given year with an  $R^2$  value of just under 0.91;  $R^2$  is a measure of 'goodness of fit' and if there was exact correlation the  $R^2$  value would be 1.

### Conclusions

The regional onshore wind capacity factors in the UK between 1998 and 2004 ranged from 19 per cent in one of the least windy regions in a year when the wind speed index was low, to 40 per cent in one of the most windy regions in a year when the wind speed index was high, with the overall UK average being 29 per cent. The quality of the data varies over this period but with ROCs data available from 2003 the quality and consistency of the data improved from this point. Using figures from both NFFO and ROCs data streams increases the data coverage/capture and means this analysis encompasses all wind farms in the UK.

The correlation between average UK wind speed and capacity factor in any given year is good with an  $R^2$  value of 0.91.

<sup>4</sup> UK Wind Speed Index, Garrad Hassan and Partners Ltd, 2005

*Special feature - Renewables*

It is proposed to carry out this detailed analysis for wind schemes on an annual basis and present the findings as part of the regular reporting of UK statistics on renewable energy.

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