

Summary of Wind Farm Performance Decline in the UK

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This note provides a summary of the paper “How does wind farm performance decline with age?” *Renewable Energy*, vol. 65, pp 775-786, which is available to download from tinyurl.com/wind-decline.

The need for a study

All machines suffer a decline in performance as they age, but there are no plausible estimates of how wind farms might age in the public domain. Government-sponsored reports on the cost of generating electricity include ageing effects for other technologies, but assume that wind turbines do not age.

The Renewable Energy Foundation published a study in 2012 that claimed the “normalised load factor for UK onshore wind farms declines from a peak of about 24% at age 1 to 15% at age 10 and 11% at age 15.” The load factor, or capacity factor, is the ratio of the output actually produced by a station to the output it would produce if it ran at full capacity throughout the year. A corollary was that “few wind farms will operate for more than 12–15 years.”

To put these claims in context, we could consider the 45 wind farms built in the UK during the 1990s (more than 15 years ago):

- 5 were repowered before their 15th birthday;
- 5 operated for between 17 and 20 years before being repowered (1 was closed completely);
- 35 are still operating today.

The actual load factor of these farms between the ages of 10 and 15 averaged 25%, with no trend over time. An ageing wind farm could produce a constant output if the wind was growing continually stronger, but it is easy to check, from the wind speed index published by the UK government, that this is not the case. The Foundation’s researcher, Professor Gordon Hughes of the University of Edinburgh, actually argued that a purely statistical technique was “a more efficient way of normalising performance for variations in wind availability over time than using any wind index.” It is not necessary to use an index, however, if site-by-site wind speeds can be calculated, and this is what we have done.

Measuring the decline in wind farm output with age

The aim of our research was to estimate the effect of varying wind speeds on the output of each of the UK’s wind farms in order to reveal the underlying pattern of how output has changed over time. Our wind speed data came from NASA, which has published the MERRA database, giving estimated wind speeds for every hour at a grid of points across the globe. We used the speeds at points on the grid surrounding each wind farm to estimate the wind speed at that farm. We tested our technique by estimating speeds for the sites of UK weather stations, and checking them against observations. The MERRA data also contained the information we needed to estimate how much faster the wind would be blowing at the height of each farm’s wind turbines than at a weather station’s wind mast.

Each model of wind turbine has a power curve which shows how much electricity it can expect to produce for a given wind speed. We used the power curve for each wind farm's turbines, or the closest match we could find, to estimate the output that the farm would produce in ideal conditions – if it was on a flat plain with no interference from neighbouring turbines, and with no downtime for maintenance. We scaled this estimate to account for effects such as rough terrain upwind reducing the wind speed at the farm, or the fact that turbines downwind from others will receive less energy. Once again, we validated our work by comparing our estimates with the half-hourly outputs recorded by the National Grid for wind farms in Scotland and offshore (those in England and Wales do not report their outputs).

The final stage of our work was to create data on weather-corrected load factors for every station. We had monthly values for the load factors of each station, taken from Ofgem's Renewables Register (they are also helpfully provided by the Renewable Energy Foundation) for the period from April 2002 to November 2012. We took our wind-based estimate of the output that the farm would have produced for each month and compared it to the long-run average over the last 20 years. If the wind-based estimate for a station's load factor in April 2002 was 5% below the long-run average estimate, we raised its observed load factor for that month by 5% to obtain a weather-corrected load factor. Figure 1 to the right shows that the weather-corrected load factor varies much less than the raw data. There are two noticeable dips in this load factor, which correspond to downtime for maintenance. The dashed line shows that there is a slight downwards trend in the weather-corrected load factor, of 0.1 percentage points per year.

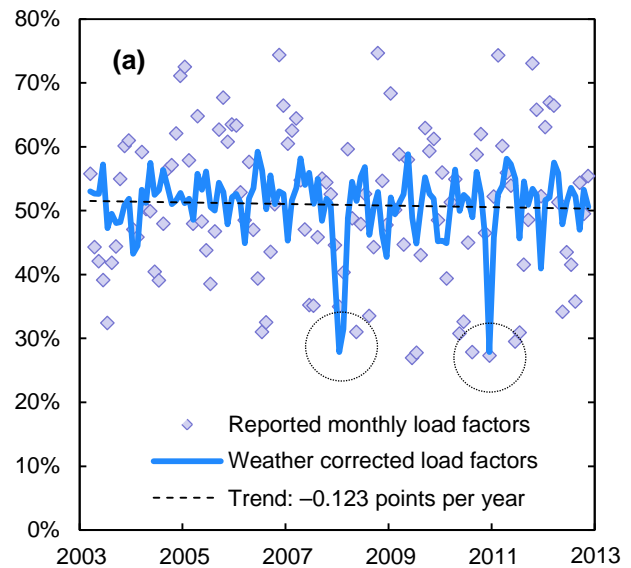


Figure 1: Actual and Weather-corrected Load Factors for Burradale 2 Wind Farm in Scotland.

The measured decline in wind farm output with age

It would be invalid to simply compare the load factor of a modern wind farm with that of an old farm that used earlier, inferior, turbines. Our approach, however, measures the trend in each individual wind farm's performance, correcting for variations in the wind speed and keeping its technology constant. Figure 2 shows the trends that we obtained for all the stations for which we had at least five years of data. In each case, we started to measure the trend from the station's first birthday, since outputs tend to increase during the first year after commissioning as the last few turbines are installed and teething problems are ironed out.

