

Capacity Concepts and Perceptions – Evidence from the UK Wind Energy Sector

By Michael Jefferson*

Introduction

We all know that the wind is intermittent. As a rough measure, wind turbines can only operate when wind speeds are between 4 metres per second and 24 metres per second. There is a further technical limit, which need not concern us here, Betz's Law – the maximum theoretical efficiency of a wind turbine is the ratio of the maximum power obtained from the wind to the total power available from the wind. This ratio is 0.593, thus under Betz's Law wind turbines can never be more than 59.3% efficient.

Here, however, we focus on 'capacity factor' (sometimes termed 'load factor'). This is the ratio of the actual output of a wind energy development (an array of wind turbines at a particular location, or locations if a country is under consideration as is the case in this paper) to the installed capacity. We will be considering actual wind energy performance in the UK, sub-divided for England, Scotland, Wales, and Northern Ireland against claims that in general have been grossly exaggerated. The implications of the actual performance against claims will finally be considered.

The UK Wind Resource

The UK's main wind energy industry association has long been prone to gross exaggeration and unqualified generalisation. For example, this body – formerly known as the British Wind Energy Association and now RenewableUK – states:

“The UK is the windiest country in Europe, so much so that we could power our country several times over using this free fuel.” (1)

There are some problems associated with this statement. There can be little or no doubt that Scotland is the windiest country in Europe. But England is far from being as windy as, say, Denmark. Wales is somewhat windier, but less so than Denmark. Most of Southern England (i.e., areas away from the coast) and the Midlands have as little wind as most of Germany and France. (2). Yet it is in the heavily populated areas of England's South and Midlands where wind energy developers have sought planning permission, all too often with success, despite concerns about visual intrusion and adverse effects on residential property values and sleep patterns for those living in close proximity. These 'social' and 'aesthetic' issues lie outside the scope of this paper, but although such concerns are dismissed as NIMBY-ism (Not In My Back Yard), there are legitimate counter-arguments based upon the conservation and stewardship motivations of those living in remaining rural areas. (3)

The key issue which this paper addresses is: what capacity factors are actually achieved in the various parts of the UK. Because the wind resource is so variable around the country it is not surprising that capacity factors achieved vary so widely. The industry seeks to disguise this fact, since its admittance might be thought to prejudice public opinion and political decision-making. However, the industry managed to make a pre-emptive move when advising public officials on planning guidelines for renewable energy in the UK. Thus Key Principle 1 (v) of Planning Policy Statement 22 (the main official guidance on renewable energy) states:

“Regional planning bodies and planning authorities should not make assumptions about the technical and commercial feasibility of renewable energy projects (e.g., identifying generalised locations for development based on mean wind speeds).” (4)

This guidance does not apply to offshore areas, where mean wind speeds tend to be significantly higher and issues of visual intrusion, residential property values and impacts of aerodynamic modulation do not apply. Installation and maintenance costs, proximity to bird migration routes and marine mammals, and potential interference with communications may be issues. The only point relevant to this paper is that the intermittency of wind also applies offshore, and the idea that offshore supplies may be maintained by switching to other areas (from the Irish Sea to the North Sea, and so on) have been challenged on the ground that frequently these other offshore areas will also be suffering loss of wind. (5)

This paper focuses on onshore wind energy developments only.

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Capacity Factors

Reference to capacity factors is, of course, standard practice. There is little value in quoting the amount of total installed capacity of wind turbines. What matters is the megawatt hours of electricity produced by these turbines. This is not closely related to the efficiency of the turbines themselves, which may vary for obvious reasons, but is a critical measure of the efficacy of the various developments.

Fortunately in the UK the necessary data are supplied by the operators to the official body responsible for oversight of the electricity market and payment of subsidies (funded by domestic and business electricity customers via their utilities). This organisation is Ofgem (Office of Gas & Electricity Markets). Their data is publicly available and can also be readily accessed from the website of the Renewable Energy Foundation (at <http://www.ref.org.uk/roc-generators/index>).

Quotation of these official figures, provided by the operators themselves, can, however, have some surprising results. Thus the Chief Executive of RenewableUK has been known to reject reference to these figures as: “bizarre pseudo-science”, “ill-informed and disingenuous”, and “absolute nonsense”. (6) Further diversion has been offered by stating that: “There is no Government subsidy for building wind farms” (6) and: “The Renewable Obligation is not a subsidy.” (7) The subsidy is nonetheless present, coming from electricity customers who have no choice but to pay up. For them the efficacy of wind energy developments in producing electricity efficiently and at low cost is important.

There are two further statements that are relevant before the actual evidence of capacity factor performance is provided. They both come from the Companion Guide to the PPS 22 document already referred to. First:

“A machine located on a site which has an annual mean wind speed of 6 metres per second will typically produce only half as much energy as the same machine on a site where the annual wind speed is 8 metres per second.”(p. 164.)

Many sites where wind energy developments have been proposed and passed in Southern England and The Midlands have mean wind speeds under 6.7 metres per second according to the UK Government’s wind speed database. This is hardly optimal or likely to result in sound capacity factors. [A more technical discussion of wind speeds, the Weibull or Rayleigh distribution, and the power weighted average of wind speeds can be found at (8).]

Second:

“Capacity factors in the UK may generally fall anywhere between 20% and 50%, with 30% being typical in the UK.” (p. 165)

How does this “typical” average (mean?) measure up to the facts; and how accurate is the claim that the range is 20% to 50%?

Performance

Examining the evidence provided by the UK’s onshore wind energy operators to Ofgem a very different picture emerges. The writer’s interest began when, as the then Chairman of the Policies Committee of the World Renewable Energy Network/Congresses, he noticed a discrepancy between the claims of PPS 22 (and the main industry body) in England for 2007. The mean capacity factor achieved by onshore developments in England was 22.7% in 2007. Capacity factors ranged from 35.09% (Haverigg 3) to 24 developments achieving less than a 20% capacity factor (out of 81 operational throughout 2007). Of the latter, six developments achieved a capacity factor below 10%.

In 2008 the performance was somewhat higher, as it was a windier year, with capacity factors for wind energy developments in the Eastern part of England up from 22.7% in 2007 to 26.2% in 2008, for example. This benevolent wind regime meant that in 2008 the Burton Wold development achieved a capacity factor of 24.2%. This example is provided as it appears in the Wikipedia entry for “Capacity factor”, where it is used to provide an example of how the figure of “just under 25%” is arrived at. (9) Burton Wold development (visually not a particularly sensitive site, and with turbines 25 metres lower to blade tip than most being currently promoted) has achieved the following full-year capacity factors since it started operating: 2007 – 22.2%; 2008 – 24.2%; 2009 – 19.0%; 2010 – 16.3%; and 18.9% for the twelve months to September 1, 2011. This example, in a less sensitive location than many proposed and approved in Central England (others are much closer to important historic assets or attractive landscapes) illustrates the rather modest performance of modern wind energy developments approved for relatively low mean wind speed sites. [Burton Wold started operating in January, 2006.]

By 2009 and 2010 the number of developments had expanded considerably – data for 105 onshore wind ‘farms’ were available in England for 2009, and 142 for 2010. The average capacity figure achieved in 2009 was 21.2%, and the range ran from 32.0% (Workington) to 4.9%. Eight developments achieved a

capacity factor of under 10%, and 35 under 20%. Eight also achieved 30% or more. All were operational throughout the year. Thus one-third of all onshore wind energy developments in England fell below the 20% to 50% range given out in official documents and by the industry.

In 2010 the average capacity figure achieved in England was 18.7%, and the range 33.6% (only one development achieved 30% or more –the revamped Ramsey in Cambridgeshire) down to 81 developments achieving below 20%. Thus of the 142 developments considered, nearly 60% failed to fall within the 20% to 50% range officially declared as extant.

Not surprisingly, given the higher mean wind speeds prevalent in Scotland, higher capacity factors have been recorded than in England. In 2009 the average was 28.46%, with a range from 48.3% (Barradale Phase 2) down to 15.8% (Isle of Luig) - noticeably higher at both ends of the scale. Out of 70 developments for which data were provided, 23 achieved a capacity factor of 30% or more. An impressive result: only eight developments fell below 20%. But this still meant just over 10% of the total fell below the 20% to 50% range officially claimed.

Then in 2010 Scotland achieved an average capacity factor of 23.75%, indicating a less windy year than 2009. There were, nevertheless, 14 developments achieving a capacity factor in excess of 30%. This was out of a total of 89 developments reviewed. Apart from one tiny scheme (Greystone Cottage) all developments achieved a capacity factor of over 10%, although 22 recorded under 20%. This meant that 25% of developments even in Scotland fell below the officially presented range.

Wales and Northern Ireland not surprisingly turned in poorer results. In 2009 the average capacity factor achieved in Wales was 23.86% (the performance of 32 developments was covered), and in 2010 18.75% (38 developments covered). Three developments achieved a capacity factor in excess of 30% in 2009 (the highest being Moelogen at 33.4%); but the highest in 2010 was only 26.1% (Moelogen again). Seven developments fell below 20%. In 2010 there were 22 developments falling below 20%, nearly two-thirds of all wind energy developments in Wales.