The vertical axis shows the date at which each station was commissioned – with the need for five years of data, the youngest stations represented are those commissioned in 2007. The horizontal axis shows whether the trend change in output is negative (giving the ageing we would expect) or positive. We would not expect a wind farm to improve its performance once the immediate post-commissioning period is over, but this could happen if initial problems took a long time to fix. Each circle represents our best estimate of the trend rate at which a particular station has aged – the horizontal lines represent the standard deviation of this estimate. The size of the circle is proportional to the capacity of the station, and it can be seen that the newer stations are generally larger than older ones. The central solid line shows how the average trend in ageing varies with the commissioning date of the station, while those on either side give a band of plus or minus one standard deviation.

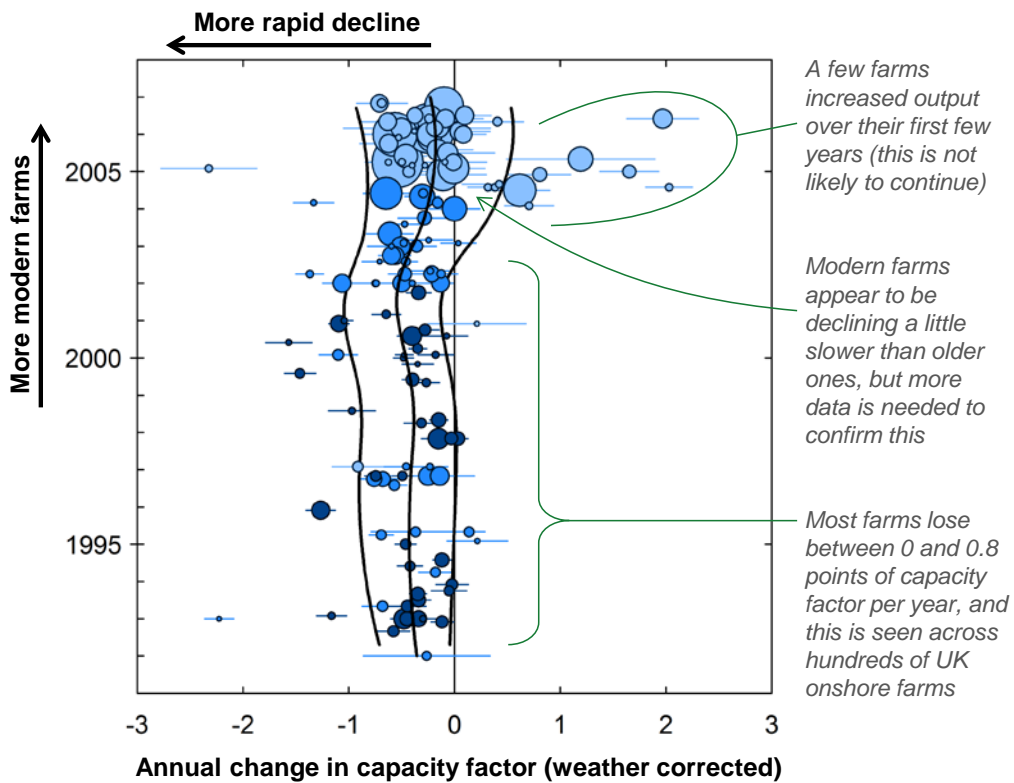


Figure 2: Estimated rates of ageing for onshore wind farms in the UK

The average decline rate is 0.4 percentage points of load factor per year – this is equivalent to 1.6% of the average station’s output. The average onshore wind farm in the UK has a load factor of 28% at age 1, and this will fall to 21% by age 15. There are some signs that the newer wind farms are ageing less rapidly, for our central line is closer to the vertical axis at the top, but the error band around it is wide enough for all cohorts of farms to be ageing at the same rate, on average.

Other methods to estimate the rate of output decline were tested in the paper. Instead of calculating a trend for each individual farm as in figure 2 above, we found the national trend in weather-corrected load factors, comparing two different adjustments for any tendency for newer stations to have consistently better load factors because of their more modern technology. We also calculated the decline in load factors with age without making any correction for wind effects, taking the average across individual farms and across the fleet as a whole. These various methods (and others we also checked) all gave broadly consistent numbers in the range of 1.4 to 1.8% per year.

Implications of this study

Our estimates of ageing are in line with those for other kinds of machinery. We are unable to say whether the decline in output is due to mechanical components becoming less efficient after wear and tear, the blade surfaces becoming damaged and less aerodynamic, more time spent awaiting maintenance or some other cause. Assuming that ageing does not accelerate in the last few years of a turbine’s life, most wind farms should expect to operate for the 25 years typically assumed when they were planned. The ageing effects we have measured imply that the farm will produce 12.5 per cent less output over its lifetime than if there was no ageing at all. Its costs will increase by less than this, however, as the worst losses are in the future. With an interest rate of 10 per cent, this would add 9 per cent to the wind farm’s levelised cost of energy – a noticeable increase that is nonetheless smaller than the difference between a good and a bad site.