In Northern Ireland 32 developments were reviewed for 2009 and 43 in 2010. In 2009 the average capacity factor achieved was 24.1%, and in 2010 17.6%. The highest capacity factor achieved in 2009 was 38.2% (at Owenreagh), and five developments achieved 30% or more. Nine developments (over 25% of the total) achieved under 20%. In 2010 the highest figure attained was 31.6% (at Corkey), when only two developments achieved 30% or more. But 22 developments (eight of them admittedly very small) failed to achieve a capacity factor of 20% (so nearly half of the total fell below the officially claimed range).

At the time of writing only data for the first nine months of 2011 are available. As 2011 was one of the windiest years in the UK for a very long period, high capacity factor performance was to be expected. High winds in May, the effects of Hurricane Katia in the second week of September, and strong winds in early December were widely noticed. The available data on capacity factors do not yet capture the latter two events, but some developments achieved their record capacity factors in December, 2011.

In the 12 months to September 1, 2011, 32 of Scotland's wind energy developments achieved capacity factors of 30% or more. Burradale I achieved 49.1% closely followed by Burradale II with 48.4%. By contrast, only six developments in England achieved 30% or more (the highest being Hare Hill with 39.8% - well ahead of all but one of its rivals). There were five in Northern Ireland and only one in Wales that achieved 30% or over (Owenreagh led Northern Ireland with 34.0%; the Welsh development was Hafaty Ucha 2 at 30.0%).

There were, three-quarters of the way through this exceptionally windy year, 47 developments in England which failed to even achieve a capacity factor of 20%; 19 in Northern Ireland; 14 in Scotland; and 9 in Wales. This meant that between about 20% and 25% of UK wind energy developments fell beneath the range officially provided in the Companion Guide to PPS 22.

But the relatively windy conditions during 2011 came at a cost to the electricity customer. As a result of pressure on matching electricity supply to demand, which requires the UK's National Grid to resort to a Balancing Mechanism, generators were paid to reduce output because more electricity was being generated than could be used. This was particularly the case for wind energy which could have been generated in Scotland but could not be used there, and the grid interconnections between Scotland and England was unable to cope with the excess. This was the result principally of high winds in Scotland and relatively low demand there for electricity. Constraint payments to wind energy generators for them to reduce output began in 2010. These payments are significantly greater than the level of subsidy (£220 per MWh against £55 per MWh for the ROC subsidy in 2011). The result was that electricity customers were obliged to bear additional costs during 2011 of over £12.8 million. In May, 2011, alone the constraint payments totalled over £2.6 million; in September, 2011, nearly £5.3 million; and in December some £820,000.

Policy Implications

Support of the wind energy industry in the UK is sub-optimal. Although wind energy operators only receive subsidies reflecting the amount of electricity their schemes generate, there are considerable costs in installing equipment (mostly imported – and therefore containing significant ‘embedded’ emissions). The contributions of far too many of these developments to electricity generation and carbon emissions avoidance are sub-optimal. As a first step to introducing greater rationality UK planning guidance (PPS 22) should be amended (a) to permit planning bodies to assess the likely contributions to electricity generation and carbon emissions avoidance based on the UK Government’s wind speed database; and (b) for those developments where capacity factors achieved fall below 30% subsidies should be incrementally reduced so that where capacity factors below 20% are achieved little or no subsidy should be received.

A further useful step would be to introduce a minimum mean wind speed barrier (of, say, 7 metres per second at 45 metres above ground level, according to the UK Government’s wind speed database, below which planning authorities would be empowered to refuse to consider any development application). This would save substantial planning resources and costs.

Further work also needs to be done to assess the costs of the intermittency of wind energy. These include the costs of building and operating traditional sources of supply (coal and natural gas, for example) required to back up wind energy when the wind fails. There is a growing body of research evidence which suggests that the carbon emissions associated with the short-term operation of traditional natural gas and coal-fired electricity generating stations are so increased that they offset the gains derived from wind energy production to a considerable extent. (10) It is simply not good enough for the UK’s main wind energy industry body to dismiss serious research as “a report based on the work of anti-wind cranks.” (11) It has long been agreed in the industry that if the share of wind energy approaches 20% of total electricity generation serious disruption can occur. Research done on the power system in Eire suggests severe disruption and little carbon emissions avoidance may occur with wind energy’s share as low as 10% - a figure which the UK is already close to in a windy year. (12)

Finally, both the grid system needs improvement to overcome current constraints (especially between Scotland and England), and a much more concentrated effort is required to investigate the validity of claims that wind power cannot be stored in significant volumes. (13)

Given that the UK authorities are relying principally upon wind energy to provide the bulk of future renewable energy used in electricity generation these are important and urgent issues.

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